2017-3

Exploring, Evaluating and Visualising Spatial Complexity of Urban Sites

Alan Mee
Technological University Dublin, alan.mee@tudublin.ie

Follow this and additional works at: https://arrow.tudublin.ie/appadoc

Part of the Arts and Humanities Commons

Recommended Citation

This Theses, Ph.D is brought to you for free and open access by the Applied Arts at ARROW@TU Dublin. It has been accepted for inclusion in Doctoral by an authorized administrator of ARROW@TU Dublin. For more information, please contact yvonne.desmond@tudublin.ie, arrow.admin@tudublin.ie, brian.widdis@tudublin.ie.

This work is licensed under a Creative Commons Attribution-Noncommercial-Share Alike 3.0 License
Exploring, evaluating and visualising spatial complexity of urban sites

Alan Mee, B.Arch, MRIAI

Submitted in fulfilment of the requirements for the award of Doctor of Philosophy

March 2017

Dublin School of Creative Arts
Dublin Institute of Technology (DIT)

Supervisor: Dr. Noel Fitzpatrick,
Gradcam, Dublin School of Creative Arts, DIT

Volume One (of Two)
Abstract

Exploring, evaluating and visualising spatial complexity of urban sites

The central aim of this study is to expand understandings of spatial conditions in urban sites through the development of the theoretical concept of spatial complexity. This significant characteristic of cities includes compositional, configurational, and systems aspects, and is currently not defined in the urban design literature. While complex urban locations are shown to have environmental, functional and social advantages, including enriched urban life, increased resilience and diversity, the specifically spatial aspect is less examined.

The research design proposes three separate phases of work. The first (theory) phase explores the literature on complexity theories of cities, integrative urban design and evaluation, and concludes that current understandings of spatial complexity need to be refined and deepened for urban analysis and design. The second (exploration) phase develops a conceptual framework, including an evaluation tool which measures three issues and nine criteria of spatial complexity, in order to reveal and understand the relationships between compositional, configurational and systems aspects of urban sites. The third (evaluation and visualisation) phase evaluates distinct and contrasting spatial conditions in three urban sites using a case study approach, thus demonstrating techniques of evaluation for urban design practice. Visualisations record and synthesise outputs and overlay observational data from the field, which supplements morphological, syntactical and systems readings.

The places evaluated are found to have specific spatial complexity levels, which allows comparison within, between, and across cases and with other urban sites, and has international relevance for other urbanising locations. The evaluation methods developed are shown to combine the qualitative depth of a morphological approach with the synoptic quantitative advantages of a syntactical analysis method, as well as adding the systems viewpoint and observer perspective of fieldwork data. The study develops the underlying theory of spatial complexity in more detail for urban design, derives an evaluation tool, contributes case studies and evidence to urban design practice, and enhances methods of exploration, evaluation and visualisation for urban description, prescription and design.
**Declaration Page**

I certify that this thesis which I now submit for examination for the award of PhD, is entirely my own work and has not been taken from the work of others, save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for graduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for another award in any other third level institution.

The work reported on in this thesis conforms to the principles and requirements of the DIT's guidelines for ethics in research.

Signature __________________________________ Date _______________
Candidate
Acknowledgements

This study began as a Fiosraigh Scholarship award within Gradcam, the Graduate School of Creative Arts and Media, at the Dublin School of Creative Arts, Dublin Institute of Technology (DIT). I wish to express my gratitude to the inspirational staff there, including Dr. Mick Wilson, Dr. Lisa Godson, Martin Mc Cabe, and especially my Supervisor, Dr. Noel Fitzpatrick.

To my family and friends, and particularly my partner Jo, thank you for the support, encouragement and patience.
Table of Contents

Chapter One  Introducing spatial complexity ......................................................... 11
  1.1 : Background to this study .......................................................... 18
  1.2: The academic rationale .................................................................. 24
     1.2.1 : Introducing complexity ...................................................... 24
     1.2.2 : Introducing urban design ................................................. 27
     1.2.4 : Complexity, urban design, and urban sites ....................... 30
     1.2.5 : Evaluation and representations of complexity .................... 32
  1.3 Problem statement, aims and research question ................................. 35
     1.3.1 : Problem statement ............................................................. 35
     1.3.2 : Purpose statement ............................................................... 39
     1.3.3 : Aims ........................................................................... 40
     1.3.4 : Research Question ............................................................. 42
     1.3.5 : The Research Hypothesis .................................................... 43
     1.3.6 : Scope of this thesis .............................................................. 45
  1.4 Outline of this Study ........................................................................... 51

Chapter Two  Theoretical dimensions of spatial complexity .............................. 57
  2.1 Complexity ................................................................................... 59
     2.1.1 Complexity Theories of Cities (CTC) ....................................... 61
     2.1.2 Complexity, design, and cities .............................................. 64
  2.2 Spatial complexity ........................................................................... 68
     2.2.1 Spatial complexity, spatial planning and design ....................... 69
     2.2.3 Other spatial complexities ...................................................... 72
     2.2.4 Two distinct spatial complexity definitions ............................ 73
     2.2.4 Qualitative understandings of spatial complexity ................. 78
     2.2.5 Definition of spatial complexity adopted for this study .......... 80
  2.3 Urban design ................................................................................. 89
     2.3.1 Urban design and the complexity ‘turn’ ................................... 89
     2.3.2 ‘Exploration’ and urban design ............................................. 92
  2.4 Evaluation ..................................................................................... 94
     2.4.1 Evaluation theory ................................................................. 94
     2.4.2 Evaluation for urban design .................................................. 96
     2.4.3 Representation and visualisation theory ................................. 100
     2.4.4 Visualization and information design .................................... 102
  Chapter Conclusions .............................................................................. 105

Chapter Three  Research design and methodology ......................................... 107
  3.1 Introduction ................................................................................... 107
  3.2 Research Design ........................................................................... 108
     3.2.1 Research philosophy .............................................................. 109
     3.2.2 Strategy of inquiry ................................................................. 111
     3.2.3 Operationalising the research question .................................. 116
     3.2.4 Theory and this research design ............................................. 118
     3.2.5 Other research design criteria ............................................... 120
     3.2.5.1 The nature of the research problem ................................... 120
     3.2.5.2 The researchers personal experience ................................. 120
     3.2.5.3 The audience for the study ................................................. 121
  3.3 Specific research methods ................................................................ 122
     3.3.1 Case study .......................................................................... 122
5.4 Three case context descriptions .......................................................... 276
  5.4.1 Liberties (context of the LAP Character Area) .................................. 277
    5.4.1.1 Context Description .................................................................. 278
    5.4.1.2 History .................................................................................. 278
    5.4.1.3 Current Planning/policy ......................................................... 279
    5.4.1.4 Spatial complexity of Liberties context .................................... 280
  5.4.2 Ballymun (context of Urban Ballymun) ............................................ 282
    5.4.2.1 Context Description ............................................................... 283
    5.4.2.2 History of Ballymun ............................................................... 283
    5.4.2.3 Current Planning/policy ......................................................... 284
    5.4.2.4 Spatial complexity of Ballymun context .................................... 285
  5.4.3 Sandyford (context of Carmanhall) ................................................ 288
    5.4.3.1 Context Description .................................................................. 288
    5.4.3.2 History .................................................................................. 289
    5.4.3.3 Current Planning/policy ......................................................... 290
    5.4.3.4 Spatial complexity of Sandyford ............................................ 290
  Conclusions on spatial complexity of the case contexts ....................... 293
5.5 Three case descriptions ...................................................................... 294
    Liberties Character Area ....................................................................... 296
    Urban Ballymun ................................................................................. 298
    Carmanhall ....................................................................................... 300
5.6 Chapter Conclusions .......................................................................... 302

Chapter Six  Three urban site evaluations ............................................. 305
6.1 Introduction ......................................................................................... 306
6.2 Case One: Liberties character area evaluation ..................................... 311
    6.2.1 Liberties morphological description ............................................ 312
    6.2.2 Liberties composition ............................................................... 314
    6.2.3 Liberties configuration ............................................................. 321
    6.2.4 Liberties system ....................................................................... 328
    6.2.5 Evaluated spatial complexity of Liberties character area ............. 335
6.3 Case Two: Urban Ballymun evaluation .............................................. 340
    6.3.1 Ballymun morphological description ......................................... 341
    6.3.2 Urban Ballymun composition ..................................................... 344
    6.3.3 Urban Ballymun configuration .................................................... 350
    6.3.4 Urban Ballymun system ............................................................. 356
    6.3.5 Evaluated spatial complexity of urban Ballymun ......................... 361
6.4 Case Three: Carmanhall evaluation ................................................ 363
    6.4.1 Sandyford morphological description ......................................... 364
    6.4.2 Carmanhall composition ........................................................... 366
    6.4.3 Carmanhall configuration ......................................................... 371
    6.4.4 Carmanhall system ................................................................. 377
    6.4.5 Evaluated spatial complexity of Carmanhall .............................. 382
6.5 Observations within, between and across cases .................................. 386
6.6 Three spatial complexity visualisations ............................................. 392
6.7 Chapter Conclusions .......................................................................... 407

Chapter Seven  Findings and Discussion ................................................ 409
  Introduction .......................................................................................... 409
  7.1 Structuring findings .......................................................................... 410
  7.2 Exploration findings .......................................................................... 413
## Chapter Eight Conclusions

### Introduction

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.1</td>
<td>451</td>
</tr>
<tr>
<td>8.1.1</td>
<td></td>
</tr>
<tr>
<td>8.1.2</td>
<td>453</td>
</tr>
<tr>
<td>8.1.3</td>
<td>456</td>
</tr>
<tr>
<td>8.1.4</td>
<td>457</td>
</tr>
<tr>
<td>8.1.5.3</td>
<td>460</td>
</tr>
<tr>
<td>8.1.5.4</td>
<td>462</td>
</tr>
<tr>
<td>8.1.5.6</td>
<td>465</td>
</tr>
<tr>
<td>8.2</td>
<td>466</td>
</tr>
<tr>
<td>8.2.1</td>
<td>467</td>
</tr>
<tr>
<td>8.2.2</td>
<td>470</td>
</tr>
<tr>
<td>8.2.3</td>
<td>473</td>
</tr>
<tr>
<td>8.2.4</td>
<td>479</td>
</tr>
<tr>
<td>8.3</td>
<td>480</td>
</tr>
<tr>
<td>8.3.1</td>
<td>483</td>
</tr>
</tbody>
</table>
8.3.2 Prescription .................................................................487
8.3.3 Design .......................................................................491
8.4 Implications, limitations and recommendations ......................495
  8.4.1 Implications of the findings and conclusions .....................495
  8.4.1.1 Implications for theory ...........................................495
  8.4.1.2 Concluding theoretical framing of spatial complexity .......498
  8.4.1.3 Implications for practice .......................................501
  8.4.2 Possible limitations ...................................................506
  8.4.3 Recommendations for future research ............................509
  8.4.4 Contributions ..........................................................510
8.5 Concluding Remarks ................................................................511

A Note on Appendices (Volume Two) ............................................516
Permissions ...........................................................................519
List of Publications ....................................................................520
Bibliography .............................................................................522
### List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>Organisational Chart of this Study</td>
<td>50</td>
</tr>
<tr>
<td>2-1</td>
<td>Overall theoretical context of spatial complexity</td>
<td>59</td>
</tr>
<tr>
<td>2-2</td>
<td>Spatial complexity definition adopted for this study</td>
<td>80</td>
</tr>
<tr>
<td>2-3</td>
<td>Papers converging around the ‘spatial complexity’ concept</td>
<td>84</td>
</tr>
<tr>
<td>2-4</td>
<td>Defining spatial complexity concept for urban sites</td>
<td>84</td>
</tr>
<tr>
<td>2-5</td>
<td>Castellani Complexity Sciences Map 2015</td>
<td>86</td>
</tr>
<tr>
<td>2-6</td>
<td>Proposal of this study to extend spatial complexity to urban design</td>
<td>86</td>
</tr>
<tr>
<td>2-7</td>
<td>Meaning of evaluation for urban design in this study</td>
<td>96</td>
</tr>
<tr>
<td>3-1</td>
<td>Selected Research Design Framework</td>
<td>111</td>
</tr>
<tr>
<td>3-2</td>
<td>PhD Study Propositions Chart</td>
<td>125</td>
</tr>
<tr>
<td>4-1</td>
<td>Conceptual framework chart</td>
<td>158</td>
</tr>
<tr>
<td>4-2</td>
<td>Visual model of spatial complexity</td>
<td>160</td>
</tr>
<tr>
<td>4-3</td>
<td>Hierarchical evaluation pyramid and proposed toolbox</td>
<td>164</td>
</tr>
<tr>
<td>4-4</td>
<td>Three ‘issues’ of spatial complexity</td>
<td>166</td>
</tr>
<tr>
<td>4-5</td>
<td>Precedents in evaluation methods of urban sites</td>
<td>168</td>
</tr>
<tr>
<td>4-6</td>
<td>Relevant compositional analysis theories</td>
<td>169</td>
</tr>
<tr>
<td>4-7</td>
<td>Relevant configurational analysis theory</td>
<td>174</td>
</tr>
<tr>
<td>4-8</td>
<td>Relevant system theory</td>
<td>177</td>
</tr>
<tr>
<td>4-9</td>
<td>Visual model of integrated theories around spatial complexity</td>
<td>180</td>
</tr>
<tr>
<td>4-10</td>
<td>Relevant visualization images of urban environment evaluation</td>
<td>210</td>
</tr>
<tr>
<td>4-11</td>
<td>Indicative Databox visualization method of urban site evaluation</td>
<td>220</td>
</tr>
<tr>
<td>4-12</td>
<td>Indicative method: Toolbox evaluation and Databox visualization</td>
<td>223</td>
</tr>
<tr>
<td>5-1</td>
<td>The Greater Dublin Area and the Dublin Region</td>
<td>230</td>
</tr>
<tr>
<td>5-2</td>
<td>Dublin Compositional Complexity Map</td>
<td>238</td>
</tr>
<tr>
<td>5-3</td>
<td>Highest Compositional Complexity location</td>
<td>239</td>
</tr>
<tr>
<td>5-4</td>
<td>Dublin Axial Map 2012</td>
<td>245</td>
</tr>
<tr>
<td>5-5</td>
<td>Highest Configurational Complexity location</td>
<td>246</td>
</tr>
<tr>
<td>5-6</td>
<td>Dublin Axial Map 2012, Choice Rn</td>
<td>250</td>
</tr>
<tr>
<td>5-7</td>
<td>Dublin Axial Map 2012, Choice 1km radius</td>
<td>251</td>
</tr>
<tr>
<td>5-8</td>
<td>Intelligibility Scatterplot for whole city of Dublin</td>
<td>252</td>
</tr>
<tr>
<td>5-9</td>
<td>Highest System Complexity location</td>
<td>255</td>
</tr>
<tr>
<td>5-10</td>
<td>Dublin System Complexity Map (connectivity)</td>
<td>256</td>
</tr>
<tr>
<td>5-11</td>
<td>Various Footfall counts combined, central Dublin</td>
<td>260</td>
</tr>
<tr>
<td>5-12</td>
<td>Dublin context and case sites locations</td>
<td>264</td>
</tr>
<tr>
<td>5-13</td>
<td>Distinct density resolutions</td>
<td>270</td>
</tr>
<tr>
<td>5-14</td>
<td>Distinct land-use clusters</td>
<td>271</td>
</tr>
<tr>
<td>5-15</td>
<td>Overall Dublin complexity maps: composition, configuration, system</td>
<td>272</td>
</tr>
<tr>
<td>5-16</td>
<td>Exploratory Spatial Complexity Map of Dublin</td>
<td>273</td>
</tr>
<tr>
<td>5-17</td>
<td>City map showing case sites</td>
<td>275</td>
</tr>
<tr>
<td>5-18</td>
<td>Liberties Local Area Plan character areas and case site</td>
<td>277</td>
</tr>
<tr>
<td>5-19</td>
<td>Ballymun neighbourhoods and case site</td>
<td>282</td>
</tr>
<tr>
<td>5-20</td>
<td>Sandyford context map and case site</td>
<td>288</td>
</tr>
<tr>
<td>5-21</td>
<td>Liberties character area boundary</td>
<td>295</td>
</tr>
<tr>
<td>5-22</td>
<td>Urban Ballymun area boundary</td>
<td>297</td>
</tr>
<tr>
<td>5-23</td>
<td>Carmanhall neighbourhood area boundary</td>
<td>299</td>
</tr>
<tr>
<td>6-1</td>
<td>Liberties urban site figure ground plan of buildings (2012)</td>
<td>311</td>
</tr>
<tr>
<td>6-2</td>
<td>Liberties morphological taxonomy analysis (sample image)</td>
<td>314</td>
</tr>
<tr>
<td>6-3</td>
<td>Compositional evaluation of Liberties character area</td>
<td>317</td>
</tr>
<tr>
<td>6-11</td>
<td>Land-use mix of Liberties</td>
<td>318</td>
</tr>
<tr>
<td>6-12</td>
<td>Density of Liberties</td>
<td>319</td>
</tr>
<tr>
<td>6-13</td>
<td>Global integration of Liberties</td>
<td>322</td>
</tr>
<tr>
<td>6-14</td>
<td>Local integration of Liberties</td>
<td>323</td>
</tr>
<tr>
<td>6-15</td>
<td>Choice measure of Liberties</td>
<td>324</td>
</tr>
<tr>
<td>6-16</td>
<td>Configurational evaluation of Liberties character area</td>
<td>326</td>
</tr>
<tr>
<td>6-17</td>
<td>Liberties system complexity evaluation</td>
<td>329</td>
</tr>
<tr>
<td>6-18</td>
<td>Street network complexity of Liberties character area</td>
<td>330</td>
</tr>
<tr>
<td>6-19</td>
<td>Path network complexity of Liberties character area</td>
<td>331</td>
</tr>
<tr>
<td>6-20</td>
<td>Pedestrian movement network complexity of Liberties character area</td>
<td>332</td>
</tr>
</tbody>
</table>
Figure 6-21  Figure ground plan of Urban Ballymun ................................................................. 340
Figure 6-29  Land-use mix of urban Ballymun ............................................................ 346
Figure 6-30  urban Ballymun density ........................................................................... 347
Figure 6-31  urban Ballymun global integration ............................................................ 351
Figure 6-32  urban Ballymun intelligibility ................................................................. 354
Figure 6-33  urban Ballymun local integration ............................................................ 355
Figure 6-34  urban Ballymun local choice .................................................................. 355
Figure 6-35  urban Ballymun street network complexity ............................................ 357
Figure 6-36  urban Ballymun metric reach ................................................................. 358
Figure 6-37  urban Ballymun pedestrian movement complexity ................................... 359
Figure 6-38  Figure ground plan of Carmanhall in Sandyford context ................. 363
Figure 6-45  Land-use mix Triangle .......................................................................... 368
Figure 6-46  Density graph ....................................................................................... 369
Figure 6-47  Overall global integration of Dublin axial map ....................................... 371
Figure 6-48  Overall local integration of Dublin axial map ......................................... 372
Figure 6-49  Intelligibility of urban site at Carmanhall ................................................ 375
Figure 6-49  Carmanhall urban site, choice measure, metric radius 400m .................. 376
Figure 6-50  Carmanhall street network complexity .................................................... 378
Figure 6-51  Path street network complexity ............................................................... 379
Figure 6-51  Pedestrian movement network complexity ............................................. 380
Figure 6-52  Spider plots of spatial complexity ........................................................... 386
Figure 6-53  Colour weightings applied to Evaluation Forms ...................................... 394
Figure 6-54  Plot Type instrument development (above) and Plot Taxonomy .......... 396
Figure 6-55  Sketch Spider Plots for three urban sites ................................................ 397
Figure 6-56  Compositional criteria Evaluation Form for three urban sites ............. 398
Figure 6-56  Applying colour weightings to Spider Plots ............................................. 399
Figure 6-57  Applying pixels and colour weightings to Databox ................................ 399
Figure 6-58  Connecting pixels and colour weightings to Irish Grid and Databox .... 400
Figure 6-59  Connecting address points and 2D section to Irish Grid and Databox .... 401
Figure 6-60  3-D Address points, Liberties, and comparable urban sites .................. 401
Figure 6-60  3-D Model of Databox for Carmanhall largest plot .................................. 402
Figure 6-61  Sample joined evaluations of the three urban sites ............................ 403
Figure 8-1  Extract from Cornmarket Spatial Complexity Report ............................ 484
Figure 8-2  Urban Ballymun Prescription Graphic ...................................................... 488
Figure 8-3  Site Description and Optimal Design Density, Carmanhall .................. 493
Figure 8-4  Scoping of Spatial Complexity ............................................................... 498
Figure 8-5  Final Theoretical Concept of Spatial Complexity of urban sites ......... 501
List of Tables

Table 3-1. Operationalising the Research Question .......................................................... 117
Table 3-2. Urban Design Complexity Classification Criteria Table ...................................... 135
Table 4-1. All proposed issues and criteria of spatial complexity ....................................... 185
Table 4-2. Issue (top) and proposed compositional criteria (bottom) ............................... 186
Table 4-3. Literature on compositional criteria .................................................................. 187
Table 4-4. Issue (top), and proposed configurational criteria (bottom) .............................. 195
Table 4-5. Issue (top), and proposed system criteria (bottom) ........................................... 201
Table 4-6. Proposed spatial complexity evaluation Toolbox .............................................. 218
Table 5-1. Compositional complexity data inputs .............................................................. 240
Table 5-2. Configurational complexity data inputs (top) and Integration core as cells ......... 244
Table 5-3. System complexity data inputs for exploration ................................................ 254
Table 5-4. Three case unit descriptions ........................................................................... 274
Table 5-5. Three explored spatial complexity results (case contexts) ............................... 293
Table 6-1 Liberties Urban Morphological Complexity Evaluation Form .......................... 316
Table 6-2 Liberties Spatial Complexity Evaluation Form .................................................. 339
Table 6-3 Urban Ballymun Morphological Complexity Evaluation Form .......................... 345
Table 6-4 Urban Ballymun Spatial Complexity Evaluation Form ....................................... 362
Table 6-5 Carmanhall Urban Morphological Complexity Evaluation Form ...................... 367
Table 6-6 Carmanhall Spatial Complexity Evaluation Form ............................................. 385
Table 8-1 Main and Minor Propositions ............................................................................ 463
List of Appendices (Volume Two)

Appendix A  Morphology of cases
Appendix B  Evaluation Protocols
Appendix C  Glossary of Terms
Appendix D  Pedestrian Movement Fieldwork
Appendix E  Syntactic Analysis of Dublin
Appendix F  Visualising Spatial Complexity
Appendix G  Applications Reports
Appendix H  Case study research design options
## List of Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACA</td>
<td>Architectural Conservation Area</td>
</tr>
<tr>
<td>AIRO</td>
<td>All-Ireland Research Observatory</td>
</tr>
<tr>
<td>BID</td>
<td>Business Improvement District</td>
</tr>
<tr>
<td>BRL</td>
<td>Ballymun Regeneration Limited</td>
</tr>
<tr>
<td>CSO</td>
<td>Central Statistics Office</td>
</tr>
<tr>
<td>CTC</td>
<td>Complexity Theories of Cities</td>
</tr>
<tr>
<td>DCC</td>
<td>Dublin City Council</td>
</tr>
<tr>
<td>DCT</td>
<td>Dublin Civic Trust</td>
</tr>
<tr>
<td>DMURS</td>
<td>The Design Manual for Urban Roads &amp; Streets</td>
</tr>
<tr>
<td>DLRCC</td>
<td>Dún Laoghaire Rathdown County Council</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System</td>
</tr>
<tr>
<td>KDC</td>
<td>Key District Centre</td>
</tr>
<tr>
<td>LAP</td>
<td>Local Area Plan</td>
</tr>
<tr>
<td>NIRSA</td>
<td>National Institute for Regional and Spatial Analysis</td>
</tr>
<tr>
<td>NTA</td>
<td>National Transportation Authority</td>
</tr>
<tr>
<td>SDRA</td>
<td>Strategic Development Regeneration Areas</td>
</tr>
<tr>
<td>SDZ</td>
<td>Strategic Development Zone</td>
</tr>
</tbody>
</table>
Chapter One Introducing spatial complexity

‘if urban design theorists do not pay attention to the science of cities, others surely will’

(Marshall, 2012a:265)

Short overview

The central aim of this study is to expand understandings of spatial conditions in urban sites through the deepening of the theoretical concept of spatial complexity, and developing an objective measure of the spatial complexity of an urban area roughly equating to neighbourhood size, referred to as an ‘urban site’. The core concept developed is that of spatial complexity, understood in relation to the urban environment as the spatial component of urban complexity. The study is located at the intersection of three fields: complexity, urban design and evaluation. Key concepts are related to the complexity theory of cities (CTC) discourse, which regard cities as complex systems. Three ideas associated with aggregate complexity theory are employed: relationality, multi-scalarity, and temporality of complex systems. Firstly, the concept of relationality foregrounds interrelationships between individual entities and others, including larger aggregates, and is valuable for describing urban complexity. Secondly, multi-scalarity emphasises the importance of considering multiple scales, improving the study of urban spatial phenomena. Thirdly, temporality as a concept focuses on understanding time as a critical factor in emergence of complex urban systems and environments.
Urban design operates at the intersection of spatial planning, landscape and architecture, and as such is an appropriate disciplinary focus for understanding spatial complexity of urban sites. Within urban design, integrative urban design theory is concentrated on. Evaluation theory related to the urban environment currently foregrounds static, monoscalar readings of urban sites, in a dynamically complexifying urban context. Understanding spatial complexity deepens connections between complexity theories of cities and the theory and practice of integrative urban design, particularly related to improving current evaluation of urban sites. The study does not expand on the meaning of spatial complexity for whole cities, or for small spatial units such as streets or urban spaces, but concentrates instead on the mid-level focus of urban design, the urban site.

Ireland is an appropriate setting for testing ideas about evaluating spatial complexity for a number of reasons. As a highly globalised island state, with a late urbanising but rapidly growing population, development is increasingly happening under a neoliberal, entrepreneurial spatial planning culture, and is increasingly related to boom and bust economic cycles, leading in turn to spatial complexification. Dublin is a suitable context for case study research on spatial complexity and urban design because of three primary characteristics: history, size and diversity. As one of the oldest European capitals outside the areas that were once part of the Roman Empire, an established urban historic structure has extended to encompass a globalised city-region containing a variety of distinct and contrasting urban site types. Dublin is considered in a medium range of European cities as regards size, density and compactness, and spatial, economic and social diversity are manifest in the inner city as well as the city-region, the context of the study of three cases.
Research question and methodology

One problem this study addresses is that fact that the domain of urban design has been barely examined from the point of view of complexity. However, the central problem of the thesis is that, despite widespread knowledge of the importance of understanding complexity in urban sites, the spatial aspect does not get the attention it deserves in the urban design discourse (theory), nor in the implementation of urban design (practice) which in turn negatively affects the (design of the) urban built environment. Another problem this study seeks to address is the current lack of comprehensive evaluation of urban sites, whether for urban description, prescription or design. The research question asks: how can complexity theory and urban design theory contribute to increased exploration and understanding of the theoretical concept of spatial complexity for urban design, as well as to development of practical urban design evaluation tools for urban sites? A mixed methods approach is adopted in a case study methodology, combining quantitative measurement of urban sites with qualitative tactics to explore, evaluate and visualise spatial complexity at urban design scales.

Literature Review

The research problem, a failure to understand the importance of optimal levels of spatial complexity of urban sites, has impacts for the urban built environment. Three broad areas of literature are relevant. The distinct fields are: complexity theories of cities (CTC), (integrative) urban design theory, and (urban environment) evaluation theory. A critical review of the literature suggests the key debates can be categorised into three themes: firstly, from complexity theories of cities (CTC), this paradigm focuses on large, abstract units of the city, so more local scales of urban design are overlooked. Useful theories from CTC set out a frame for understanding spatial complexity in
relation to urban environments, but do not specifically deal with urban sites. Secondly, urban design theory and practice is seen to lack an evidence base, which leads to accusations of pseudo-scientific character for the discipline as a whole. In practice, a lack of evidence for urban design (decisions and designs) leads to insubstantial grounds for decision-making in urban description, prescription and design. Thirdly, the fact that evaluation theories fail to account for assessment which encompasses relationality, multi-scalarity, and temporality is a feature of the literature.

**Contribution**

This study contributes to the existing literature in three ways, related to theory, a tool, and cases. Firstly, by describing underlying theories of spatial complexity and deepening these for urban design. Secondly, developing an evaluation tool provides an objective measure of spatial complexity. Thirdly, generation of multiple case evaluations of spatial complexity forms a new source of empirical evidence for urban analysis and design practice. This study is distinctive in that it is introducing a complexity frame (relational, multi-scalar, and temporal) to urban design evaluation for use in description, prescription and design of urban sites. Previously, little attention has been paid to complexity at local urban scales. This contribution will lead to an improved understanding of the role of composition, configuration, and system properties in affecting evaluated levels of spatial complexity of urban sites, resulting in a better understanding of global and local spatial complexity patterns, and in improved evidence gathering for evaluation and design. The primary contribution of this study is to deepen spatial complexity theory, by developing a conceptual framework and evaluation tool for exploration, evaluation and visualisation of spatial complexity of case urban sites, which forms a new base of empirical evidence for urban analysis and design.
Relevance

The purpose of this study is to explore and adapt an under-developed theoretical framework found both in complexity theories of cities (CTC) research and in urban design research, as well as other fields, as a contribution to urban design discourse, for use in urban exploration, evaluation, visualization and design practice. This thesis argues that the level of spatial complexity of urban sites in global and local terms can be evaluated, and that this evaluation can assist in the description, prescription and design of urban sites. This is seen as relevant to a discourse on spatial and design quality. The need for spatial complexity understandings of urban sites in the selected range can be described as including the lack of previous focus by spatial research on these types of location, the dynamically changing character of these site types, as well as the claim that these types of sites demonstrate conditions of cultural definition and international relevance. The particular interest in this thesis for evaluating is in order to strengthen this aspect of urban design, as urban design evaluation is currently lacking in practice. Results of this research could also support decision-makers and communities seeking more optimal levels of spatial complexity of urban sites. The conceptual framework for evaluation developed in this study assists urban designers and spatial planners in making evidence-informed analysis about existing spatial conditions. The results can support better design decisions about proposed changes in urban sites, and improve urban evaluation. In addition, this analysis can support dynamically changing and urbanising cities to understand the spatial and other consequences of sub-optimal spatial complexity patterns.
Data sources

Data sources, including primary generation of an evaluation framework and measurement tools, collection of observation data, preparation of mapping and graphics, and quantitative and qualitative evaluations, help to generate visualisations of results. Secondary sources including historic mapping, a syntactical database, and published data on spatial aspects of the city of Dublin which contribute quantitative and qualitative information, ensuring comprehensive exploration, evaluation and visualisation of spatial complexity.

Structure of the thesis

In response to the research question, the research design proposes a structure involving three separate phases of work. Briefly, the first (theoretical) phase (Chapters Two – Four) argues that optimal levels of spatial complexity enrich urban sites, and therefore cities, and that current understandings of this concept need to be refined and deepened for urban analysis and design. This phase arrives at coherent and useful evaluation indices of spatial complexity for urban analysis and design, in order to understand the relationships between compositional, configurational and systems aspects of urban sites. The second (exploratory) phase (Chapter Five) tests the explored spatial complexity of the contexts of three urban sites, in order to link the theoretical framing and the practice of evaluating spatial complexity. The third (evaluation and visualisation) phase (Chapter Six) is focused on certain distinct and contrasting spatial conditions, in a case study approach, thus demonstrating new tools and techniques of evaluation and visualisation for urban design (research and practice). In summary, the research question asks how the theoretical concept of spatial complexity can be constituted and operationalised for urban design, and in response the research design proposes three phases of work: theoretical development, exploration and evaluation.
Conclusions

The conclusions of the study can be categorised into three parts: on exploration, evaluation and visualisation. Firstly, in relation to exploration, it is concluded that in a useful deepening of existing concepts, a new definition of spatial complexity can be proposed, as an integration of compositional, configurational, and system complexity. Furthermore, in the linkages and associations between the scalar levels useful information about exploring spatial complexity of urban sites can be uncovered. Following this revised theoretical definition, the core conceptual frame of this thesis, that of spatial complexity, can be operationalised to usefully improve classification and description of urban sites in an integrative evaluation. Secondly, in relation to evaluation, and following three case demonstrations, this study concludes that spatial complexity theories of cities can usefully be extended to evaluation of spatial complexity of urban sites for urban design. Further, by integrating three separate concepts into one integrative idea of spatial complexity, urban design understandings of urban sites are deepened and extended. It is also concluded that mixed methods and tools enhance urban design evidence and analysis. Thirdly, in relation to visualisation, this study concludes that infographic visualisation of spatial complexity enhances urban design evaluation, that data visualisation for urban design includes visualising spatial complexity, and that interpretative analysis contributes to urban design practice. In summary, explorations of spatial complexity of case contexts, as well as the evaluations of three urban sites, demonstrate that an integrative exploration, evaluation and visualisation approach reveals distinct and contrasting levels of spatial complexity in one city.
1.1 : Background to this study

Urban sites as contested spaces

In international terms, urban sites are seen as increasingly contested spaces (Pullan, 2013). While there is evidence in the literature of responses of spatial planning in dealing with rapid change and increasing urban complexity, including relational planning at regional scales (Healey, 2007) new processes for managing increasingly complex change and design in urban areas are suggested, including adaptive planning processes (Kwakkel et al., 2012). While the complexity theories of cities (CTC) domain has investigated policy and theory implications of ever more connected research fields related to the city (de Roo, 2012b), less focus has concentrated in the literature on understanding, evaluating and measuring the spatial complexity of urban sites, especially at local urban design scales. In defining a specifically spatial approach, a primary assumption is that: ‘space, represented in terms of relative location and a set of physical attributes of geographical locations, strongly influences the behaviour of individuals, households, firms and organisations’ (Rasouli and Timmermans, 2012). This supposition underpins all policies and instruments of government to guide and control urban and other land use in the public interest. Although a complex systems approach to urban questions sees uncertainty and dynamic change as important influences to also consider (Sengupta et al., 2016), the continuing primacy of the spatial aspect of phenomena is the reason that this aspect of complexity predominates in this study of urban sites.

Irish urban sites

Reviewing the design and planning literature for Ireland, it is notable that research on evaluation of urban sites for urban design is missing, especially but not exclusively in
the cases of sites on the edges of built-up areas of the city. While contested Irish ruralities have been investigated (Scott, 2006), (González et al., 2016) within a broadly spatial frame (planning), official urban design evaluations of urban sites, for example, have happened only twice since the start of the ‘entrepreneurial phase’ of Irish planning in the mid-1980’s (Bartley, 2007:31), and this was solely in relation to tax incentives for inner urban sites. Thus, information is missing on suitability of receiving environments, levels of demand for proposed development, of quality of urban design proposals in advance of construction, of relative phasing and environmental aspects, and expected urban design impacts of developments on urban sites. At local scales, Irish urban sites are undergoing dynamic change, often in a context without overall understandings of the importance of design quality, and in the absence of an established urban design culture. Nationally, a lack of policy and guidance is apparent, often manifesting in anarchaic spatial conditions (Gkartzios et al, 2015). While contemporary Irish urban spatial conditions vary substantially, with some sites under more pressure than others due to the uneven spatial distribution of urban centres nationally (McCafferty, 2007:64), some urban sites, especially in and around Dublin, are in the forefront of spatial change nationally (Davoudi and Wishardt, 2005), and have so far been under-examined at urban design scales.

**The Irish spatial ‘turn’**

Although recent writings on the changing spatial conditions of contemporary Ireland and the emergent discourses suggest a belated Irish spatial ‘turn’ (Crowley, 2013) (James-Chakraborty, 2011) (Kearns, 2014), the urban condition is not foregrounded, and the disciplinary focus of urban design is mostly absent from commentaries. Furthermore, research for urban design in Ireland has been lacking, which in turn has
contributed to a lack of criticality in design culture nationally. Other, more general urban design practice challenges include globalizing and neoliberal influences, as evidenced by a weakening planning system, increasingly entrepreneurial forms of planning, and increasing commercial pressures. Recent literature on spatial aspects of contemporary Ireland, in geography, architecture, and morphological research, tends not to foreground the urban condition. In geography, significant new readings of specific contemporary spatial conditions on the island of Ireland have been developed in recent years. For example, NIRSA’s\(^1\) review of a boom in new housing and consequent development of ghost estates\(^2\) in Ireland concluded that a laissez-faire planning system and tax incentive schemes allowed a large oversupply of housing units and zoned land to develop nationally (Kitchin, 2010). However, the review did not concentrate on the broader spatial implications of the over-supply of housing, and did not concentrate on urban-specific profiling. Another commentary sees the architecture of landmark developments and ghost estates as emblems of Irish society after the Celtic Tiger era (O’Sullivan, 2011).

‘Spacing Ireland’ (Crowley, 2013), a compendium of essays dealing with ‘the spatial signature of the Celtic Tiger and its aftermath’ (Crowley, Linehan, 2013:7), considers the spatial and other impacts of the downturn of the Irish economy, after an economic boom which ended in 2008. It describes the country as a ‘turbulent place’, and concentrates on a geographical approach. Following an unprecedented growth of Irish urban development in the twenty years up to 2008, resulting challenges to urban livability is the subject of one essay (Lawton, 2013), but specific cases are not

---

\(^1\) The National Institute for Regional and Spatial Analysis (NIRSA) is based at Maynooth University, Dublin, Ireland.

\(^2\) The concept of ‘ghost estate’ was first described by David McWilliams, a prominent Irish author and journalist, in 2006, as an output of tax-driven schemes for rural housing. O’Callaghan defines the type as ‘housing estates of ten or more houses where 50% are either vacant or under construction’ (O’Callaghan, 2013). Ghost estates are mainly located in areas with few amenities, such as the edges of Irish towns.
investigated. Another relevant Irish-related publication, ‘Crossing Borders’ (James-Chrakraborty, 2011), considers spatial discourses through essay contributions from separate disciplinary perspectives, including architecture and art history, although none is from an urban design viewpoint, or focused on specific Irish urban sites.

Another recent study looks at the “wholly new forms of socio-spatial conditions” in Ireland, Spain and China, as a result of what is described as ‘asset urbanism’, (Soules, 2013: 686) particularly created in the years to 2008. The research refers to the complexity of market dynamics and urbanization in a general sense as contributing factors in spatial transformation. The spatial changes described include rapid development, the over-supply of built space, mass vacancies, and volatile fluctuations between growth and decay, and the argument is that current design discourse lags behind the advances of capital in producing space. However, there is little engagement with local spatial conditions at urban sites scale in the three locations described. A geographical and urban planning appraisal of Dublin (MacLaran, 2014) examines recent consequences of neoliberalism, including of over-development in the residential sector in the city, gentrification and contested urban environments, arguing that neoliberalism brought about major transformations in the city. Although many single case study locations are examined, the detailed spatial focus is again not the driver of the enquiry.

Irish urban morphological research generally studies changes and growth of elements of urban form such as historic towns and cities. Over time, a focus on the study of historical urban morphological development was seen to grow in response to the perceived and real loss of quality in cities and towns in Ireland from the economic development boom in Ireland of the 1960’s onwards (Kealy, 2008). This research
output was slow to develop in international terms, is still small by international standards, and is focused on historic urban form (Kealy, 2010). In one study, the usefulness of morphological analysis to Irish urban design has been highlighted with examples (O'Connell, 2013: 53), and the need for dialogue between research and practice is stressed. Another contribution highlights the need for practical morphological method in the face of loss of cultural meaning, and a perpetuation of incoherence of Irish urban form (McCormack, 2013: 45).

**Dublin**

Publications in the field of Irish urban history were few in number before 1960, and even after that date, emphasis was on the antiquarian and topographical (Irish towns) up until the 1980’s (Daly, 1986) to the exclusion of the capital city. According to Kealy & Simms (Kealy & Simms, 2008), the earliest work to use the concept of urban morphology in an Irish context was Burke’s study of morphogenesis in Dublin (Burke, 1972). By the mid 1980’s urban design in Dublin was considered to exist ‘mostly in paper projects’, promoting the idea of the city as an architectural entity (Malone, 1989). By the 1990’s the urban design culture in Dublin was considered too reliant on ‘grand projects’, to the exclusion of incremental change through design (Shaffrey, 1996). While McCullough’s urban historical and urbanist description of Dublin (McCullough, 2007) comes closest to a spatial overview which foregrounds urban design, it concentrates on the past and the historic core (mainly between the Grand and Royal canals). Casey’s (2005) historical guide and gazetteer of central Dublin, also covering only the historic centre, operates mainly at the level of individual buildings (Casey, 2005). No recent publication on Dublin investigates contemporary urban conditions from a spatial perspective by using case studies.
In summarising the background to this study, recent relevant research about contemporary Ireland with a spatial perspective confirms that rapid change is a feature, especially up to 2008, that the literature on Irish spatiality does not focus on specific urban settings or urban design, and that Irish urban morphology research output is small and concentrated on historic urban form. It is also noted that research on evaluation of urban sites for urban design is missing, especially but not exclusively in the cases of sites on the edges of built-up areas of the city. Also, recent literature on spatial aspects of contemporary Ireland, in geography, architecture, and morphological research, tends not to foreground the urban condition. Furthermore, studies of spatial aspects of Dublin, the largest urban settlement in Ireland, do not foreground urban design qualities or recent spatial change in specific sites of the city. These are the key factors which feature as a background to this study.
1.2: The academic rationale

This second section of Chapter One outlines the academic motivation of this research by firstly outlining the understanding of complexity adopted in this study, and then the field of urban design is introduced. The claim that reductionist approaches are not adequate for urban design theory, policy or practice is advanced. The more specific issue of connections between complexity, urban design and urban sites is then discussed. Discussion of the need for appropriate evaluation and representation of spatial complexity completes the description of the academic rationale of this study.

1.2.1 : Introducing complexity

Accepting that the urban environment is complex (Barredo et al, 2004)(Rydin, 2012), and that complexity is an important way to organize knowledge in relation to cities, (Batty, 2009), a complexity approach is adopted in this study. The word ‘complexity’ is applied to research in three major streams: algorithmic complexity (mathematical complexity theory and information theory), deterministic complexity (chaos theory and catastrophe theory) and aggregate complexity, defined as ‘the study of how individual elements working in concert create complex systems which have internal structure relative to a surrounding environment, and which may also exhibit learning and emergence’ (Manson, 2006:678). Aggregate complexity is considered most relevant to studies of complexity related to space and place (Manson, 2006:681), and relates most directly to this study.

This research focuses on one specific area within complexity theory, that of complexity theories of cities (CTC). Complexity theories of cities (CTC) are proposed by spatial
planners, scientists and others as “attempts to understand our world assuming it neither evolves linearly nor is in balance” (de Roo, 2012a: 207). Characteristic elements which complexity theories of cities deal with include adaptive capacity of cities, the ability of cities or parts to ‘self-organise’, which in turn is seen as determined by the diversity of the city, and the positive encounter between developments in the past, or ‘path dependancy’, resulting in ‘evolutionary processes’ of urban form (Portugali, 2012c: 213). Much of CTC theory on urbanism relates to the increasing computer facility available for measuring complexity in urban environments, working from known spatial data and facts. This growing field will be described in more detail in Chapter Two.

Key concepts in this study originate in the complexity theory of cities (CTC) discourse, which regard cities as complex systems. Three ideas related to aggregate complexity theory are employed: relationality, multi-scalarity, and temporality of complex systems. Firstly, the concept of relationality foregrounds interrelationships between individual entities and larger aggregates, and is valuable for describing urban complexity (Jones, 2009). Relationality, as a theoretical concept related to complexity, involves understandings of the world as one in which ‘objects, situations, values, ideas, and behaviour acquire meaning in their relationship to other objects, situations, values, ideas, and behavior’ (Healey, 2012:9). Healey uses this concept of relationality in arriving at a definition for relational spatial planning in a complexity frame. Behaviour and process for example, understood in terms of complexity and CTC, emphasize the non-material aspects of relations and actions in defining complexity (Partanen, 2010). Although spatial aspects of urban sites are concentrated on in this study, relations between spatial and other aspects of urban sites, in particular social, economic and political contexts, are important in understanding evaluated spatial complexity. For this
study, demonstrations of relationality, between spatial context and cases, also within, between and across cases, and between issues and criteria of spatial complexity, are core objectives.

Secondly, multi-scalarity emphasises the importance of considering multiple scales, improving the study of urban spatial phenomena. In relation to scale, complexity thinking, like network theory (Brenner, 2008: 395) has been described as ‘ascalar’ or independant of specific scales of operation, and this feature makes complexity thinking relevant to urban design, where definitions of scalar limits of the discipline are unclear (Marshall, 2015). While in the study of cities, phenomena are observed to have self-similar patterns across scales (Batty, 1994), it is the necessity to simultaneously consider many scalar manifestations that makes the complexity frame more primary as a ‘paradigm’ for this study than architecture (building/object scale), urban design (groups of buildings, etc) or spatial planning (policy, large scale area or city planning). New interpretations of spatial phenomena in a complexity frame which reduce the primacy of one scale (Chapura, 2009), could be described as ‘simultaneous scales’ understandings, a theme explored in a later chapter of this thesis (Chapter Six), which examines the case sites. Manson & O’Sullivan (2006) consider that complexity (theory) provides a new way to address problems in space-and-place-based research ‘by focusing attention on the importance of scale to generalization and specialization’ (Manson, 2006:680). For this study, multi-scalarity provides a conceptual background to exploration of spatial contexts at a higher scale, while simultaneously evaluating urban sites at a lower scale, while also keeping in play the overall, whole-city background.
Thirdly, temporality as a concept focuses on understanding time as a critical factor in emergence\(^3\) of complex urban systems and environments. Although Soja argues that in the relation between social and spatial processes, there has been, over the past hundred or so years, a privileging of time over space, and history over geography (Soja, 1989), complexity thinking requires that time and space are held equally in mind (Thrift, 1999:31). For this study, temporality provides a conceptual fix for describing impacts of spatial change on a ‘static’ exploration and evaluation of spatial complexity of urban sites in a historic and dynamically changing city. In summary, a complexity approach is adopted in this study, within the CTC paradigm, and three concepts from aggregate complexity theory are employed: relationality, multi-scalarity, and temporality.

1.2.2 : Introducing urban design

Cuthbert (2006) defines urban design as: ‘the purposive production of urban meaning in certain urban forms’\(^4\) (Cuthbert, 2006:93), and Carmona and Tiesdell provide another encompassing definition of urban design: ‘Urban design…is…variously a product (the design of the created environment) interventions into a process (eg. a land and property- or real estate- development process) and a process itself (i.e. the design process)’ (Carmona and Tiesdell, 2007:120). However, as both of these definitions are slightly vague and unspecific, Marshall’s more succinct definition of urban design is the one adopted in this study: ‘an art or technical practice involving the physical organisation of buildings and spaces, towards a civic purpose’ (Marshall, 2012b:258). This understanding keeps open both the qualitative and quantitative aspects inherent in

---

\(^3\) The concept of emergence in complexity thinking involves dynamics by which local interactions give rise to a global structure (Byrne, 2001:67). Emergence relates to another idea, that of the ‘nested nature’ of complex systems, and the fact that systems have components which in themselves are systems, and these can display emergence. In this definition, higher level properties emerge from interactions between lower level components Rothmans J, Loorbach, Derk, Rene Kemp. (2012) Complexity and Transition Management. In: de Roo GE (ed) Complexity and Planning : Systems, Assemblages and Simulations. Ashgate, 177-198.

\(^4\) This borrows from Castell’s (1983) similar, but arguably more comprehensively outlined definition: ‘We call urban design the symbolic attempt to express an accepted urban meaning in certain urban forms’ (Castells, 1983:119).
The discipline and practice of urban design are currently undergoing dramatic change (Al-Douri, 2013), especially in globalised economies where development is driven by neoliberal and entrepreneurial forms of city planning and design, of which Ireland forms a part (McGuirk and Maclaran, 2001). While it has been argued that historically, urban design often coincided with ‘the speculative development model’ in cities like London (Carmona, 2014a: 13), increasingly urban design is required to perform as an economically profitable ‘device’ in urban sites, providing ‘perceived economic benefit’ (Bell, 2005: 90). In this context, urban design aspects such as ‘theming’ developments to attract middle class home buyers, which imply publicness but actually reduce it (Meier and Reijndorp, 2012), or increasingly ‘private’ developments of peripheral urban sites (Lawton, 2009) are mainstream aspects of urban design practice, and are required to be evaluated empirically, as much by clients of development and communities
affected, as by policy and planning authorities at local and city level. It is these strained economic conditions, which affect the design, management and life of urban sites, which forms the background to this research.

**Integrative urban design**

This study focuses on one area within urban design, that of integrative urban design. While Carmona (2014) sees the discipline of urban design as ‘an integrated process or continuum’ (Carmona, 2014), integrated urban design theory has been defined more specifically as combining: ‘(i) insight into how the world works; (ii) a stance on how the world ought to be; (iii) a view on how to get from here to there’ (Marshall, 2012b), (thus combining ‘substantial, procedural and normative aspects’) and this is claimed to give credence to urban design ‘as a dedicated, coherent intellectual discipline’ (Marshall, 2012b: 258). Integrative urban design theory is contrasted, in this account, with disparate pseudo-scientific theories of urban design on the one hand, and the art or craft of urban design practice on the other. Buchanan proposes ‘integral’ theory in response to contemporary urban design approaches, which he sees as “still inflected with modern functionalist thinking” (Buchanan, 2013: 6). Other prior literature agrees that reductionist approaches are not adequate for urban design theory (Sorkin, 2009), policy (Collier et al., 2013), or practice (Gil, 2013). Three particular theoretical concepts related to urban design are concentrated on and employed in this research: urban morphology theory, space syntax theory, and urban systems theory. Each of these is defined and described in detail in Chapter Four, as part of the development of a conceptual framework of the study. The three separate theoretical concepts are then integrated to develop a conceptual framework for exploration and evaluation of spatial complexity of urban sites.
1.2.4 : Complexity, urban design, and urban sites

Having introduced a complexity approach, and then discussed the relevant literature on space as regards the academic rationale of this thesis, here the more specific issue of connections between complexity, urban design and urban sites is discussed. Although complexity theory and urban design theory have been recently linked in the literature (Kasprisin, 2011; Marshall, 2009; Bentley and Kiddle, 2014), there is currently insufficient overlap of research interests between design and complexity (Alexiou, 2010: xiii) and little published work which extends complexity thinking into urban design practice, with exceptions (Weinstock, 2013), (Dekay, 2012). While complexity has been studied for individual aspects and elements of the urban environment such as perceived complexity of streets (Elsheshtawy, 1997), or complexity of tall buildings facades (Heath, 2000), these are isolated elements examined at a single scale only. In one account, the public realm has become so ‘imbued with complexity’ that is is difficult to measure (Talen, 2003:204).

There are three particular ways in which understanding complexity can be useful for urban design and urban sites. Firstly, optimal complexity has advantages for urban sites. Marshall gives three reasons for seeking ‘functional’ or ‘urban’ complexity: “perceptual richness, functional capacity, and synergy”5 (Marshall, 2012a:193). Though not corresponding in precisely literal terms, these three suggested advantages are interpreted in this thesis as corresponding to, respectively environmental, functional and social benefits. Firstly, as regards environment, Salingaros, in seeking urban coherence and complexity, sees benefits of ‘an efficient, livable and psychologically nourishing human

---

5 The concept of ‘synergy’ is described by Marshall as ‘the quality by which a whole entity is greater than the sum of its parts, or a whole operation is greater than the sum of the individual actions. This ‘added value’ typically arises where the entity is heterogeneous, and the individual components are complementary’ (Marshall, 2012a:194). However, while Marshall uses ‘physical’ examples such as a Swiss Army knife, and contiguous urban objects (newsstand next to crossing points), in this study the social aspect of synergy, such as co-presence of diverse ethnicities and its benefits, is concentrated on.
environment’ (Salingaros, 2000). Jacobs’ development of Weaver’s concept of ‘organized complexity’ describes cities as containing ‘organisms that are replete with unexamined, but obviously intricately interconnected, and surely understandable, relationships’ which ‘contain seeds of their own regeneration, with energy enough to carry over for problems and needs outside themselves’ (Jacobs, 1961: 452).

Secondly, as regards functional benefits, optimal complexity can be useful for urban sites by maintaining potential for change through adaptation over time, a feature of complex systems (Heylighen, 1999), although, in city terms, Lynch did not agree that complexity necessarily implies adaptability (Lynch, 1958:17). Salat argues that the complexity of the urban structure of cities has a direct impact on urban structural efficiency and resilience (Salat, 2011:26). In this interpretation, urban sites can be seen as ‘learning’ environments, where optimal functional complexity is monitored through assessments of adaptability of aspects of urban sites over time.

Thirdly, optimal complexity can have social benefits. Vaughan demonstrates that street network complexity helps contribute to a town centre’s resilience against external disruptive forces, such as economic downturns or social change (like different populations moving into an area)(Vaughan, 2015:172). Talen (2003) points out that, although New Urbanists6 for example point out the need to decrease (urban) monocultures, increase complexity and diversity, the concepts prove intangible without effective tools to measure these qualities (Talen, 2003:203). Social benefits of optimal complexity include enriched urban life (Salingaros, 2000), increased potential for urban co-presence (Legeby, 2013), and increased social diversity (Munoz,

---

6 New Urbanism is a movement in urban design, which arose in the 1980’s in the United States, and seeks mixed-use, walkable neighbourhoods and city centres.
In summary, environmental, functional and social benefits of optimal complexity of urban sites are established in the literature. Spatial aspects of this complexity are concentrated on in defining spatial complexity.

Complexity can be useful for understanding urban sites in practice, as the complexity approach relies less on ‘plans’ and masterplans for large scales, or fixed futures which have one solution, and more on individual processes and overlaps with other processes (Kasprisin, 2011). A complex systems view firstly suggests widening the number of variables to be evaluated for an urban site, as compared with current urban analysis methods for planning and urban design, which generally include a single scale of analysis, and suggests a small number of variables need to be considered in analysis (like overall historical development, land use, urban density, height analysis, etc). This ‘complexity approach’ sees design projects as ideally realised in small phases, so that these can be tested for feedback loops (Rothmans, 2012: 180), to see ‘what works’ before larger decisions are made for urban sites. In conclusion, the literature on complexity thinking in relation to urban sites at urban design scales, though small, suggests potential for further research and new understandings of relations between complexity principles and urban design.

1.2.5 : Evaluation and representations of complexity

A short discussion of the need for appropriate evaluation and representation of spatial complexity completes the description of the academic rationale of this study. In evaluation theory related to the urban environment, and more specifically related to urban analysis and design, one complication is the inherent complexity of the discipline of urban design itself (Brophy, 2000:22),(Gil, 2008:258). The complexity of separate
aspects of the urban environment is sometimes unevenly measured and evaluated (Elsheshtawy, 1997)(Heath, 2000). In relation to the necessity for an evidence base for urban design, and therefore measurement of the urban built environment, evaluation is often just lacking at building level (Bordass and Leaman, 2005), some techniques measure too much of the wrong things (Roaf et al., 2015), and at public space level there is often ‘remarkably little evidence’ for claims (Carmona, 2014a). In landscape, the development of an evidence-based design culture is associated with a maturing of the discipline (Brown et al, 2011). Most relevant for this study, urban environment quality assessment at national level in Ireland is an aspect which has received little attention (Pender, 2000:26). One relevant paper reviews sustainable infrastructure provision in a new town in Dublin using urban design indicators, and concludes that although the development is lacking in certain respects, the evaluation checklist also has shortfalls (Hunt et al, 2012).

Given its complexity, information visualisation is transforming understandings of urban environments. Visual representation of data has emerged as a significant factor in communicating complex data sets, including evaluation related to urban environments. Representation of data, landscapes and urban form in the spatial sciences has been divided into three strands: vector-based maps delineating land cover types as polygons, raster lattices representing the landscape as a grid, and graph theory representations, whereby graphs represent landscapes as sets of nodes (eg. habitat patches, or streets in urban landscapes) connected to some degree by edges or links, that join pairs of nodes functionally (Urban, 2001). Ratti also describes ‘raster models of urban form’ as ‘a two-

---

7 Hunt et al (2012) reviews sustainable infrastructure provision in Adamstown, a stalled, partly-complete ‘New Town’ in southwest Dublin, using the Irish recently published Urban Design Manual’s “60 indicators” items checklist, (in 12 categories), and concludes that though the development is lacking in certain respects, the checklist also ’has shortfalls’ in terms of appropriate evaluation.
dimensional, rectangular, pixel grid (such as a digital image) storing some urban attributes (such as building height)’ (Ratti, 2004:297). To further represent spatio-temporal data, the traditional methods of cartography such as single maps, series of maps and animation maps (Kveladze, 2015:2), have been supplemented by innovations such as the ‘space-time cube’, originally developed in time geography (Hägerstrand, 1970). The standards and ideas of data visualisation proposed by Tufte (1983,1990, 2006) although originating in graphic design, have been seen over time as significant contributions to development of the fields of architectural representation (Burkhard, 2004), and urban design (Talen, 2003) and have been described as ‘information design’. In essence, Tufte seeks clarifications of complex data through clearer visualisation.

In summary, this outline of the academic motivation of this research firstly outlined the understanding of complexity adopted in this study, and then the field of urban design was introduced. The claim that reductionist approaches are not adequate for urban design theory, policy or practice has been advanced. The more specific issue of connections between complexity, urban design and urban sites was then discussed. Lastly, an argument is made about the need for appropriate evaluation and representation of spatial complexity, which completes the description of the academic rationale of this study.

---

8 Tufte’s description of the core task in information design is stated in the Epilogue to his book titled ‘The Visual Display of Quantitative Information’: ‘What is to be sought in designs for the display of information is the clear portrayal of complexity. Not the complication of the simple; rather the task of the designer is to give visual access to the subtle and the difficult that is, the revelation of the complex’ (Tufte, 1983:191).
1.3 Problem statement, aims and research question

This section describes the research problem the study seeks to solve, the significance of this study for particular audiences, the aims of the research, and the context and scope of the research question.

1.3.1 Problem statement

There are three key dimensions to the research problem which this study seeks to address: firstly, at the theoretical level, a failure within urban design to investigate complexity: secondly, as a practice dimension, a lack of integrative evaluation at the scale of the urban site: and thirdly, also related to practice, a failure to understand the benefits of spatial complexity to the urban built environment as outlined earlier. The spatial aspect of complexity of urban sites is concentrated on in this study, spatial complexity.

Firstly, having established the idea that the urban environment is complex (Barredo et al, 2004)(Rydin, 2012), that complexity is considered to be increasing\(^9\), that urban and spatial complexity are especially manifest in urban sites (Krafta, 1997), (Hillier, 1988, 1989), (Batty, 2011:1), and that complexity is an important way to organize knowledge in relation to cities, (Batty, 2009), it is problematic that the domain of urban design has been barely examined from the point of view of complexity (Portugali, 2012:2).

The second key dimension of the research problem relates to urban design practice. It is that, despite widespread knowledge of the importance of understanding complexity in

---

\(^9\) The theory of 'complexification' Lefebvre H. (1970) The Urban Revolution, Paris: Editions Gallimard. ('according to which social phenomena acquire increasingly greater complexity') (Lefebvre, 2013:45) is discussed in complexity theory, (Cilliers, 2005), (Capra, 2005) critical urban theory (Read, 2013), philosophy (deLanda, 2011) humanities (Notonwy, 2006) and geography (Urry, 2005a, 2005b) but with the exception of Lefebvre, has not been theorised for the urban spatial realm.
the urban environment generally (Salingaros, 2001)(Healey, 2007), the spatial aspect
does not get the attention it deserves in the urban design discourse (theory), nor in the
implementation of urban design (practice) at urban site scales (eg. a neighbourhood)
which in turn negatively affects the (design of the) urban built environment. This
second dimension can be summarised as a lack of integrative evaluation at the scale of
the urban site.

Thirdly, there is a failure to understand the benefits of spatial complexity to the urban
built environment. It has been argued that the design of the urban built environment has
impacts on health (Jackson, 2003)(Leyden, 2003), resilience (Salat, 2011), social
formation (Hillier&Hanson, 1984),(Legeby, 2013), public life (Gehl, 1981),(Mehta,
2014) commercial value (CABE, 2001)(Law, 2012), and aesthetic/visual satisfaction
(Rapoport, 1970, 1977)(Elshestaway, 2009). In this complex urban context, a large set
of variables is interacting, and manifesting spatially. However, although environmental,
functional and social benefits of optimal complexity of urban sites are established in the
literature (See Section 1.2.4) the specifically spatial aspects of urban complexity are
under-examined.

Chapter Two will demonstrate that very few studies have operationalized the concept of
spatial complexity in urban analysis, and none have specifically addressed urban design.
Three broad areas of literature are related to the research problem, (that is, a failure
within urban design to investigate complexity, a lack of integrative evaluation at the
scale of the urban site, and a failure to understand the benefits of spatial complexity).
These are: complexity theories of cities (CTC), urban design theory, and (urban
environment) evaluation theory. Within the complexity sciences, in the field of
complexity theories of cities (CTC), spatial complexity has been theorised in hard-scientific terms, related for example, to mathematical principles, scaling, self-similarity and fractals (Batty, 2011:7). In urban design theory, spatial complexity has been conceptualised as related primarily to the ‘whole city unit’ (Hillier, 1998,1999a), though in design more generally, architecture has also researched the concept as an indicator of architectural quality, (Dai, 2014). However, the ‘in-between’ scale of urban design is absent in the literature. In evaluation theory for urban design, current evaluation techniques apply mostly to single ‘units’ of the urban environment, like urban spaces, and cannot be directly applied to urban design process (Gil, 2008:258). Current mixed methods approaches to evaluation reviewed in later Chapters do not sufficiently address integrative evaluation of spatial complexity of urban sites.

In the field of complexity theories of cities (CTC), firstly, philosophical treatments of the concept of spatial complexity diverge, while omitting a specifically spatial perspective, especially for planning and urban design. Secondly, spatial planning definitions and other planning /policy understandings of spatial complexity vary across the dimensional scales and specialisms of the territories and disciplines described. Thirdly, a hard-scientific focus has dominated the discourse (See Chapter Two).

Spatial complexity has been theorised as a city level concept (Batty, 2011) and although the urban design scale is considered relevant (Hillier, 1999, 2005), this key level of focus is not concentrated on. Talen (2003) has reviewed urban ‘measurement, evaluation and representation’ for urbanism, concluding that new measurement approaches are needed to more appropriately reflect the material aspects of cities

---

10 Chapter Two, Section 2.4, ‘Evaluation’, and Chapter Four, Section 4.3, ‘Structure around an evaluation tool’.
(Talen, 2003:694). In essence, urban design as a discipline is regarded as lacking a ‘cohesive and robust’ basis (Khan et al, 2014:394), and missing a ‘diagnostic and analytical apparatus’ (Marshall, 2012b:268).

Previous relevant urban design research has emphasized three aspects of urban sites: compositional, configurational and system. These aspects are currently investigated either separately\(^1\) or combined\(^2\) and sometimes compared\(^3\). This latter category of previous studies, that of mixed methods approaches, sometimes includes two of the three aspects of spatial complexity explored and evaluated in this research, but almost\(^4\) none combine all three aspects, which are important to an integrative evaluation of spatial complexity. In summary, as described in more detail in Chapter Two, none of the three literatures reviewed reveal satisfactory ways to address the research problem.

The significance of this study for particular audiences is now outlined briefly. In essence, three audiences are suggested to benefit form the response of this study to the research problem: those who seek to describe, prescribe and design for urban sites. Firstly, in relation to improved description of spatial complexity of urban sites for urban design, this means urban designers, spatial planners and architects (and possibly landscape architects) in the main, as the spatial scientists most likely to be guiding the urban design process. Other urban design researchers, whether for urban design theory and/or practice are also a particular audience for this study in this first category. Secondly, in relation to introducing prescription of spatial complexity of urban sites for

---

\(^1\) (eg. compositional aspects of urban design, Gil, 2012), (configurational aspects of urban design, eg, Hillier, 2008, 2009), (system aspects of urban design, eg. Marshall, 2005)

\(^2\) (Van Nes, Berghauser Pont, 2014)(Marcus, Berghauser Pont, 2015)

\(^3\) (Oliviera, 2014),(Oliviera, Partenen, 2015).

\(^4\) Marcus et al combines compositional, configurational and system analysis methods, but the aim is primarily to make a comparison between a typological and configurational approach to urban analysis (Marcus, Berghauser Pont, 2015).
urban design, the significance for this particular audience means enabling those guiding the urban design process, whether planning officials, project managers, or clients, as examples. Briefly, prescriptive use of a spatial complexity evaluation could qualitatively enhance future development of an urban site. Thirdly, in relation to design uses, the significance of this study for this particular audience means assisting urban designers in the making of better iterative, projective urban design proposals, by enhancing evaluation methods and guiding urban designers in their core practice, designing. In this third use, iterative spatial complexity evaluation at different stages of urban design, or when considering design options, could improve decision-making on final design proposals.

In summary, the three dimensions of the research problem (a failure within urban design to investigate complexity, a lack of integrative evaluation at the scale of the urban site, and a failure to understand the benefits of spatial complexity) are related both to theory and practice, are supported by the literature, and are related to a need in urban design theory and practice, in particular from three audiences: those engaged in description, prescription, and design.

1.3.2 : Purpose statement

The purpose of this study is to explore and adapt an under-developed theoretical framework found both in complexity theories of cities (CTC) research and in urban design research, as well as other fields, as a contribution to urban design discourse,

---

15 According to Biddulph, as regards thinking ‘about’ or ‘for’ urban design, “if you cannot design, then you are not embracing urban design as a field” (Biddulph, 2012:1)

16 A purpose statement is defined in research design as: “establishing the intent of the entire research study” (Cresswell, 2009:111) and is considered fundamental in setting out introductory terms of the work.

17 The concept of spatial complexity is also employed in some other related (eg. landscape, ecology) and unrelated (eg. medicine) fields.
and for use in urban analysis, evaluation, visualization and design practice. This study does not expand on the meaning of spatial complexity for whole cities, or for small spatial units such as urban spaces, but concentrates instead on the mid-level focus of urban design, the urban site. The study particularly explores and evaluates compositional, configurational and system aspects of urban sites, which, it is claimed, together comprise spatial complexity. In the proposal of an evaluation tool, a theory of spatial complexity for urban design is tested. These three variables are compared, correlated and evaluated within, between and across three case study sites. The aim of this study and the research question are described next in order to further the argument, which has included the background introduction, an outline of practice challenges, a problem statement, and definitions of key concepts. This following section is set out in advance of an outline of the structure of this document.

1.3.3 : Aims

The aims of this study set out here relate to exploratory (theory and discipline) and evaluation (practice and evidence) aspects of the research:

• Theory: To introduce a spatial complexity frame to the theoretical discourse on urban design
• Discipline: To deepen the meaning and significance of the concept of spatial complexity for the discipline of urban design.
• Practice: To investigate the relationship between spatial complexity, urban sites and evaluation by proposing a new evaluation tool which is useful for urban design practice.
• Evidence: To apply an evaluation tool which presents an exploratory and empirically rich account of spatial complexity levels of multiple urban sites in one city,
visualising differences within, between and across three urban sites, and in descriptive, prescriptive and design applications.

While the overarching aim of this study is to introduce a spatial complexity frame to the discourse on urban design, the first two aims (theory and discipline) can be seen as urban design theoretical and exploratory aspects of the study, while the second pair of aims (practice and evidence) can be seen as more related to urban design evaluation and practice. The discipline of urban design is a context where complexity thinking has not yet been embedded, and this theme is returned to in Chapter Two (Section 2.3).

The practice-related aim is to contribute to the exploration and evaluation of spatial complexity of urban sites for urban analysis and design. Spatial complexity, argued here to be a characteristic feature of urban sites, includes compositional, configurational and system criteria, which are already separately seen in the literature as key components of qualitatively rich cities. As regards the fourth, evidence-related aim, applying an evaluation tool can integrate these three criteria into one useful value for use in urban design practice. In this respect, there are three practice-related uses for the tool. The intention of this research to be useful for urban analysis (description), is distinct from the aim of this research to be useful for control over spatial change (prescription). These objectives are also distinct from the third requirement of this research, to be useful in support of the proposition of change (design) in urban sites. The three requirements are often closely allied, and often the related tasks are undertaken in a concurrent approach, iteratively informing each other with new data and outputs. However, the requirement in some cases to consider urban evaluation (analysis) alone, where design review or guidance (prescription) is not involved, or creative activity (design), where analysis and
guidance may have been undertaken by others in advance, means that a spatial
complexity evaluation tool can be useful beyond a single application, as well as in the
primary case considered in this research, that is, as an aid to design activity for urban
design in practice. In summary, relevance and transferability of the methods and
findings of this study to urban design practice are core to the inquiry.

1.3.4 : Research Question

The research question is: how can complexity theory and urban design theory contribute
to increased exploration and understanding of the theoretical concept of spatial
complexity for urban analysis and design, as well as to development of practical urban
design evaluation tools for urban sites? The first part of the question relates to
exploration of spatial complexity for urban design, and is more related to qualitative
research methods (eg. logical argumentation, interpretative mapping), in order to
usefully increase knowledge and understandings for urban design discourse, seen as a
more theoretical emphasis. The second, connected part of the research question, relates
to evaluation, and is more associated with quantitative research methods (eg.
measurement of urban morphological complexity) and specifically seeks to develop
evaluation tools for urban design practice.

In response to the research question, the research design proposes three separate phases
of work, described in more detail in Chapter Three (Section 3.2.3). Briefly, the first
(theoretical) phase (Chapter Two) argues that optimal levels of spatial complexity
enrich urban sites, and therefore cities, and that current understandings of this concept
need to be refined and deepened for urban analysis and design. The second
(exploratory) phase (Chapters Three-Five) develops a conceptual framework, and
arrives at coherent and useful evaluation indices of spatial complexity for urban analysis and design, in order to understand the relationships between compositional, configurational and systems aspects of urban sites. This phase tests the explored spatial complexity of the contexts of three urban sites, in order to link the theoretical framing and the practice of evaluating spatial complexity. The third (evaluation and visualisation) phase (Chapter Six) is focused on certain distinct and contrasting spatial conditions, in a case study approach, thus demonstrating new tools and techniques of evaluation and visualisation for urban design (research and practice). In summary, the research question asks how the theoretical concept of spatial complexity can be constituted and operationalised for urban design, and in response the research design proposes three phases of work: theoretical development, exploration and evaluation.

1.3.5 : The Research Hypothesis

The main hypothesis of this thesis is that evaluated levels of spatial complexity in urban sites depend on compositional, configurational and system properties. It is argued that this proposition can be tested, and that evaluation tools can be devised and applied to evaluate spatial complexity conditions. These evaluations could in turn contribute to an evidence base for change and improvements in urban sites, which could lead to optimal levels of spatial complexity.

Complex systems, as they may relate to planning, have been described as ‘open systems which interact with their environment, comprising many diverse components and interactions, containing feedback loops, a ‘history’, they are nested, and encompass various organisational levels, emergent properties and multiple attractors’ (Rothmans, 2012). While most complex systems are open, some are not, and though many complex systems are adaptive, not all are. Complex systems are of two types, natural and
artificial, and cities are in the second category (Holland, 2012). Current scientific
research sees an increasing need to understand more fully the complexity arising from
coupled human and natural systems (Liu et al., 2007). For example, landscape
heterogeneity (a measure of landscape complexity) is seen to increase with the degree of
urbanization, but this differs substantially within the region depending on urban land
use patterns, infrastructures and spatial distribution of activities (Liu, 2007:1516).
Complexity in cities is seen to have particular benefits, including perceptual richness,
benefiting the ‘user’ of the city, functional capacity, benefiting the ‘system’, and
‘synergy’\textsuperscript{18} benefiting (or most appreciated by) the ‘designer’ (Marshall, 2012a).
Reduced complexity of planned urbanism has been associated with ‘failure of town
planning’, and it is considered that ‘rather than being part of the problem, complexity
could be part of the solution’ (Marshall, 2012a: 192).

While there are constraints on the comprehensiveness of any evaluation tool of an
object as complex as the urban environment (Carmona, 2014a: 5), the proposed new
evaluation tool presented in this thesis is valuable as a contribution to knowledge and
discourse on urban sites, especially as regards optimal levels of spatial complexity in
these locations. Therefore, it is argued that sites can be rated or audited for levels of
spatial complexity considering the independent variables of composition, configuration
and system. It is also important to state that optimal spatial complexity is not a fixed
aspect of urban sites, and can change over time, so evaluation is time related. As regards
the relevance of the research, four aspects are outlined. Firstly, a theoretical model for
the evaluation of spatial complexity at urban design scales is advanced, which

\textsuperscript{18} The concept of ‘synergy’ is described by Marshall as ‘the quality by which a whole entity is greater than the sum of its parts, or a
whole operation is greater than the sum of the individual actions. This ‘added value’ typically arises where the entity is
heterogeneous, and the individual components are complementary’ (Marshall, 2012a:194). Marshall uses ‘physical’ examples such as
a Swiss Army knife, and contiguous urban objects (newsstands next to crossing points).
contributes to urban design theory. Secondly, case studies and evidence are presented to expand and deepen knowledge for the built environment at urban design scales linking these to urban design practice, which is particularly of relevance for the expanding field of complexity theories linking architecture, spatial planning and urban design (Weinstock and Gharleghi, 2013). Thirdly, an evaluative (urban design) tool and method for analysing urban sites is demonstrated, which could be used for description, prescription and design. One possible use for example is in testing different urban design proposal options in an iterative way in advance of construction. This contributes to the discipline and practice of urban design. Fourthly, by identifying degrees, manifestations and characteristics of spatial complexity, relevant new knowledge is developed in relation to the emerging field of spatial quality auditing (Khan et al., 2014), and therefore the tool developed here is useful for the professions of urban design and architecture.

One central proposition of this thesis is that the concept of complexity is insufficiently defined and operationalized for theory and practice in urban design. Furthermore, the construct of spatial complexity, while theorised in the science of cities domain, is poorly understood for urban design, so it will be deepened here, in order to become more operationally relevant and useful to the discipline of urban design in theory and practice.

1.3.6 : Scope of this thesis

Six relevant aspects to describe the scope of this thesis are now described. Firstly, the various understandings of the concept of spatial complexity in distinct fields apart from urban design are set out briefly in Chapter Two, but this thesis does not discuss in any detail any of these disparate fields. Those disciplinary areas with a particular interest for
urban analysis and design, like software programming for example, where the ‘lexical distance’ can indicate spatial complexity (Gold, 2005), are a reminder of the syntactic base of space syntax, and so could be worthy of enquiry by other research in relation to lessons for urban design. However, for this thesis it is considered that the (already developed) coherent understandings of methods, terminology, and indices of spatial complexity in other fields have insufficient relevance to the urban analysis and design realms to be discussed here in detail. Integrative urban design is concentrated on (as described in Section 1.2.2).

Secondly, conceptions of complexity allied to the spatial, such as ‘social’ (DeLanda, 2006) and ‘absolute’ (Gold, 2005) complexity aspects of the urban sites are outside the scope of this thesis. Soja’s critical geographical viewpoint defines a ‘socio-spatial dialectic’, whereby, in his proposition, there is an essentially dialectical character in relations between the social and the spatial. Although this research acknowledges the importance of the ‘socio-spatial dialectic’, this research concentrates on urban form, primarily in its spatial and physical aspects, on the basis that: ‘Through its ordering of space the man-made physical world is already a social behaviour.’ (Hillier & Hanson, 1984: 9). Gold’s quantification of spatial complexity metrics for use in software engineering are an example of an over-quantitative prescription of ‘orders’ of spatial complexity (Gold, 2005). Precisely computable prescription of ‘orders’ of spatial complexity are not considered to equate to the combination of quantitative, qualitative and integrative methods employed in this thesis, which are seen as more appropriate to

---

19 DeLanda’s philosophical concept of social complexity for example, combines complexity theory with an assemblage theory approach, seeing social life as a complex set of components, virtualities and potentials, whereby the social is both non-material and real, including space (DeLanda, 2007).

20 Soja argues: ‘The structure of organised space is not a separate structure with its own autonomous laws …it represents instead, a dialectically defined component of the general relations of production, relations which are simultaneously social and spatial.’ (Soja, 1980:208).
urban analysis and design. Abductive\textsuperscript{21} understandings of the specific spatial complexity conditions of the urban sites studied could lead others to further new research on social and hard-scientific computable meanings related to this research, including defining ‘orders’ and benchmarks, but these are beyond the scope of this study.

Thirdly, urban sites\textsuperscript{22} are concentrated on because, although spatial complexity is a feature of all sites and manifests at multiple scales, these types of sites are the focus of urban design, and one primary aim is to contribute a spatial complexity frame to the discussion on urban design. Although relevant, the national, regional, rural, coastal, landscape, town, village, spatial planning and architectural scales do not feature as central objects of this research. The scalar focus is analysis of the urban site, an area roughly equating to neighbourhood size, during and after design, or by third parties situated in or around an urban design proposal or urban site, either spatially or as a community. A fourth relevant aspect to describe the scope of this thesis is that this study takes a ‘static’ evaluation approach to selected urban sites, and therefore necessarily cannot also be a synoptic review of Dublin. An interesting example of an attempt to address equally both a single city (Glasgow), and the topic of sustainable urban design (Frey, 1999) was considered to have concentrated equally on both the physical object and the broad topic of sustainability to the detriment of the overall work (Miles, 2000).

\textsuperscript{21} Abduction, in philosophical terms, is defined as: ‘the formation or adoption of a plausible but unproven explanation for an observed phenomenon; a working hypothesis derived from limited evidence and informed conjecture’(OED). A hybrid combination of abductive, inductive and deductive approaches are argued to advance understandings of phenomena, and are recommended in research involving big data (Kitchin 2014:5) particularly related to geography (Kitchin, 2014), also in design (Cross, 2011), urbanism and urban design Çaliskan O. (2012) Design thinking in urbanism: Learning from the designers. Urban Design International 17: 272-296. (See also, Appendix C, Glossary of PhD Terms).

\textsuperscript{22} Evaluation of existing urban sites is concentrated on, and this could be considered to be the ‘in itinere’ (in progress) stages of development, that is, not considering any specific plan to develop or change an urban site, and with no recently completed development to evaluate. In this sense ‘in progress’ here means ‘change over time’ and ‘development’ here means normal changes in character of urban sites over time, such as single building planning applications. This important topic is discussed in more detail in Section Four.
The primary focus of this thesis is spatial complexity, and the evaluation of this characteristic of urban sites for use in urban analysis and design. The cases are illustrations, and spatial complexity is the ‘target’ (Yin, 2003), or primary object of the research.

A fifth relevant aspect to describe the scope of this thesis, is that the work does not examine the prevalence of phenomena, for example the prevalence of optimal levels of spatial complexity in urban sites in Dublin. The research design, (consisting primarily of multiple case study units), is of a type which is not the best method for assessing the prevalence of such phenomena (Yin, 2003:48). Lastly, a sixth relevant aspect to describe the scope of this thesis relates to urban design. Even though it is argued, firstly that processes are typically of greatest importance and intrigue in a case study design (McClintock, 1985:206) and secondly, that process in urban design is more important to study than urban form (Alexander, 1987) (especially of one city (Miles, 2000)), urban design process is not the primary focus of this thesis. Carmona (2014) argues that an examination of processes has advantages over social sciences or design based approaches to research in urban design. However, urban design process is already developed as a sub-field of enquiry (Madanipour, 1996)(Carmona et al, 2003)(Carmona, 2014, 2016), whereas evaluation for urban design is not (Ratti, 2004). Other aspects related to urban design process (Boyko, 2010) such as those cited by Gil (Gil, 2013:314), including externalities such as affordability of housing stock or lifestyles, and indicators which can only be measured at different stages of the urban design process (eg. before or after a design for monitoring progress) are also beyond the scope of this research.
Therefore, despite the emphasis on the need for urban design process research in the literature, this thesis still prioritises urban design as ‘product’, that is: composition, configuration and system properties of physical urban sites. This aspect is favoured over process for three further allied reasons. Firstly, more immediate impacts of this research could result from the approach adopted, particularly in relation to spatial complexity evaluation methods and tools for urban sites, for use in urban design practice. The urban design literature repeatedly stresses the need for an evidence base for urban design proposals (Karimi, 2012)(Talen, 2003), including for improved methods of urban site evaluation (Carmona, 2013:311). Secondly, exploration of the theoretical and framing aspects of the concept of spatial complexity for urban design could focus urban design discourse in a national context beyond scientifically ‘unquantifiable’ aspects such as ‘good urban form’ (Lynch, 1981), ‘aesthetics’ (Banai, 1999)(Tucker et al, 2005), and ‘spatial quality’ (Moualert et al, 2013). Thirdly, this thesis research is clearly directed at research for urban design (the substantive nature of the activity), as opposed to research about urban design (how urban designers understand their activities and how they operate), which is an important distinction made in the urban design (Biddulph, 2012) and planning (Faludi, 1973) literatures. It has been suggested that urban design could benefit from more attention being directed to research for urban design (Biddulph, 2012:2) and this research seeks to contribute to filling that gap.
Figure 1-1 Organisational Chart of this Study
1.4 Outline of this Study

In this first chapter, the background and international context to the study is explained, including that a general turbulence of contemporary spatial conditions in Ireland is observed, that the literature does not focus on urban settings, and that Irish urban morphology is a small research field, focused on the historic city. The academic rationale is set out, including relevant theoretical understandings of complexity, spatial complexity, urban design and evaluation. The central problem of the thesis is then introduced: that despite widespread knowledge of the importance of optimal spatial complexity in urban sites, this aspect does not get the attention it deserves in the urban design discourse, nor in the implementation of urban design. The research aim, that is, to contribute to the achievement of optimal levels of spatial complexity for urban sites, is described. The research question and hypothesis are also outlined, and in relation to relevance of the research, four aspects are described. The scope of this study is described, including focus within the field of integrative urban design, that conceptions of complexity such as social and absolute complexity are outside the scope of the study, and that the scalar focus is analysis of the urban site, an area roughly equating to neighbourhood size. Furthermore, this study takes a ‘static’ evaluation approach, and therefore necessarily cannot also be a synoptic review, the work does not examine the prevalence of phenomena, and lastly, this thesis prioritises urban design as ‘product’, that is: composition, configuration and system properties of physical urban sites.

Chapter Two (Theoretical dimensions of spatial complexity)

Chapter Two focuses on the theoretical framing of the research problem, and a review of the relevant texts. Literature relating to primary concepts of complexity, and then to spatial aspects of complexity theories of cities is reviewed. Some gaps in the literature
are identified, including that those theories combining complexity and urban design theories are largely missing. In relation to spatial complexity theories, it is concluded that the few philosophical treatments of the concept of spatial complexity that exist diverge, while omitting a specifically spatial perspective, especially for planning and urban design. Secondly, it is found that spatial planning definitions and other disciplinary understandings of spatial complexity vary across the dimensional scales and specialisms of the domains and disciplines cited, and thirdly that a hard-scientific focus has dominated the discourse. These findings confirm that a rigorous encompassing definition of spatial complexity as a concept for urban design theory and practice has not yet been provided in the literature. In relation to complexity and urban design research, it is argued that complexity theory and urban design theory have arguably only very recently begun to interact in a general way. It is argued that urban design is well placed, at a scalar ‘level’ above architecture and ‘below’ spatial planning, to act as a useful link in connecting to evaluation in a complexity frame.

Chapter Three (Research design and methodology)

In Chapter three, in order to expand on the claim of Chapter One (that exploration and evaluation of spatial complexity of urban sites is useful for urban design theory and practice), and following the literature review of Chapter Two, the main driver of this chapter is the setting out of a case study-driven research design for exploration and evaluation of spatial complexity. Case study research options are also described, in order to show the possible methods of researching spatial complexity for urban design. The advantages and limitations of comparative and correlational research approaches for this study are described before it is concluded that this is a mixed methods, multiple-
Chapter Four

(Conceptual framework of spatial complexity)

Chapter Four develops a conceptual framework for understanding spatial complexity in an urban analysis and design context. The central argument of this chapter is that observed levels of spatial complexity in urban sites are related to and influenced by compositional, configurational and system properties. It is argued that this proposition can be tested, and that an evaluation tool can be devised and applied to assess current conditions. This chapter builds on Chapters One and Two by developing the key concepts introduced there, and follows description of this research design and methodology in Chapter Three. Firstly, the claim that spatial complexity evaluation methods can be advanced for urban sites is introduced and a tool for evaluation is proposed. The reasons for focusing on an urban design ‘lens’ are then set out, as well as reasons to combine compositional, configurational, system and urban design research methods in an integrative way. This Chapter therefore develops one overall aim of this research, which is to investigate the relationship between spatial complexity, urban sites and evaluation by proposing a useful tool for urban design practice. This is done in advance of exploration of site contexts in the next chapter, and detail evaluation of multiple urban sites for urban design in the Chapter Six. The main driver of this chapter is demonstrating the importance of the development of a conceptual framework and tool in advance of evaluation of urban sites. The three primary issues and nine criteria to be considered in evaluating spatial complexity of urban sites are set out and developed in this Chapter. The proposed use of a Toolbox and Databox for evaluation and visualisation is also introduced. This proposal is linked to Chapter Five by discussing...
the respective weightings of indices to be applied in exploring the whole-city scale, as well as contexts of urban sites in Dublin.

**Chapter Five**  
(Exploring spatial contexts of urban sites)

This chapter is linked to the previous development of methods, units and tools of evaluation of spatial complexity by the use of the three issue structure developed in Chapter Four for a wider exploration in this Chapter, at case context scale. The central argument of this chapter is that descriptions of spatial contexts of cases can illuminate distinct and contrasting conditions, and can advance knowledge on spatial complexity at large scales in a meaningful way through exploration of the three key issues of spatial complexity around an urban site. This chapter advances the overall argument of the study through a primary generation of visual representations of explored spatial complexity for the spatial unit of Dublin, including original mapping and graphical representation. This is done in advance of detail evaluation for urban design of multiple urban sites in the next Chapter.

**Chapter Six**  
(Three urban site evaluations)

The questions asked in this Chapter are linked to the second part of the research question of this thesis, which asks, following an increased exploration and understanding of spatial complexity, how practical urban design evaluation tools can be developed in order to evaluate the spatial complexity of urban sites. This chapter advances the overall argument of the thesis through demonstration of evaluation tools and generation of data, including visual representations of evaluated spatial complexity levels for urban sites. The main driver of this chapter is generation and representation of primary data, demonstrating evaluated spatial complexity at the scale of the urban site. Chapter Six therefore develops the overall aim of evaluating spatial complexity by
linking explored general aspects of spatial complexity (in Chapter Five) to specificities of particular urban sites evaluated, in advance of detailed discussion of the results and findings about the case urban sites in the next Chapter.

**Chapter Seven**  (Findings and discussion)

Chapter Seven brings together the findings of the previous two chapters, on explorations and evaluations of spatial complexity respectively. This chapter includes a synthesis of substantive findings for each case study unit site, and then concludes by visualising evaluated levels of spatial complexity. The central argument of this chapter is that multi-scalar understandings of urban sites, in a complexity frame, are enhanced by the use of a Toolbox and a Databox to evaluate and visualize spatial complexity of urban sites. This setting-out of findings of three evaluations and discussion of outputs is linked to the final concluding chapter by setting the context for the return to the core propositions of the research.

**Chapter Eight**  (Conclusions)

This concluding Chapter firstly returns to a summary of the findings of this study as regards the research aim, question and objectives of this study, in order to show how these have been fulfilled. This chapter is linked to the findings and discussion of the previous chapter by synthesizing the outputs in a wider context. The second section of this Chapter demonstrates that the purpose, issues, criteria and propositions of this study have been fulfilled in the description of the data analysed in Chapters Five and Six. This advances the overall argument of this study by showing how exploration and evaluation of spatial complexity of urban sites can be achieved. In particular, the data analysis techniques proposed in Chapter Three are used to structure the reporting of the conclusions of this study. Employing two of these techniques, theoretic patterns are
firstly observed, and then cross case synthesis is described. As part of the concluding section, the implications of combining complexity and urban design theories in exploring and evaluating spatial complexity of urban sites are described, including increased understanding and potential for optimisation of spatial complexity levels where appropriate. This research is summarised as an integrative theory approach to evaluating spatial complexity for urban design, combined with proposed new evaluation methods for use in urban design. The relevance of spatial complexity for urban design practice is also outlined. The chapter includes a review of possible limitations of the methods employed, and a discussion of recommendations for further research on spatial complexity.
Chapter Two Theoretical dimensions of spatial complexity

“Whereas previous bodies of scientific theory were chiefly concerned with temporal progression, complexity theory is equally concerned with space.”

(Thrift, 1999: 31)

Following the general introduction to this study of the spatial complexity of urban sites, in Chapter One, this Chapter advances the overall argument by developing the study’s academic rationale. This is informed firstly by bringing together a number of texts related to four themes: complexity, spatial complexity, urban design and evaluation. The literature is reviewed in advance of a full description of the research design and methodology of this study in the next Chapter. The questions of this chapter include: what are the connections between complexity theory, spatial complexity theories and urban design, according to prior theories? Also, how has spatial complexity been evaluated in other domains? Furthermore, what does evaluation theory contribute to a fuller understanding of spatial complexity of urban sites, and what value does complexity theory have for urban design research? The main driver of this chapter is a review of the main theories and concepts which converge around the theoretical understanding of spatial complexity of urban sites for urban design.

The research topic of this thesis is the concept of spatial complexity, defined earlier as the spatial component of urban complexity. Although complexity is considered to be “the most essential characteristic of our present society” (Heylighen, 2007: 117) urban design has not been linked to complexity in any significant way in either the urban design or complexity literatures. So while complexity has been associated with many different meanings in relation to the cities and urban condition, including organized
complexity (Jacobs, 1961: 445) visual complexity (Lynch, 1960; Lynch, 1984; Lynch, 1995) (Banai, 1999) urban complexity (Salingaros, 2000) and system complexity (Allen, 2012), these are somewhat abstract and contested concepts for urban design. Furthermore, although design complexity (Rittel and Webber, 1973) (Bachman, 2010: 25) and architectural complexity (Venturi, 1966) (Laurence, 2006) are considered to be desirable components of certain forms, a coherent understanding of the concept of spatial complexity for theories of cities, urbanism and urban design is still not agreed upon. The fact that complexity can be argued to be omnipresent: in all scales of building, in city layouts, planning, aesthetics, but also in details like paving or facades, makes the absence of clear understandings in the spatial disciplines remarkable. The first part of this chapter positions this thesis research in the debate on complexity theories of cities (CTC), while the second part narrows the focus to understandings of spatial complexity in some so-called spatial disciplines (Vaiou and Mantouvalou, 1999: 5), (Soja, 2001: s6.1)23. The third section of this chapter looks at current understandings of complexity in urban design. In the fourth part, current discourse on urban evaluation and evidence for urban sites is reviewed, as these types of locations are at the core of this thesis enquiry. This first part of this Chapter reviews the interdisciplinary research domain of complexity theories of cities (CTC), in advance of connecting this field to the concept of spatial complexity, in the second Section.

23 Viaou et all use the term but do not define ‘spatial disciplines’, and mention planning and human geography. Soja also uses but does not define the term, and mentions variously geography, architecture, and urban studies. Spatial planning, architecture, and urban design are understood as included within the spatial disciplines in this thesis.
2.1 Complexity

It is claimed that there is no ‘one’ complexity theory, but that complexity theories comprise instead “an array of concepts applicable to complex systems across many fields” (O Sullivan et al., 2006: 678). The word ‘complexity’ is applied to research in three major areas: algorithmic complexity (mathematical complexity theory and information theory), deterministic complexity (chaos theory and catastrophe theory) and aggregate complexity, defined as “the study of how individual elements working in concert create complex systems which have internal structure relative to a surrounding environment, and which may also exhibit learning and emergence” (O'Sullivan et al., 2006: 678). Aggregate complexity, despite its widespread reliance on simulation and

Figure 2-1   Overall theoretical context of spatial complexity
modeling, is considered most relevant to studies of complexity related to space and place, as it is argued it focuses attention on “the importance of scale to generalisation and specialization”, and “entities, and relations between them” (O'Sullivan et al., 2006: 681). Aggregate complexity relates most directly to this study, which focuses on spatial aspects of complexity for urban design.

One way to define a complex system is through observation of local behaviour or interaction of components, and if global behaviour emerges from the local behaviour of its components, it can be defined as a complex system, as the system creates a new order (Prigogine, 1997). However, complexity science has shown that the future behaviour of a complex system cannot be predicted, as different components could act in different ways over time, altering the global order, so there is no ‘end’ state. Also, it is claimed that to acknowledge that something is complex, is also to admit that our knowledge of it will always be limited (Cilliers, 2005). Another relevant concept from complexity for this study is the idea that there is no ‘unambiguous optimality’ in complex systems (Marshall, 2012a:42), and that optimality is constantly changing. The particular complexity theories that apply in understandings of cities are gathered under the general heading ‘complexity theories of cities’ (CTC)(Portugali, 2012)\(^\text{24}\).

\(^{24}\) Portugali (2012) states that it was Peter Allen who first developed a complexity theory of cities (Portugali, ‘What makes cities complex?’, 2012:2) referencing Allen and Sanglier (1981). Allen was part of an interdisciplinary group which began at the Universite Libre de Bruxelles in 1976 with the aim of ‘investigating the importance of the ideas of non-linear dynamics and self-organising systems in providing a new basis for understanding human systems’ (Allen, 2012:ix).
2.1.1 Complexity Theories of Cities (CTC)

Patrick Geddes, in his book ‘Cities in Evolution’ (Geddes, 1915), first introduced ideas from complexity theory to city planning (Batty, 2010: 2), though these would not be disseminated widely until the 1960’s, in books by Jane Jacobs (Jacobs, 1961) and Christopher Alexander (Alexander, 1964). Jacobs’ ‘The Death and Life of Great American Cities’, included a final chapter on the significance of the concept of ‘organised complexity’ to considerations of the city, working from ideas of Dr. Warren Weaver, a pioneer of complexity science. Jacobs contends that the variables to be negotiated in the design of the city fall somewhere between those of problems ‘of simplicity’ (two variables) and the problems of ‘disorganised complexity’ (billions of variables) (Jacobs, 1961: 443). Alexander’s book ‘Notes on the synthesis of form’, first introduced his ideas on the importance of understanding pattern in relation to design, which recur again in later books (Alexander et al., 1977) (Alexander, 1987, 2002). In the late 1960’s McHarg proposed an ecological method of design, linking of concepts from rural and urban landscape, ecology, and complexity (McHarg, 1967). However, over a century after Geddes’ book, the domain of urban design has been barely examined from the point of view of complexity (Portugali, 2012:2).

A brief explanation of what the contemporary domain of complexity theories of cities (CTC) comprises is offered here in order to give a background to the specific complexity theories relevant to this thesis, and indicate why certain theories are favoured over others in this research for urban design. Urbanism is described in CTC as “a way of thinking, perceiving, cognizing space, which morphologically implies a special cognitive map” (Portugali, 2012a). In response to this phenomenon, CTC theory proposes approaches to seeking urban order through use of open and complex systems
of organisation, with emergent urban form, arrived at through consideration of multi-scale networks, and running of continuous modelling, suggesting these methods as a ‘knowing’ way to proceed towards design in response to this generative impulse. As defined in Chapter One, complexity theories of cities (CTC) are a group of theories which are proposed as “attempts to understand our world assuming it neither evolves linearly nor is in balance” (de Roo, 2012a: 207). Characteristic elements which complexity theories of cities deal with include adaptive capacity of cities, the ability of cities or parts to ‘self-organise’, which in turn is seen as determined by the diversity of the city, and the positive encounter between developments in the past, or ‘path dependancy’, resulting in ‘evolutionary processes’ of urban form (Portugali, 2012c: 213). Much of CTC theory on urbanism relates to the increasing computer facility available for measuring complexity in urban environments, working from known spatial data and facts. Whereas previously, individual complexity scientists with an interest in cities have been seen as acting independently to derive theory relevant to cities, the domain of complexity theories of cities (CTC) has been described as:

    giving a single and sound theoretical basis to a variety of urban phenomena and properties that until then were perceived as independent of each other and thus interpreted by reference to different theoretical bases (Portugali, 2012c: 48)

This tendency towards integration of complexity scientists around the theme of the city as ‘organism’ as opposed to ‘city as machine’ (Batty, 2011: 1) has been led by the discipline of spatial planning. Three collections of CTC writings have been published, which comprise the collected writings of the domain. CTC are considered to be “an established interdisciplinary research domain engaging urban geographers, planners, urban designers, regional scientists, mathematicians, physicists and others” (Portugali, 2012b), which emerged especially in the last thirty five years. An early example of CTC
is a theory of ‘spatial entropy’ which brought together information theory, communication theory, mathematics, city design and geography with an account of ‘a formula’ for spatial entropy, applicable to ‘spatial aggregation problems’, including boundary definition in cities and regions (Batty, 1974). The fractal nature of cities has been studied for CTC across scales, linking this type of organization to “a geometry of organised complexity” (Batty, 1994: 57). Analysis of large urban data sets over time has revealed that cities manifest universal quantifiable features, and that size is the major determinant of most characteristics of a city, with history, geography and design in secondary roles (Bettencourt and West, 2010). These CTC research emphases are generally concerns of large scale, whole city phenomena, studied as hard-science problems, especially in studies such as on transportation networks, and modeling of settlement patterns of cities. The ‘science of cities’ paradigm (Batty, 2011, 2013), concentrating as it does on networks and flows, relates closely to the CTC domain, which sees itself as representing the ‘qualtitative urbanists’, who develop scientific theories and methods (Portugali, 2009). Both however, are defined by hard-scientific bias. It is notable that the spatial planning realm is the ‘collector’ of the CTC writings, which brings its own biases and strengths, and that urban design and architectural viewpoints are mostly absent. It has been remarked for example, that “planners are manifestly unfit to cope with the urban design process” (Cuthbert, 2003: 11) and later that planning is “the agent of the state”, in a critique which also sees architecture as a ‘closed system’, and urban design as inherently open, “focused on social interaction and communication in the public realm” (Cuthbert, 2006: 13).
2.1.2 Complexity, design, and cities

In this section, overlaps and connections between concepts of complexity, design and cities are reviewed, including those related to urban and visual complexity, spatial quality, and complexity in architecture. In terms of design generally, the first substantial collection of writings connecting complexity and design (Alexiou, 2010) considers complexity principles related to whole city scales in one section (Batty, 2010), and also single buildings scales in another (Bachman, 2010), but does not discuss complexity at urban design scales of the city, the ‘in-between’ level (Panerai, 2004). Design complexity in itself is considered as dealing with ‘wicked problems’, concerning indeterminate problems and no single right answer (Rittel and Webber, 1973) and spatial planning and urban design have been described as disciplines dealing primarily in this type of problem (Carmona, 2014:5). DeRoo argues that the very early narrative approaches to complexity began to some extent within planning, when Rittel, an urban planner, defined the difference between ‘tame’ and ‘wicked’ type problems (deRoo, 2012:18).

Urban complexity, as a concept applied within the spatial disciplines, is understood in broad terms as relating to variety, scale, growth, intensity, continuity, density, (Krafta, 1997:1). Measurement varies from artistic methods (Koch, 2009) through visual (Elshestaway, 1997)(Purceil, 2009), cognitive modeling (Occelli et al, 2006) and purely quantitative methods to measure complexity of urban morphology (Adolphe, 2001) (Haghani, 2014). However, urban complexity does not yet have systematically developed measurement methods in urban design practice for considering urban sites. Visual (Cooper, 2010), (Oswald, 2014) aesthetic, experiential (Lynch, 1984) and sensory complexity (Mehta, 2014) are all associated with urban sites and design of the
urban built environment, but have similarly failed to coalesce into a usable measure for urban design practice to date.

Spatial quality, also associated with urban complexity, is more established as a usable concept within urban design for understanding urban environments. The concept of spatial quality has been theorised since at least the late 1960’s in environment-behaviour studies (Rapoport, 1970) is gaining increasing importance in planning and urban design. In planning, though the first Dutch official introduction of the concept was in 1974, (Van der Toorn Vrijthoff and Talstra, 2003) it was expressly connected to basic concepts of spatial planning. It has been defined very broadly within planning as ‘the extent to which a space satisfies a community, expressed both in very general terms (values) and in very specific configuration principles (or reference images, models) for that space”(Goethals, 2008). However, spatial quality is considered in planning by some as a concept that is ‘hard to cope with’(Jan Schreurs, 2013 #637) and it is argued by others that a universal understanding of the concept of spatial quality does not exist (Khan et al, 2014), and separately by others that: ‘spatial quality is very much project-based and time-based, which precludes giving a generic definition of it’ (Van der Toorn Vrijthoff and Talstra, 2003). Spatial quality is also considered to have potential for bias in matters of its measurement and evaluation (Dewaelheyns et al., 2014).

Within architecture, complexity is seen as a foundation for rebuilding urban systems modelling in ‘post-traumatic conditions’ in economies, urbanism and cities, and is associated with new design opportunities through the concept of a continuously

---

25 This development is signalled by a special themed issue of Journal of Urban Design in 2014.
generative urban dynamic (Burke, 2010). Weinstock (2013) explores the concept of cognitive complexities in urbanism and architecture, whereby sensory processing and behavioural responses lead to the development of a city within which there is a hierarchical scale of cognition, thus contributing to the architectural development of future cities (Weinstock, 2013: 58). In another account, autopoietic, self-organising systems for architecture are suggested as driving successive reorganization at higher levels of complexity (Sorkin, 2014). Bhat argues for better understanding among design practitioners of the benefits of complexity of architecture (Bhat, 2014:9). However, the current overlapping urban design and architectural discourses around complexity are considered to be sometimes limited to a ‘system city’ view, thus failing to encompass more than system thinking, and failing to think beyond current definitions of the city (Fournier, 2013: 124). Although Venturi’s claim that “everywhere, except in architecture, complexity and contradiction have been acknowledged” (Venturi, 1966: 16) may no longer be true, engagement with the literature of complexity is still considered to be outside of the architectural mainstream (Salingaros, 2014: 5).

In response to the first part of the research question, which asks how complexity theory and urban design theory can contribute to increased exploration and understanding of the theoretical concept of spatial complexity for urban analysis and design, this section has reviewed the relevant literature on complexity, CTC, and design related to cities. From this review, it is concluded that the concept of aggregate complexity applies to this study. It is also apparent that to acknowledge complexity in phenomena is to understand that our full knowledge of these objects will always be limited, and that optimality in complexity understandings is constantly changing. From reviewing CTC,

26 The claim above appears in the opening pages of ‘Complexity and Contradiction in Architecture’ (1966), in a book which includes a critique of the banality of post-war modernist architecture and urban renewal projects.
it is apparent that the domain of urban design has been barely examined from the point of view of complexity, that CTC concentrates on scales of the city larger than those of urban design, and that a hard-scientific bias is associated with the science of cities and CTC domains. In reviewing concepts of urban and visual complexity, spatial quality, and complexity in architecture, some of these concepts do not yet have systematically developed measurement methods in urban design practice for considering urban sites. Spatial quality is considered hard to define, associated with a planning approach, and has potential for bias in matters of its measurement and evaluation, while complexity is still considered to be outside of the architectural mainstream.
2.2 Spatial complexity

The focus of this study is now narrowed from CTC to understandings of spatial complexity in spatial planning and design, described earlier as spatial disciplines. This is the arena where this thesis research seeks to operate, between abstract or top-down concepts about cities, and detail, bottom-up, or site specific single building scales. Certain concepts of complexity, such as relationality, multiscalarity, and temporality, have importance for understanding urban sites in this study, for reasons which have been outlined earlier (Chapter One, Section 1.2.1). However, important spatial aspects of complexity are absent in the CTC literature, and some related issues like design do not figure prominently to date. This is possibly because the CTC disciplines discourses attract ‘hard-scientifically’ focused researchers, primarily concentrating on the technological, mathematical and innovation aspects of these emerging fields. The tendency of CTC researchers and thinkers towards totalizing concepts of ‘the city’, or ‘cities’ has been noted (Marcus, 2012a: 5), and it is suggested that they are possibly less intimately connected to the scales most relevant to this study, of urban design. These ‘lower’ scales, closer to the scale of a single building, invite more emphasis on real physical sites, typology of urban blocks and buildings, the cross-section, the modeled form, and ‘designerly’ and other qualitative aspects of sites, rather than an exclusively top-down, abstract view. This section firstly reviews definitions of spatial complexity in spatial planning (the link from complexity to urban design) then reviews some other understandings of the concept, before examining two distinct definitions of the concept.
2.2.1 Spatial complexity, spatial planning and design

Across the spatial sciences, definitions of the concept of spatial complexity vary considerably. Spatial planning, landscape and architecture (taken together to represent design) all differ in understanding the concept for example. In current regional planning terms, complexity is associated with the idea of complex spatial systems (Wilson, 2000) and is seen as providing new policy approaches to regional planning and governance in dynamically changing territories (Healey, 2007) (Allen, 2012). This is a perceived shift from deterministic systems in equilibrium, as evidenced by uncertainty in data, behaviour under conditions of uncertainty, and unreliability of forecasts and scenarios, with ‘stochastic dynamic spatial systems’ suggested as one response (Rasouli and Timmermans, 2012). In another assessment, so-called ‘dynamic adaptive planning’ methods (Kwakkel et al., 2012) are proposed in response for infrastructure planning. While the spatial aspect is relevant and often central in these accounts the concept of spatial complexity is not in itself discussed. Self-organisation, a characteristic of complex adaptive systems, and an aspect of complex urban systems, has been studied for planning praxis, with the conclusion that through examination of certain characteristics of the city, emergent patterns appear which cannot be controlled by traditional hierarchical methods of planning, and that areas can be identified as nodes of higher potential for self-organisation, which in turn builds overall complexity (Partanen, 2015b). Another study suggests the entire city as a unit is an emergent phenomenon ruled by self-organisation, with occasional disruptions of top-down planning (Barthelemy, 2013). In city and spatial planning, the question of how to design for ‘functional complexity’, raised by Alexander’s (1965) paper “A City is not a Tree” (Alexander, 1965), is considered to be ‘to a large extent unresolved’ (Marshall, 2009:
In conclusion, while spatial planning understandings of complexity vary across the dimensional scales and specialisms of the territory and discipline of spatial planning, and there is no commonly understood definition of spatial complexity as a concept.

Architectural studies of spatial complexity are rare, often treating the concept in a trivial way (Sheng, 2015), ranging too widely across disciplines (from biology to cities) (Bhat, 2014), or tending to concentrate only on a qualitative aspect to be sought in good projective design (Dekay, 2012). One recent study of spatial complexity at architectural scales explores users perceptions through three data analysis methods and concludes that a building has ‘spatial complexity and navigation problems’ (Dai et al, 2015). The implication is that assessed high levels of spatial complexity of this building (designed by a prize-winning architect) impede wayfinding. No definition of spatial complexity is provided in evaluating the building, and no generally agreed definition of spatial complexity is employed in architecture.

In landscape, understandings of concepts of spatial complexity are employed. From the late 1960’s, when McHarg proposed an ecological method of design, linking of concepts from rural and urban landscape, ecology, and complexity (McHarg, 1967) research into landscape of settlements and cities has considered ways to understand complexity. For example, landscape heterogeneity (a measure of landscape complexity) is seen to increase with the degree of urbanization, but this differs substantially within the region depending on urban land use patterns, infrastructures and spatial distribution.

---

of activities (Liu, 2007:1516). Researching spatial metrics of cities (Huang, 2007) and developing indicators for characteristics of cities at landscape scales (Schwartz, 2010) focuses on abstract conceptions of spatial complexity, related to remote sensing and aerial photography. More interesting for local urban design scales are ecosystem sciences and services approaches, because many scales of phenomena are ‘held’ in a complexity frame of analysis, from single species to large geographical regions. Specific concepts of spatial complexity in landscape at useful analysis/design scales include work ranging across ecosystems (Laterra et al, 2005)\(^{28}\), and wildlife management and landscape ecology (Cushman, 2008, 2009). Cushman comes closest to defining spatial complexity for landscape, but the focus is on mechanistic relationships between organisms and their environments at multiple scales, without a single clear classification of what spatial complexity actually means (Cushman, 2009:56). While some findings within the landscape discipline are still based on large scale readings of raster data, relationality between dynamic and static objects, combinations of scales and other mixed input data give a fuller picture than other spatial disciplines approaches to the concept\(^{29}\). In summary, while neither architecture nor spatial planning have commonly understood definitions of spatial complexity, landscape gives a fuller picture than other spatial disciplines, and while a single definition is not established, landscape studies do employ the concept of spatial complexity.

---

\(^{28}\) Laterra examines impacts of losses of spatial complexity of rural landscapes or ‘simplification’, employing component analysis (water filtration rates, soil carbon storage, etc) at two spatial scales, finding that combinations of configuration indices have higher explanatory value than composition ones (Laterra et al, 2005:56).

\(^{29}\) For example, Cushman et al (2009) discuss spatial complexity in relation to a potentially unifying paradigm, focusing on organisms and their environments at multiple spatial scales (Cushman et all, 2009:56). A so-called ‘gradient paradigm’ is proposed as a conceptual and analytical framework for landscape ecology, which depicts and measures and characterises heterogeneity of organisms and processes at appropriate scales (Cushman et all, 2009:83).
2.2.3 Other spatial complexities

Some separate other disciplinary fields have definitions for the concept of ‘spatial complexity’. From software and computing, the term has been defined as follows: “spatial complexity is informally defined as the distance a maintainer must move within source code to build a mental model of that code” (Gold et al., 2005). In medicine and thermoetical biology, spatial complexity has been associated with ‘surface characteristics and morphology’ (Pham, 2013) including a spatial chaos and complexity in cancer cells of normal and other body cells in ‘intracellular space’. Contrastingly, in the field of geoinformatics related to urban form, spatial complexity has been described as ‘the degree to which an urban shape is irregular or complex’ (Zhenlong et al., 2010) as opposed to ‘relatively simple shapes’. In geography, complexity theory has been treated as “a set of metaphors concerning holistic emergent order” (Thrift, 1999: 35)\textsuperscript{30}. In this interpretation, spatial complexity is seen as a particular perspective on scientific understandings of phenomena, in which appropriately sourced models are part of a geographical narrative. So in medicine, spatial complexity is studied in order to better understand cancerous cells, while in landscape generation of knowledge about land and ecosystems is the focus. In relation to causal effects, and in a complexity frame for the social sciences, it is suggested in the literature: ‘we will do far better if we think about causal processes which are neither linear nor indeterminate, but are instead complex’ (Byrne, 1997: 49). In summary, these varied definitions indicate that spatial complexity can be understood as occurring within cells of the body, as well as across large geographical scales, and therefore is not considered to attach to any single scale. Also, new knowledge can be derived from analysing spatial complexity of phenomena.

\textsuperscript{30} Human geography in particular has an engagement with complexity defined in these terms, with complexity science seen as a path to renewed engagement between human and physical geography O’Sullivan D. (2004) Complexity science and human geography. Transactions of the Institute of British Geographers 29: 282-295.
2.2.4 Two distinct spatial complexity definitions

Two prominent theorists of complexity of cities, Bill Hillier and Michael Batty, have presented distinct treatments of the concept of spatial complexity. In order to draw out possible reasons for the differences in emphasis, and detect possible gaps in their treatment of the concept of spatial complexity for use at urban design scales and in practice, the two approaches are outlined below. Bill Hillier and Michael Batty are both associated with ‘hard-scientifically’ focused research (Marcus, 2012a: 5) with one commentary suggesting: ‘Hillier’s models require doctoral level mathematics to understand them’ (Cuthbert, 2006: 20). Hillier’s original primary interest was in language, and this goes a way towards explaining his original space syntax theory which proposes a ‘common language of space’ (Hillier, 1999) and which has since tended towards a totalizing theory for the ‘organism’ of the city. Hillier and Hanson’s initial theories also dealt with the micro scales, of the individual room and groups of plots, and how these tiny units of the town or city can be studied across scales.

Hillier published two papers which focus on his theorisation of the concept of spatial complexity. Both are of the same title, ‘The Common Language of Space: a way of looking at the social, economic and environmental functioning of cities on a common basis’ (Hillier, 1998) and (Hillier, 1999). Spatial complexity is a theme that Hillier has not returned to extensively in his writings since these two papers. The two Hillier papers vary distinctly in engagement, depth and treatment of the concept of spatial complexity. Hillier’s first paper to explicitly explore the concept of spatial complexity is a long and detailed account of the concept, and argues that physical complexity, as measured by configurational analysis (space syntax methods) is a primary component of spatial

---

31 The original theories of space syntax were devised by Bill Hillier, working in conjunction with a group of researchers at University College London, and the first book on the subject, The Social Logic of Space (1984), was co-authored with Julienne Hanson.
complexity. However, in the subsequent paper of the same title (published one year later), he seems to withdraw slightly from attaching such prominence to the concept. Here are his introductory remarks in the first paper:

there is…. a need for research which directly addresses the physical and spatial complexity of the built environment itself as the main variable of interest, and explores any effect this may in itself have on the functioning of the urban system. This type of research reflects the many questions architects and urban designers typically ask, rather than those that preoccupy planners. For such research to be effective, the physical complexity variable must be controlled at the level at which real design decisions are made (Hillier, 1998: 1).

It is clear from this quotation that Hillier considers that the ‘physical complexity’ aspect within spatial complexity is a measurable variable, and he goes on to assert that space syntax methods can measure this. He further associates the concept of spatial complexity with the level at which real (built environment) design decisions are made, implicitly connecting to urban design. His claims for the theory and methods of space syntax include that: “Space syntax is an attempt to build a domain theory of the urban object itself” (Hillier, 1998: 21), and the subsequent development of this theory in research by him and others, and success in practice and business have sought to test that theory across scales and urban cultures. The first paper goes on to propose a domain theory of the urban object itself: ‘research which treats the built environment not as one of a number of intervening variables in a policy question, but as the primary variable, as it is in the real world design and development process’(Hillier, 1998: 23). He further argues that policy has proven less effective in improving cities than evidence-based research. The second Hillier paper about spatial complexity (of the same title) is brief,
later, and less focused on the development of a definition of spatial complexity, but it does repeat exactly one section related to the research question of this study:

‘..no one knows how to control the physical complexity variable. There is no formal language in which differences between one form of complexity and another can be described with the required rigour and consistency. Without controlling the variable we cannot measure its effects, and what we cannot measure we prefer not to discuss’. (Hillier, 1999: 344)

This comment points to Hillier’s frustration at the fact that a method of evaluation of certain types of complexity (possibly including spatial complexity?) is missing, which recurs in other commentary on complexity and the built environment. However, disappointingly for this study, the second, shorter paper replaces one whole section titled ‘Analysing spatial complexity’ (1998) with the title ‘Analysing emergent complexity’ (1999) suggesting a retreat from significant theoretical claims for the concept of spatial complexity. Given that the first text is a working paper published by Space Syntax Ltd, and that the second appears in shorter form in an established peer reviewed journal, it is likely that Hillier was trying out ideas in the first in long form before formal publication of the second shorter paper. In summary, Hillier’s definition of spatial complexity emphasises the urban built environment itself, at urban design scales, and calls for methods of measuring and comparing this form of complexity.

Batty has also engaged in theorizing the concept of spatial complexity, but with a distinct emphasis, related more to his ‘science of cities’ focus. He describes in cities ‘a complexity of spatial behaviours that only now are we beginning to recognize and articulate’ (Batty, 2011: 1). Batty’s primary, prominent and consistent engagement with the concept of spatial complexity within the science of cities domain and field of CTC

---

32 Ratti, for example, who has engaged in built environment analysis and modeling in a complexity frame, states: ‘New algorithms could probably be written to analyse the full complexity of urban texture and take into account its metric properties’ (Ratti, 2005:547).
includes many tutorials and seminars devised around this term. The concept of spatial complexity has formed the cover title for an extensive body of work\textsuperscript{33}, which encompasses a large published output on the science of cities (Batty, 2011: 7). However, there are almost no published written definitions of his meaning of the concept of spatial complexity. One discussion and description by Batty of the concept of spatial complexity in relation to the development of a science of cities concerns ideas about scaling that relate ‘size, shape and scale’ to morphologies which illustrate fractal patterns and self-similarity, together considered by Batty to be key signatures of spatial complexity that define this new science (Batty, 2011:1).

Although this development of the concept of spatial complexity in space and time is explicit, all accompanying diagrams illustrating the paper are either graphs or two dimensional pattern illustrations, connected mainly to abstract mathematical principles. While these theoretical connections are important for understandings of cities because of rapid change in urbanization processes, and the consequent challenges for society, and while acknowledging that in science, scaling and self-similarity do cross all scales, it is evident that the theoretical writings of Batty do not engage at urban design scales, nor in senses that the concept of ‘space’ would be commonly understood in the spatial disciplines. It is possible that Batty considers the term spatial complexity to be self-explanatory, though it does self-define in quite hard scientific terms if seen through the work he has published. For example, his lecture course at CASA\textsuperscript{34} titled ‘Lectures on Spatial Complexity’ offers no substantial definition of the term, (in the online text material) though it does refer students to his many published texts including books, articles, and an encyclopedia entry on complexity science and systems science (Batty, 2011:1).

\textsuperscript{33} Much of Batty’s published output is available on the website www.spatialcomplexity.info.

\textsuperscript{34} The Centre for Advance Spatial Analysis (CASA), School of Geographical Sciences and Urban Planning, University College London, is ‘an interdisciplinary centre focused on the development of mathematical models and digital technologies in geographical information science, urban and regional modelling, and the science of cities’. (Source; ‘Michael Batty Cv’, downloaded from http://www.complexcity.info, accessed 010515.)
2013). None of these publications are explicit about the term, although Batty is clear that complexity is an important way to organize knowledge in relation to cities, (Batty, 2009) an important point for this study. Batty’s published understandings of spatial complexity tend towards a non-spatial or non-designerly aspect, and his research is critiqued as having ‘social content overly abstracted’ (Marcus, 2012a: 5), part of wider criticisms of complexity theories of cities (Pulselli, 2006) (Bettencourt and West, 2010). In comparing the two distinct definitions of spatial complexity, the focus is on core concepts of complexity of interest for this study, including relationality, multiscalarity and temporality. Although these three concepts are considered important in both author’s work, as well as in their definitions of what constitutes spatial complexity, differences are apparent. Hillier’s subsequent research, connected to his original and persistent interest in (topological) relationality, has consistently developed ideas of multiscalarity, from relations between single rooms to configurational relations across whole urban regions. The critical link Hillier observes between temporality and development of complexity is exposed in his studies of historic settlements worldwide (Hillier, 1984, 1996, 2002). Batty’s interest however, appears to settle at the scale of the entire organism35, and is not so easy to operationalise for urban design.

---

35 However, Batty’s interest in ‘Pseudo-Dynamic Urban Models’, (PhD Thesis, Batty, 1984) emphasises relations between entities, self-similarity across scales, and the importance of understanding time in the emergence of urban complexity.
2.2.4 Qualitative understandings of spatial complexity

CTC is associated with a spatial planning ‘bias’ (Marcus, 2012a: 5; Batty, 2015), (Portugali, 2006; Portugali, 2011; Portugali, 2012a), and the relatively small amount of published research on complexity theories of cities with a spatial, designerly and specifically urban design focus have not concentrated on refining and developing the concept of spatial complexity. These ‘meta’ understandings of complexity and cities extend to research in computational (Derix, 2012), ‘parametric urban design’ (Beirão et al., 2011), or generative design (Beirão, 2012), space syntax and other city modelling or diagrammatic reasoning, and can occasionally be applied to a one–dimensional or even blank canvas, far from the topological, temporal and qualitative realities of an urban site. If this tendency is combined with a propensity towards a totalising ‘urban’ or cities discourse, and the large scalar fix which this implies, it can miss some of the smaller objects and subjects of study at urban design scales, such as areas, neighbourhoods, and urban sites. Another apparent tendency of generative design research in particular is an emphasis on the invention of wholly new methods, software and systems to deal with somewhat abstract manifestations of selected spatial phenomena.

In contrast, qualitative aspects of urban complexity are investigated in the urban design literature, with variety (Rapoport, 1970)(Kaplan&Kaplan, 1972)(Elsheshtawy, 1997), sensory aspects, and ‘urban design qualities’ examined as factors influencing urban and environmental complexity. Rapoport, in environment-behaviour studies, discusses ‘the desirability of (urban) complexity and its achievement’ (Rapoport, 1970:106) and researches an optimal rate of perceptual input from urban environments. Mehta argues that public spaces in cities are pleasurable when they have high levels of spatial quality and sensory complexity (Mehta, 2014:61). Ewing et al, (2006) measure five ‘urban
design qualities’ related to walkability, (imageability, visual enclosure, human scale, transparency, and ‘complexity’) concluding that ‘qualitative urban design qualities can be quantified’ (Ewing et al, 2006:236). However, these and other studies reviewed do not in general combine qualitative evidence with the more quantitatively measurable spatial aspects of urban sites. In summary, it is evident that the discourse around environmental and urban complexity evaluation has had an over-emphasis on qualitative aspects of complexity.
2.2.5 Definition of spatial complexity adopted for this study

This section reviews prior theory to inform a working definition of spatial complexity in advance of developing a conceptual framework for this study. While the links between geography and complexity were first made in the 1970’s, arguably the ‘complexity turn’ (Urry, 2005) did not reach planning till the mid 2000’s (Healey, 2007), and given the relatively recent ‘urban design turn’ of the early 2000’s (Gunder, 2011: 186) (Cuthbert, 2007) complexity theory and urban design theory have only recently begun to interact in a general way (Bachman, 2010: 22). However, since the first significant association of organised complexity with life and design in cities (Jacobs, 1961), numerous synthesizing theories of urban design (Hillier & Hanson 1984, Alexander 1987,
Salingaros, 2005, Shane, 2005\(^{37}\)) have considered complexity to be an important component related to urban design. While an association between complexity and urban design theory has been criticized as merely ‘mathematical modelling’ (Cuthbert, 2007: 208), urban design theory and research which is useful for this thesis has recently been developed to expand the potential of this association, especially in three areas: compositional, configurational and systems related urban design research. While ‘composition’ here means the combination of elements constituting an urban site\(^{38}\), compositional complexity, in relation to this study can be defined here as complexity of compositional aspects of urban form. The complexity of urban form is extensively researched for urban design (Marshall, 2005)(Batty, 2007, 2008)(Clifton et al, 2008)(Ewing, 2009)(Haghani, 2009)(Kasprisin, 2011). Configurational urban design theory deals with topological analysis of urban sites, ‘including ordering (relative position, but not necessarily metric distance) of urban elements, adjacency and connectivity’ (Marshall, 2005: 86) (Box 4). Although Krafta has discussed configurational complexity and developed one definition of spatial complexity, (‘the spatial component of urban complexity’) (Krafta, 1997:2) he does not develop the concept. Configurational complexity of urban sites here means complexity of topological relations between elements. This can be distinguished from the primarily geometric relations of compositional complexity. In describing system complexity, Marshall states that this type of organised complexity: ‘is different from artefactual complexity in that the parts are not necessarily assembled with respect to the whole, and

---


\(^{38}\) While the Oxford English Dictionary contains numerous definitions for ‘composition’, two are especially relevant to urban form and environments. While the first, used here, is of ‘the forming (of anything) by combination of various elements, arts, or ingredients; formation, constitution, construction, making up’ (OED, noun, 2), another definition, ‘the action or art of disposing or arranging in due order the parts of a work of art, esp. of a drawing or painting, so as to form a harmonious whole’ (OED, noun, 8), relates to the later discussion in this study of urban design as art. (See Chapter 4, Section 4.5.2, and Chapter 8, Section 8.1.3.4, in relation to outputs of this study, and how they relate to urban analysis and design practice.)
the whole is in practice unknown by any agency’ (Marshall, 2012a). Alexander’s understanding of systems in relation to urbanism begins with his description of a ‘set’ as ‘a collection of elements which for some reason we think of as belonging together’, before he defines a system as follows: ‘When the elements of a set belong together because they cooperate or work together somehow, we call the set of elements a system’ (Alexander, 1965:58). According to this definition, the complexity of a system could be related to the ‘kinds of entities and relationships’ which are ‘more common, important, and necessary than others’ (Manson & O’Sullivan, 2006:681). Therefore, here system complexity of urban sites means a measure of the numbers, size and relations between entities of the evaluated systems. This definition is developed further in Chapter Four (Section 4.3.1.3).

Krafta (Krafta, 1997), in describing complexity related to urban studies and form, describes complexity as ‘a value, belonging to the domain of evaluation’, and goes on to define spatial complexity in relation to the urban environment as ‘the spatial component of urban complexity’ (Krafta, 1997:2). This definition arises in the context of a primarily mathematics-based development of the concept of spatial complexity in order to empirically measured space, providing ‘(configurational) systems description of urban space’ (Krafta, 1997:3), and thus could be seen as an over-quantitative description. However, the clarity of the statement helps to communicate the basic meaning of spatial complexity for this thesis research, especially in relation to urban sites. Although Krafta does not define urban complexity, and he does confine his disciplinary scope to urban configurational studies (Krafta, 1997:1), he does agree that urban designers and urban morphologists regard complexity as an urban property:

39 Krafta’s paper, titled ‘Urban configurational complexity: Definition and Measurement’, was presented at the first International Space Syntax Symposium, the bi-annual meeting of space syntax researchers, in London in 1997. Given that it is likely that Bill Hillier, (the primary originator of theories of space syntax at the time) attended this meeting, interesting questions arise about the tone and content of his own two ‘spatial complexity’ papers, of 1998 and 1999. The possible connections are discussed again in Chapter Eight.
related to at least one of the concepts of variety, scale (size), growth, intensity, continuity, density. Hence complexity could be understood as a particular state of urban form/life, in which one or more of those aspects are present in a great extent, or beyond a given threshold (Krafta, 1997:1)

This description of aspects of urban complexity is supported by the spatial sciences and urbanism literature, with variety (Rapoport, 1970)(Kaplan&Kaplan, 1972) (Elsheshtawy, 1997), scale (size)(Healey, 2006), growth (Batty, 2008), and density (Salat et al, 2012) all examined as factors influencing urban complexity. Intensity and continuity are aspects of urban complexity which feature less in the urban design literature. Other studies on spatial complexity related to urban design do not engage fully with this concept, define it, or develop it. Consequently, Krafta’s definition of spatial complexity, as the clearest description, is adopted as a short working definition at this exploratory stage for discussion and use of the concept of spatial complexity in urban analysis and design in this study.

---

40 Spatial sciences disciplines are considered to include regional, spatial and urban planning, landscape, and architecture. The term is used in connecting complexity and planning (O’Sullivan et al, 2006),(Rasouli, 2012), also in architecture (ETH, NSL research group) and mapping (Journal of Spatial Science).

41 Bhat, (2014) examines the relations between biological and architectural (urbanism) complexity, and sets out ‘principles which are crucial in their ability to give rise to spatial complexity in both biological and man-made architectures’ (Bhat, 2014:17) but does not define the concept.

42 Spatial complexity has been researched (but not defined) in the ‘science of cities’ domain Haghani T. (2010) Fractal Morphology & Urban Complexity. Phd Thesis, School of Architecture, BIAD, Birmingham City University (BCU), UK., and considered as having a large visual dimension, categorised by pattern recognition in pixels of aerial views at large scales. However, the scalar focus is broad, on applications of complexity theory across architecture, urban design and planning, and therefore differs in focus from this study of urban sites for urban design.

43 DeKay (2012) uses design strategy maps to introduce spatial complexity to climatic design, but focuses on architectural aspects of nested design pattern layers at different scales.
Figure 2-3  Papers converging around the ‘spatial complexity’ concept

Figure 2-4  Defining spatial complexity concept for urban sites
As regards positioning this study within the prior theory and many fields of previous studies within the complexity sciences, Castellani has developed a ‘Complexity Sciences Map’, (See Figure 2-5) which he describes as ‘mapping the complexity turn’ (Castellani, 2014). In the 2015 edition of the map, which traces a temporal progression of ‘spatial/geographical complexity’ from beginnings in complex systems theory, through network science and connected latterly to data science, this category of complexity science is seen as one of four developing streams, alongside ‘multi-level complex systems’, ‘data-science’, and ‘case-based complexity’, Castellani’s own specialism (Castellani, 2015). In positioning itself according to the Complexity Sciences Map, this study aims to extend understandings of this study’s meaning of spatial complexity for urban design (See Figure 2-6).
Figure 2-5  Castellani Complexity Sciences Map 2015

Figure 2-6  Proposal of this study to extend spatial complexity to urban design
Given that this thesis concentrates on usefulness for urban design practice, and that description, prescription and design aspects of urban sites are in the first instance the focus here, evaluation of sociospatial, environmental, visual and other potentially important aspects of spatial complexity of certain urban sites is beyond the scope of this research. Other characteristics of urban sites such as ‘sensory complexity’ of public spaces (Mehta, 2014:61), which could be argued to be components of spatial complexity, are beyond the scope of this study, as prior theory has not explicitly associated the two concepts. As described in the previous Section, two relevant prior competing theories of spatial complexity do not engage with urban design practice. In this research the important entities to study are urban sites, and the most common, important and necessary relationships studied within, between and across sites are of a compositional, configurational and system nature. Previous relevant urban design research has often emphasized these three aspects either separately (Gil, 2012), (Hillier, 2008, 2009), (Marshall, 2005), or combined (Van Nes, Berghauser Pont, 2014)(Marcus, Berghauser Pont, 2015), and sometimes compared (Oliviera, 2014),(Oliviera, Partenen, 2015). This study seeks an integrative understanding of these separate approaches to understanding the city and urban sites, by developing the concept of spatial complexity.

This second section of Chapter Two has reviewed the philosophy of spatial complexity and other spatial related complexity definitions, as well as two particular competing CTC spatial complexity definitions. It is concluded firstly, that philosophical treatments of the concept of spatial complexity diverge, while omitting a specifically spatial perspective, especially for planning and urban design, secondly that spatial planning definitions and other understandings of spatial complexity vary across the dimensional scales and specialisms of the territories and disciplines cited. Thirdly, it is concluded
that a hard-scientific focus has dominated the discourse. These observations confirm that a rigorous encompassing definition of spatial complexity as a concept for urban design theory and practice has not yet been provided in the literature. The spatial complexity concept therefore requires increased exploration and understanding for urban sites, which is important because optimal levels of spatial complexity can assist urban sites in evolving as qualitatively rich locations. The short working definition of spatial complexity adopted for this study is described as Krafa’s definition (‘the spatial component of urban complexity’), and linked to the exploratory and evaluation aspects of this study. These are outlined in the next Section, which examines the literature linking complexity to urban design research.
2.3 Urban design

Having outlined the connections between CTC and current understandings of the concept of spatial complexity, the third section of this Chapter looks at current understandings of complexity related to urban design research, in order to precisely locate the disciplinary focus of this study. Urban design, as described in Chapter One, is an art or technical practice involving the physical organisation of buildings and spaces, towards a civic purpose. Integrative urban design was introduced earlier as the area within urban design on which this study focuses. This section serves to substantiate a claim of this study that the discipline of urban design is a context where complexity thinking has not yet been wholly embedded. Complexity thinking combines aspects from relative, social scientific thinking, and objective, natural-scientific orientation, enabling a dynamic knowledge formation process, in which computer aided methods are, in one account, considered essential (Partanen, 2015a: 15). Urban design deals with complex urban problems from contrasting disciplinary perspectives (Carmona, 2014b: 5). In these aspects, complexity and urban design draw from similarly broad knowledge bases. Concepts from complexity theory have relevance for urban design in offering reference points for reframing the processes inherent in urban design as a discipline.

2.3.1 Urban design and the complexity ‘turn’

In contrasting traditional sciences approaches to knowledge with a complexity approach, Thrift states: ‘the geographical world is a messy one, it does not cohere’ (Thrift, 1999: 32), and he further distinguishes defining aspects of the complexity sciences as follows:

the idea of a science of holistic emergent order; a science of qualities as much as
of quantities, a science of 'the potential for emergent order in complex and unpredictable phenomena' (Goodwin, 1997: 112), a more open science which asserts 'the primacy of processes over events, of relationships over entities and of development over structure' (Ingold, 1990: 209) (Thrift, 1999: 33).

In connecting geography to complexity theory, Thrift was ahead of the so-called ‘complexity turn’ in academic discourse (Urry, 2005), which had followed from the ‘cultural turn’ (Whyte, Geertz, Foucault, Bourdieu, 1970’s) and the ‘spatial turn’ (Foucault, Lefebvre, Soja, Harvey, 1990’s) (Arias, 2009). The ‘scalar turn’ (Brenner, Deas, 2000’s) in political and economic geography, and was seen to be followed by the ‘mobility turn’ in global urbanism terms (Urry, 2006). Urry describes how the complexity turn, in particular, follows an array of developments in the scientific disciplines, including ‘chaos, complexity, non-linearity and dynamical systems analysis’ (Urry, 2005:1) along with shifts from reductionist approaches to those that involve complex adaptive systems.

Complexity has been considered to be an ‘urban design quality’, and given an operational definition for urban design, of: ‘the visual richness of a place’ (Clifton, 2008:226). Measurement protocols are also proposed, related to perceptual qualities of the urban environment that may influence walking behaviour (Clifton, 2008:224). One conclusion of the study is that ‘urban design qualities can be quantified’ (Clifton, 2008:236). Jacobs and Appleyard seek ‘many separate, distinct buildings with complex arrangements and relationships (as opposed to few large buildings)’ (Jacobs, Appleyard, 1987:117) as one of the five physical characteristics they consider central to urban life. Mehta argues that public spaces in cities are pleasurable when they have high levels of spatial quality and sensory complexity (Mehta, 2014:61). Rapoport, in environment-behaviour studies, discusses ‘the desirability of (urban) complexity and its achievement’
(Rapoport, 1970:106) and researches an optimal rate of perceptual input from urban environments.

Urban design has been defined as ‘an applied field, where the distinction between understanding how a society is, and it could or should be, is at the core of the discipline’ (Griffiths, 2014: 159) so as such, understanding emergent spatial properties is important for urban design theorists and practitioners. The realm of urban design theory has been described as “the kind of integrative theory that gives credence to urban design as a dedicated, coherent intellectual discipline” (Marshall, 2012b: 258) supported by a range of theories of a scientific, social-scientific or artistic nature. However, criticisms of the broad field of urban theory, including urban design theory, have included its lack of coherence, either internally or collectively (Cuthbert, 2011), and claims of ‘insufficiency and incoherence’, leaving it open to interpretation as being “of a pseudo-scientific nature” (Marshall, 2012b). Recent urban design theory literature has discussed the move of emphasis from closed to open systems design thinking in urban design theory (Birkeland, 2012) and in the design and management of cities (Sennett, 2006) (Sennett, 2014) coinciding with the tendency in spatial planning towards regarding cities and indeed regions as complex spatial systems (Wilson, 2000). These systems are regarded as dynamical, uncertain, (Rasouli and Timmermans, 2012), in flux, and hard to predict. In this unstable context, it has been argued that urban design has so far not developed sufficient consciousness of adaptability of physical, natural and social processes in connection with resilience (Bosselmann, 2008). Salat (2011) claims that the concept of urban complexity is rarely used in urban analysis (for urban design) and suggests a reason: ‘perhaps because it is hard to handle’ (Salat, 2011:26). In conclusion, while complexity has featured sporadically in the related literature, urban design can be seen as a discipline where complexity thinking has not yet been wholly embedded.
Current understandings of complexity in the related field of spatial planning, the field most closely connected to urban design in practice, tend to place similar levels of emphasis on both spatial and policy/management/governance aspects (Healey, 2007) (de Roo, 2012a). A planning research approach to complexity would concentrate more on policy, zoning and other normative and positivist readings (Davoudi, 2012) of urban sites than the approach of this urban design study. Planning theory also tends to overlook emerging research on complexity and complex systems (Healey, 2012:343), a particular interest in this study. A three-dimensional approach to visualisation is also an important aspect of urban design readings of urban sites (Trancik, 1986)(Alexander, 1987) another distinction from a planning research approach. This thesis argues that urban design is well placed, at a scalar ‘level’ above architecture and ‘below’ spatial planning, to act as a useful link connecting these three disciplines in a complexity frame.

2.3.2 ‘Exploration’ and urban design

In discussing the concept of ‘exploration’ for urban design research, the emergence of the concept of ‘exploratory science’ is relevant. Kitchin claims that the current scientific paradigm is the fourth, (after experimental, theoretical and computational) named ‘exploratory science’, and that its form is ‘data-intensive, involving statistical exploration and data mining’ (Kitchin 2014:3). In an era dominated by digital, big-data-driven enquiry, it has been claimed in the critical data studies field that data-driven science will lead to more holistic and extensive models and theories of entire complex systems rather than elements of them (Kitchin, 2014). In this respect, big data has been defined as as ‘huge in volume, high in velocity, diverse in variety, exhaustive in scope, fine grained in resolution and uniquely indexical in identification, relational in nature, and flexible, holding the traits of extensionality (can add new fields easily) and
scaleability (can expand in size rapidly)...in other words, not simply denoted by volume’ (Kitchin 2014:2). Data-driven science is described as seeking ‘to hold to the tenets of the scientific method, but it is more open to using a hybrid combination of abductive, inductive and deductive approaches to advance the understanding of a phenomenon’ (Kitchin 2014:5). While there have been criticisms of purely data-driven approaches, including the fact that most data used to represent the state of spatial systems is self-reported (Rasouli and Timmermans, 2012), increasingly the digitalization and data-driven conception and direction of cities is dominating urban research. The first guide to conducting research in urban design, titled ‘Explorations in urban design’, (Carmona, 2014) treats urban design as an inter-disciplinary research field, spanning the arts, sciences, and social sciences dimensions, and presents a meta-approach to urban design research within this exploratory science context.

In response to the first part of the research question, which asks how complexity theory and urban design theory can contribute to increased exploration and understanding of the theoretical concept of spatial complexity for urban analysis and design, this third section has reviewed the relevant literature on understanding integrative urban design theory in a complexity frame. From this review, it can be concluded that, although recent urban design theory has moved in emphasis from closed to open systems design thinking, complexity theory and urban design theory have arguably only very recently begun to interact in a general way.
2.4 Evaluation

In the design of the urban built environment generally, evaluation is: ‘an integral, if informal, element of an abductive design process, which we are just beginning to understand (Coyne et al., 1990)’ (Alexander, 2009:4). This section moves from discussing exploration of spatial complexity to the more precise subject of evaluation of spatial complexity for urban analysis and design, and then relevant representation theory, as visualisation is considered core to useful evaluation. A brief description of evaluation in fields allied to urban design shows that some cognate disciplines have more developed cultures of evaluation than urban analysis or urban design. Then representation and visualization theory are introduced, as logical next stages of understanding evaluation of complex phenomena.

2.4.1 Evaluation theory

In spatial planning, evaluation has a developed culture which has evolved through four distinct generations. Currently, different paradigms or rationalities in planning theory see for example, ‘instrumental, substantive and communicative rationality’ as separate classes, with separate related evaluation methods (Alexander, 2006). A ‘communicative rationality’ approach is described as; ‘putting the actor in context, (and) assumes actors seeking consensus (more than to achieve their own goals), and

---

44 The first ‘generation’, characterised by a reliance on scientific measurement, is associated with a positivist paradigm. The second combines empirical assessment with some assessment of goals-achievement, the third generation, in reaction to the second, sought objective and value-free ways of assessment, and the fourth ‘transcends raw empiricism into post-positivist intersubjective interaction’ (Alexander, 2006:12).

45 Rationality in this respect, and in relation to planning theory, is defined as ‘the application of reason to purposeful action’ (Alexander, 2006:39).

46 Alexander defines two of these three as follows: ‘The simplest rationality is the form that reductionist stereotypes often attribute to rationality as a whole: instrumental rationality. Instrumental rationality is the logic of choosing the best means to achieve a clearly predefined or given goal. Substantive rationality is more complex. Subsuming instrumental rationality, it also demands consideration of goals themselves, including selecting between objectives and assigning their respective priorities. Both these forms of (Weberian) rationality premise an autonomous individual and focus on his reasoning for decision.’ (Alexander, 2006:40). Cost benefit analysis is given as an example of the former, while environmental impact assessment, is an example of the latter evaluation method, and cited as having strong links to substantive rationality (Alexander, 2006:45).
focuses on the interactions leading to decisions, rather than the decision itself” (Alexander, 2009:48). Spatial planning evaluation is associated primarily with ‘ex-ante’ (pre-construction) evaluation, but could also apply to ‘ex-post’ (post-occupancy) or ‘in itinere’ (in progress) stages of development. One other aspect of development is also currently considered important in spatial planning: plan-evaluation, i.e. the assessment of completed plans (Alexander, 2009:8). Evaluation as discussed in spatial planning generally does not include program, processes, or planning activity evaluation.

In landscape evaluation, once described as a ‘theoretical vacuum’ (Appleton, 1975) contemporary understandings tend towards quantitative criteria in practice. Cushman (Cushman and Huettmann, 2010) (Cushman, 2016) developed spatial complexity metrics for wildlife management and landscape ecology, and (Leitão et al., 2012) develop quantitative measurement indices of landscapes, including of spatial complexity, for specific use in planning. In assessing spatial complexity for landscapes, it has been considered in one instance that ‘combinations of configuration indices showed higher explanatory value than composition ones’ (Laterra, 2012), demonstrating combined methods of assessment. So although landscape metrics for evaluation and decision-making are in development, the approach has a hard-scientific emphasis to large scales, often concentrating on ‘patches’ of landscape or numerics related to species at single scales. In architecture, evaluation is often just lacking at building level (Bordass and Leaman, 2005), and some techniques measure too much of the wrong things (Roaf et al, 2015). In this respect, although Bachman (2008)(2010) develops theory and ways to recognize manifestations of complexity in buildings, he does not follow through on specific evaluation methods for particular structures. In summary, spatial planning evaluation theory as it applies to the urban built environment generally
concentrates on planned development, that is plans or projects, in advance of construction. Landscape evaluation theory tends towards purely quantitative evaluation of landscape sites, while architecture theory has currently uneven concepts, levels and standards of evaluation.

2.4.2 Evaluation for urban design

In this study, evaluation for urban design means a site survey or assessment of current spatial and formal conditions of an urban site or neighbourhood. This is in contrast to evaluation for planning, which could focus on many time-related aspects, and where the primary object of focus is generally ‘planned development’ (Alexander, 2006:8). (See Figure 2-7)

By comparison with spatial planning, landscape and architecture, evaluation theory for urban design is even more under-developed. Gil reviews contemporary tools to evaluate
urban design, (Gil, 2013)\textsuperscript{47}, including the format, structure, content and output of selected sustainable urban development evaluation tools, based on planning evaluation theory and ‘the requirements of urban design practice’. It is concluded that evaluation tools based on systems of indicators are ‘preferred as an evaluation method for application in practice at the scale of an urban area’ (Gil, 2013:323), and that there is a gap between theory and practice in the development of sustainable urban development evaluation tools ‘where collaboration between academic and other institutions is most rare’(Gil, 2013:323). Gil’s analysis is returned to in more detail in Chapter Three. Theories of evaluation and measurement in urban design are varied and contested, and the encompassing scales involved range widely (Marshall, 2015). Given that a perceived problem of urban design is the perception that it is ‘big-architecture’ (Carmona, 2010), a ‘subset’ of planning (Gunder, 2011:184) or design at whole-city scales (Frey, 1999) it could be possible to lose focus on the core relevant scales. In this study, an urban site, an area roughly equating to neighbourhood size, is concentrated on. The literature repeatedly claims that there is a gap in focusing on understanding and evaluating the ‘middle’ urban scales (eg. an urban site, a neighbourhood). Panerai et al (2004:10) describe the long-ignored ‘in-between level’, that is, neither ‘grand layouts’ of cities nor ‘domestic details’, but the scale of the urban block. Quinn (2012) has argued that while a complexity perspective for the larger scales of cities has led to work on global city size and scaling, “less work has focused on identifying patterns at the neighbourhood scale that are common for all cities” (Quinn, 2012). Sullivan (2014)

\textsuperscript{47} Gil’s enquiry is specifically in relation to the ‘sustainability’ of ‘urban design’, though his investigation is primarily about ‘ex-ante’ or ‘before the event’ evaluation of new construction, and better or less ‘good’ early stage urban design options and their evaluation.
claims that, in understanding neighbourhood sustainability frameworks, few papers focus exclusively on neighbourhood schemes (Sullivan et al., 2014).

Evaluation for urban design is somewhat supported by theory and empirical research, including by psychological, aesthetic, ‘response to context’, and user satisfaction studies, but these assessments vary in detail, authorship, levels of assessments and time, whether before or after implementation (Forsyth et al., 2010: 28). Theories of evaluation of the designed environment for urban design suggest this aspect is subjective (Rapoport, 1970), multi-dimensional (Carmona, 2014b), and provisional or ‘subtle’ (Ewing et al., 2006). If evaluation can be seen as a broader understanding of environments, for example of urban networks (Gil, 2014), or public space quality indices (Mehta, 2013), urban design evidence is more specifically understood in the literature as associated with decision making for design.

Evidence of spatial configurational conditions in urban sites in New Towns, for example, is considered important for informing design decisions about future change (Karimi, 2014). As already outlined in Chapter One, the use of evidence-based methods in urban design is a relatively new proposition, and the literature points to a need for more evidence at many of the scales around urban design, including evidence on impacts of innovative street designs (Biddulph, 2012b), and public spaces (Carmona, 2014a). Al-Sayed has studied systems based approaches related to evidence for urban design, concluding that systems thinking can support design reasoning, and that this is particularly valuable in urban design where “dependencies between variables are often too complex to solve intuitively” (Al-Sayed, 2014).
Measurement in urban design tends towards quantitative methods, such as for walkability (Sohn et al., 2012) though there are exceptions (Ewing and Handy, 2009), and a standardisation in quantitative operational definitions and measurement protocols has been called for (Clifton et al., 2008). Measurement of urban design quality tends towards simplifying the object of study to one scale or element, for example the urban design quality of the street (Ewing, 2013), perceived complexity of streets (Elsheshtawy, 1997), or perceived complexity of tall building facades (Heath et al., 2000). One study has concentrated on a series of public spaces (Carmona, 2010), even though it is claimed that there is no consensus on how a high quality space is defined (Dempsey, 2008). Talen (2003) has reviewed urban ‘measurement, evaluation and representation’ for urbanism, concluding that new measurement approaches are needed to more appropriately reflect the material aspects of cities (Talen, 2003). Bell (2005) considers value in urban design as assessed by estate developers, concluding that while there is renewed interest in urban design quality from these agents, there are also questions raised about the ‘private’ production and planning of the urban environment (Bell, 2005). Later in this study⁴⁸, specific selected urban design evaluation procedures will be discussed, including Gil’s proposition as regards the use of urban design ‘indicators’ in evaluation. Gil states: ‘it is important that the indicators make the consequences of design actions directly observable and understood by the stakeholders to facilitate the interaction and iteration processes.’ (Gil, 2013:314). It is in this context that representation and visualisation theory is relevant to considering evaluation for urban design. In summary, the literature in relation to evaluation for urban design reveals a number of current features, including that many different scales are evaluated, and that there is a gap in focusing on understanding and evaluating the ‘middle’ urban

⁴⁸ See Chapter Four, Section 4.3, Structure around an evaluation tool’.
scales (eg. an urban site, a neighbourhood). Theories of evaluation of the designed environment for urban design suggest this aspect is subjective, multi-dimensional, and provisional, and tends towards quantitative methods, a standardisation in quantitative operational definitions and measurement protocols has been called for, and it is suggested that new measurement approaches are needed to more appropriately reflect the material aspects of cities.

2.4.3 Representation and visualisation theory

The urban environment is complex (Barredo et al, 2004)(Rydin, 2012), and complexity is associated with data rich environments (Kitchin et al, 2015). In this context, information visualisation is transforming understandings of urban environments. In the spatial sciences, the concept of spatial complexity has a large visual dimension, and has been categorised by pattern recognition in pixels of aerial views at large scales (Haghani, 2010), classification of spatial complexity of rural landscapes (Laterra, 2012), and recognition of fractal or geometrical patterns across population, remote sensed imagery and street network representations (Batty, 2011). Research has sometimes implied that the visual dimension is the predominant property of spatial complexity (Bhat, 2014:10) and the concept of visual complexity has an extensive supporting literature (Lynch, 1984)(Heath et al, 2002)(Tucker, Oswalt, et al, 2008)(Oswald, 2014). While theoretical concepts of ‘visuality’ and ‘scopic regime’, relating to the ways in which both what is seen and how it is seen are socially constructed, it is sometimes suggested that the ‘privileging’ of the visual empowers the researcher, thus reducing objectivity. It is argued that understandings of visualisation require knowledge about provenance as well as ‘the social work that the image does’ (Fyfe & Law, 1988).
Stanczak (2007) emphasises the need for reflexivity is considering visual research methods. This intersection of researcher and tactics or tools is subject of debate in artistic research and in architecture and design (Nilsson et al, 2014:7), where tools are sometimes associated with a ‘practice’ rather than a ‘research’ aim. In defining the term ‘tools’ in relation to urban design evaluation processes, Gil describes the term ‘tool’ as ‘used in a broad sense, encompassing a range of design and decision-support instruments’ (Gil, 2013:311) the meaning adopted in this study.

In the field of visual research, a critical visual methodology approach (Rose, 2007:12) is proposed in the study and analysis of visual culture, including close attention to the actual visual artifact, thinking about the social conditions and effects of visual objects, and consideration of the researchers approach to viewing images. Visual research methods for design tend to emphasise the visual features of the built environment (Sanoff, 2016) and include evaluative responses for urban design (Nasar, 1994), whereby general principles in aesthetics related to urban environments are sought.

Data-informed urbanism (Kitchin, 2015) is seen as a key emergent phenomenon globally, as cities are increasingly the generators of big data. This form of urbanism is being complemented and replaced in some instances by data-driven, networked urbanism as ‘cities are becoming ever more instrumented and networked, their systems interlinked and integrated, and vast troves of big urban data are being generated and

49 Stanczak (2007), in discussing visual research methods for social sciences, describes an epistemology of visual research methods, as follows: ‘just as subjectivity and realism interact in the space between the image and the viewer, the same happens between the producer of the image and the subject or content. We may select the time and space that we want to capture, but the mechanical operation of the camera will document all that is before it in that moment. In other words, the camera is susceptible to the selectivity of the operator, but it is not selective once the shutter is opened (Collier & Collier, 1986)’ Stanczak GC. (2007) Visual Research Methods: Image, Society, and Representation: SAGE Publications.

50 Lesage (2009) describes the concept of artistic research as follows: ‘The notion of artistic research implies that artistic practice can be described in a way more or less analogous to scientific research. An artistic project, then, begins with the formulation, in a certain context, of an artistic problem, which necessitates an investigation, both artistic and topical, into a certain problematic, which may or may not lead to an artwork, intervention, performance or statement, with which the artist positions himself/herself with regard to the initial artistic problem and its context’ (Lesage, 2009:5). The distinction of the artistic research approach as defined here from the urban design research approach of this study is discussed in Section 4.5.2.
used to manage and control urban life in real-time’ (Kitchin, 2015). In this context, developments such as ‘city-dashboards’ (live feeds of real-time data communicated to citizens) are improving on simply providing raw data by producing visualisations that aid interpretation and analysis, especially for non-expert users, ‘allowing citizens to monitor the city for themselves’ (Kitchin, 2014:7). Although visualisation is not new, visual representation of data has emerged as a significant factor in communicating complex data sets including evaluation related to urban environments.

2.4.4 Visualization and information design

A distinction is made in the data visualization literature in defining ‘data visualization’ and the separate concept of ‘informatics’, related to form and origin of images. Data visualizations are defined as ‘algorithmically generated and can be easily regenerated with different data, are usually data-rich, and are often aesthetically shallow’ (Iliinsky et al, 2011), while ‘infographics’ are defined as ‘visualizations that are manually generated around specific data, tend to be data-shallow, and are often aesthetically rich’ (Iliinsky et al, 2011). In this respect, visualizations are seen as the more ‘serious, rigorous or academic’ of the two approaches (Iliinsky et al, 2011:4). It is argued that: ‘the difference between infographics and data visualization may be loosely determined by the method of generation, the quantity of data represented, and the degree of aesthetic treatment applied’ (Figure 1-2)(Iliinsky et al, 2011:5). The count of the number of ‘data dimensions’ of a data visualization is a measure of its complexity, with optimal complexity considered to be around three or four data dimensions. Infographics are considered to be limited in how much information they can convey, and in potential for

---

51 Dr Snow’s linking of the spread of cholera to water supply in London in 1854 is an early example of data visualisation (Minty et al, 1995).

52 Data dimensions are defined as ‘discrete types of information that are encoded in a diagram’ (Iliinsky et al, 2011:3), with, for example, a single line graph showing the price of a company’s stock (on the y – axis) over time (on the x-axis), thus showing two data dimensions.
changing or updating the information, as changes must be updated manually.

The concept of ‘scientific visualization’, described as ‘using computer-generated pictures to gain information and understanding from data (geometry) and relationships (topology) (Nielson et al, 1997) originally developed in computing and engineering sciences. The term refers to methods and procedures of analyzing and understanding rapidly increasing volumes of data for analysis results and seeks standardizing of approaches to visualization. In visualisation research, scientific visualization applications can be loosely divided into two categories: expository and exploratory (Kirby et al, 2005). Exploratory applications typically represent complicated scientific data as fully as possible so that a scientific user can interactively explore it, whereas expository visualization applications seek fewer but key summary visualisations. In using data for exploration, the scientist seeks to prove a hypothesis, but also to potentially generate future and insights and hypotheses from visualization results.

Concepts of information visualisation and information design are also features of the literature around representation. While rapid change is a feature of the development of data visualisation for urban analysis and design (Batty et al, 2000 ), information visualisation is also transforming understandings of urban environments. Described as ‘not only about creating graphical displays of complex and latent information structures; it (information visualisation) (also) contributes to a broader range of cognitive, social, and collaborative activities’ (Chen, 2013). The standards and ideas of data visualisation proposed by Tufte (1990, etc) although originating in graphic design, have been seen over time as significant contributions to development of the fields of architectural representation (Burkhard, 2004), and urban design (Talen, 2003) and have been described as ‘information design’. In essence, Tufte seeks clarifications of complex data through clearer visualisation. In conclusion, theory suggests that representation and
visualisation of complex data associated with urban environments requires a clear epistemological framework. The reviewed representation and visualisation theory, when triangulated with theories of visualisation of complexity suggests that visualisation of spatial complexity of urban sites may be most closely related to data-mining and information design as practices. This topic is discussed again later in Chapter 4, Section 4.5.
Chapter Conclusions

This literature review of spatial complexity is structured thematically, related to four subjects: complexity, spatial complexity, urban design and evaluation. In firstly positioning the study within complexity theory, and then describing the relevance of complexity theories of cities (CTC), cities and design at urban design scales are shown to be in need of focused examination.

In the second part of Chapter Two, multiple definitions of spatial complexity are reviewed, as well as two particular distinct CTC definitions. It is concluded firstly that philosophical treatments diverge, while omitting a specifically spatial perspective, especially for planning and urban design. Secondly, it is observed that spatial planning definitions and other understandings of spatial complexity vary across the dimensional scales and specialisms of the territories and disciplines cited. Thirdly, it is concluded that a hard-scientific focus has dominated the discourse around spatial complexity. It is also confirmed that a rigorous encompassing definition of spatial complexity as a concept for urban design theory and practice has not yet been provided in the literature.

In the third section of Chapter Two, connections between complexity and urban design are considered, and it is was noted that complexity theory and urban design theory have arguably only very recently begun to interact in a general way. Urban design is seen as well placed, at a scalar ‘level’ above architecture and ‘below’ spatial planning, to act as a useful link connecting these three disciplines in a complexity frame.

In the fourth section of Chapter Two, the current discourse on evaluation of urban sites is studied, as these locations are at the core of this thesis enquiry. It is concluded that
new measurement approaches are needed to more appropriately reflect the material aspects of cities. Furthermore, as the urban environment is complex, and complexity is associated with data rich environments, information visualisation is transforming understandings of urban environments. In this context, visual representation has emerged as a significant factor in communicating complex data sets related to urban environments. These theoretical underpinnings are now built upon in the setting out of the research design and methodology for the study of spatial complexity of urban sites, the subject of the next Chapter.
Chapter Three  Research design and methodology

3.1 Introduction

The question of how to approach exploration and evaluation of spatial complexity of urban sites has not been addressed in the urban design literature. Therefore, following a theoretical review and definition of the concept of spatial complexity, in the last Chapter, it is now demonstrated that a research framework can be presented which usefully makes the link between theoretical concepts and practical urban site evaluation. This Chapter on research design and methodology is divided into four sections. The first part outlines the overall research design, including research philosophy and strategy of inquiry. The second section deals with specific research methods, including case study and the overall methodological approach. This describes the case study design in detail, as this aspect determines all subsequent decisions on numbers of cases, types of analysis and reporting procedures\(^5\). This is followed by an explanation of the selected approach, a multiple case research design. The third part deals with data collection and analysis. The fourth section describes the consideration of a comparative approach to the research topic, and an outline of the correlational aspects of the selected research design. The main driver of this chapter is the clear setting out of a case study-driven research design for exploration and evaluation of spatial complexity. This is done in advance of setting out the conceptual framework of the study in the next Chapter. This chapter is linked to the review of theories of spatial complexity in the last Chapter by the way in which it builds on the conclusion of that Chapter that urban analysis and design can usefully

\(^5\) A fuller description of all the case study (units of analysis) research design options considered is also included in Volume Two in order to demonstrate the exploratory nature of this research. See Volume Two, Appendix H, ‘Case Study Research Design Options’.
benefit from deepening and bringing together of certain complexity and urban design theories. This chapter advances the overall argument of this thesis through demonstrating the appropriateness of a case study approach to explorations and evaluations of spatial complexity. In this way, subsequent enquiries into spatial complexity of urban sites for urban design can benefit from the descriptions of research design decisions taken in this research, as described in this Chapter.

3.2 Research Design

The research design decisions of this thesis are described in this section. The process of arriving at a research design has been an integral part of the wider exploration of the definition, scope, and usefulness of understanding spatial complexity of urban sites for urban analysis and design. This process in turn serves as a description of the meaning of ‘exploration’ in this thesis, and relates to the concept of exploratory science as undertaken in this study. The research design literature recommends that research design decisions should be informed by a number of considerations including: assumptions the researcher brings to the study, procedures of enquiry (called strategies), specific methods of data collection, analysis and interpretation, as well as the nature of the research problem, the researchers personal experience, and the audience for the study (Creswell, 2009:22). These aspects are described later in this Chapter. The research design for this thesis includes three connected components: research philosophy, strategy of inquiry and specific methods (Cresswell, 2009:23). Each is now described.

54 See Chapter Two, Section 2.3.2, ‘Exploration and evaluation of urban sites’.
3.2.1 Research philosophy

The philosophical position adopted in this study to the research is a ‘pragmatic worldview’ (Cresswell, 2009: 27) whereby, because of the partly exploratory nature of the enquiry, researchers focus attention on the research problem and use all approaches available to solve the problem. The ‘problem’ of this research is a lack of clear definition of the concept of spatial complexity for urban design, and failure to understand the importance of spatial complexity of urban sites. Pragmatic approaches to solve the problem in this research include refinement of the concept of spatial complexity for urban design, and categorization of components of spatial complexity, including composition, configuration and system aspects, which have special relevance in urban sites. Other approaches to solve the problem include proposition of an evaluation tool and methods of visualization of results, in order to improve understandings of this important characteristic of cities. Adopting a pragmatic worldview as a philosophical position in the research design involves the making of pragmatic knowledge claims.

A critical (ie. neither positivist nor wholly interpretative) spatial theory approach to partly qualitative and partly quantitative methods is adopted in this research. This aligns with postpositivism in acknowledging ‘that the experimental model often used in the natural sciences is often inappropriate for research involving people’ (Groat & Wang, 2002). In this research, the ‘human’ aspect is understood for example in the experiential and visual experiences of aspects of complexity, especially in the understandings of compositional analysis, and the potential bias of the researcher in this regard in defining issues and criteria of evaluation. Another example is the fieldwork observation of pedestrian movement network complexity in this study.
The ontological assumptions of the work could be said to be interpretative, with emancipatory aspects, in that the work acknowledges the multiple realities of political, social, cultural and other values. Interpretative research does not predefine dependant and independant variables, but focuses on the full complexity of human sense-making as the research develops (Kaplan, Maxwell, 1994). The interpretative paradigms employed could be described as mainly inductive, in that the research seeks to generate descriptions and explanations of objects and relationships in the world through strategies of enquiry grounded in the world of experience and empirical evidence. As a separate and additional (though less prominent) system of inquiry, a deductive research strategy used in this thesis includes readings of complexity and other theories, and the development of explanations from theory, as well as the systematic testing of these explanations through formal processes of observation, evaluation and argument. However, given that an ‘exploratory science’ approach is adopted, and that this approach, though holding to the tenets of the scientific method, is also more open to using a hybrid combination of abductive, inductive and deductive approaches to advance the understanding of a phenomenon (Kitchin 2014:5) abductive reasoning is also an important part of the adopted research philosophy.
3.2.2 Strategy of inquiry

Strategies of inquiry are types of qualitative, quantitative or mixed methods designs or models that provide specific direction for procedures in a research design (Creswell, 2009:28). Numerous approaches to research strategy within research design exist in the literature. Four examples are compared here. Firstly, for the human and social sciences generally, Creswell describes his proposed three alternative strategies of inquiry: quantitative, qualitative and mixed methods strategies (Creswell, 2009:29) with several
variations within each. Secondly however, and in contrast, Groat and Wang describe seven different possible research strategies (methods)\textsuperscript{55} in architectural (and therefore urban design) research: historical-interpretative, qualitative, correlational, experimental, quasi-experimental, simulation and modeling, logical argumentation, case studies and combined strategies. As a third approach to research strategy, in urban design, Carmona suggests four ‘grand families’ of (urban design) research methods: scientific method, social sciences methods, humanities methods, and design methods, but also suggests many are mixed in the pragmatic conditions of urban design research (Carmona, 2014b:77). Carmona also offers a taxonomy of five ‘meta-approaches’ to urban design research: philosophical approaches, process investigations, physical explorations, propositional experiments and performance enquiries (Carmona, 2014b:10). Physical explorations are described as: ‘a range of analytical studies in which the shape, configuration and growth of space and built form is examined as the physical ‘product’ of urban design and the container for urban activity, uses and movement’ (Carmona, 2014b:10). As a fourth and final approach to strategies of inquiry, Yin considers five basic research strategies: experiment, survey, archival analysis, history and case study, and suggests combination is possible (Yin, 2003:5).

Having reviewed the four recommended approaches described above to a research strategy for this study of spatial complexity, a combined (mixed methods) strategy approach is adopted. In relation to the last of Groat & Wang’s suggested strategies, (a combined strategy approach), a mixed methodology research design is considered to be the most complete level of integration among two or more research designs (Groat & Wang, 2002). In this research design type: ‘the researcher conducts aspects of both

\textsuperscript{55} Groat & Wang distinguish between strategies (methods) and tactics (techniques) stating: “This distinction has been adopted by many other authors writing about research methods. The term strategy is defined as “the skillful management and planning of anything”’. This contrasts with the more detailed level of tactics, defined as “any skillful move” (Groat & Wang, 2002:10)
strategies in roughly comparable sequences, and with approximately equal degrees of emphasis’ (Groat, Wang, 2002:368). A general advantage of a mixed methodology design is that ‘the strengths of each methodology can compliment each other, while the weaknesses of each design can be substantially offset’ (Groat, Wang, 2002:368). A general disadvantage is that ‘the mixed methodology may require a level of familiarity with multiple research designs that is uncommon for people trained in a very specific research tradition. Also, some ‘purists’ may find the combination of research designs too unconventional and therefore suspect’ (Groat, Wang, 2002:368).

A combined (mixed methods) strategy approach is adopted in this study for four reasons: suitability to architecture (urban design) types of research, correspondence to a complexity research approach, responds to an aim of this research to be relevant to urban design practice, and usefulness in reducing bias. Each of these is now briefly outlined. Firstly, combined research strategies in architecture research are strongly recommended by Groat & Wang on the basis that architecture is a multidisciplinary professional field, and it is also considered that much current architectural research takes place in subdisciplinary topic fields, such as environmental technology and architectural history. These authors of the primary source on architectural research methods consider that there are many topic areas in architecture that defy easy categorisation, and that architecture research which combines strategies ‘represents an important and necessary frontier in (the architecture) field’ (Groat, Wang, 2002:370). As urban design practice is increasingly seen as an integral part, or a specialization of, architecture (Loew, 2012:328), and as a small but significant part of urban design research deals with the ‘space shaping nature’ of architecture (Carmona, 2014:4) architectural research methods are considered most appropriate to this investigation of
spatial complexity of urban sites. Secondly, a combined (mixed methods) strategy corresponds to a complexity theory approach, in that a case study approach generates a rich and detailed description both of context and cases. Examining cross-scalar relations between and across objects corresponds to a complexity research approach. Complexity, in this reading, is defined in social sciences terms as ‘interdisciplinary understanding of reality as composed of complex open systems with emergent properties and transformational potential.’ (Byrne, 2005:1997).

Thirdly, a combined (mixed methods) strategy approach as adopted in this study responds to an aim of this research to be relevant to urban design practice. Mixed methods studies are philosophically underpinned by a pragmatic worldview, using pluralistic approaches to derive knowledge about the problem (Creswell, 2009:27). This philosophical paradigm, which is real world problem centred, suits the study of evaluation of spatial complexity of urban sites for urban analysis and design. In deciding to use a mixed methods approach, the fact that although a quantitative approach is considered best to test a theory or explanation (Creswell, 2009:35), the theory of spatial complexity as related and applied in urban analysis and design scales to date is under developed. Therefore, the advantages of qualitative research, including an exploratory nature, can usefully combine with a quantitative approach, as exploration of spatial complexity of urban sites is a new topic, at a scale where existing theories of spatial complexity do not yet apply. A fourth reason to adopt a combined (mixed methods) strategy is as regards usefulness of a mixed methods approach to reducing bias. An advantage in selecting a mixed methods approach is that the bias in any one method could potentially neutralize or cancel the biases of other methods. For example, observation data of pedestrian movement (qualitative data) could reveal limitations of
space syntax axial mapping (quantitative data) of urban sites, leading to richer knowledge generation. In conclusion, a combined (mixed methods) strategy approach is adopted in this study for four reasons: suitability to architecture (urban design) types of research, correspondence to a complexity research approach, responding to an aim of this research to be relevant to urban design practice, and usefulness in reducing bias.

Therefore, the intent of this mixed methods study is to explore and evaluate spatial complexity of urban sites for urban design theory and practice. The first (theoretical) phase (Chapters Two – Four) is a qualitative exploration of the theory of spatial complexity through logical argumentation, employing tactics of textual analysis, and theory development. A deepened theory of spatial complexity (independent variable) is arrived at, one that examines compositional, configurational and systems aspects (dependant variables) of urban sites. These variables (which include qualitative and quantitative features) are arrived at from a review of prior theories and claims in the literature about how these aspects affect cities and urban sites. Findings from the first phase of the study are then used in the second (exploratory) phase (Chapter Five) which tests the explored spatial complexity of the contexts of three urban sites, in order to link the theoretical framing and the practice of evaluating spatial complexity. In the third (evaluation and visualisation) phase (Chapter Six), the theory is tested by the carrying out of evaluations and visualisations of spatial complexity of three urban sites in the context of Dublin.

Four reasons are given for collecting and developing qualitative data initially: firstly, instruments of evaluating spatial complexity are not developed, secondly, variables in understanding spatial complexity of urban sites are not developed or established in the
urban design literature, thirdly, there is little guiding theory, and fourthly, there are few guiding taxonomies of spatial complexity (landscape is an exception, but the scales concentrated on are too large for urban sites). The research methodology adopted includes logical argumentation, historical interpretative analysis, case study approach, simulation and modeling, and visual research methods. The reason to adopt a sequential approach to data collection and research enquiry is that findings from the first (theoretical) phase are used to test a theory of spatial complexity in the later two phases. The reason to adopt a mixed methods approach is in order to capture the dual nature of spatial complexity, as a concept related to both qualitative and quantitative aspects of urban sites.

3.2.3 Operationalising the research question

As part of this research design, the framing of the methodological process of the research leads to operationalising of the research question (see Chapter One, Section 1.3). In this study, the research question asks: ‘how can a combination of complexity theory and urban design theory contribute to an increased exploration and understanding of spatial complexity (composition, configuration and system properties), as well as to development of practical urban design evaluation tools and methods for urban sites?’ To move from the first (theoretical) phase to the second (exploratory) phase of this study, this research question needs to be operationalised, in order to make it empirically testable, in advance of the third (evaluation and visualisation) phase. See Table 3-1.
<table>
<thead>
<tr>
<th>Operationalised Questions</th>
<th>Methodological Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How can a combination of complexity theory, and urban design theory contribute to an increased understanding of spatial complexity (composition, configuration, system) aspects of urban sites?</strong></td>
<td>Focus from complexity to complexity theories of cities (CTC) Define spatial complexity for integrative urban design Define ‘urban site’ Investigate composition, configuration, system definitions Focus on specific ‘aspects of complexity’ : relationality, multiscalarity, temporality</td>
</tr>
<tr>
<td>How can the spatial analysis of urban sites reveal information about the level of spatial complexity in the city? How is this relevant to urban analysis and design?</td>
<td>Devise/use a spatial model of whole city as ‘context’ reflecting specific measures: compositional, configurational, and system</td>
</tr>
<tr>
<td>How can patterns of spatial complexity, (eg. of formal and informal morphology, of spatial integration and segregation, and of simple or complex systems) be established and represented?</td>
<td>Analyse context (global) scale, city wide patterns of: composition (urban structure/form, land use, density), configuration (of local and global integration, choice and intelligibility) and system complexity (patterns, paths, people) (‘4 key features’, Batty, 2007:11)</td>
</tr>
<tr>
<td><strong>How can a combination of complexity theory and urban design theory lead to development of a practical spatial complexity evaluation tool for urban sites?</strong></td>
<td>Study urban site (local) scale composition, configuration, system properties in the field. Consider formal, spatial, social, system, and human aspects.</td>
</tr>
<tr>
<td>What methods may be suitable to use in evaluating levels of spatial complexity of urban sites? What information is it relevant to collect (a) in, and (b) about, urban sites</td>
<td>Combine methods, eg. Digital data assess and record pedestrian movement onsite. Use a sample that is not too limited in order to make comparisons with other urban sites.</td>
</tr>
<tr>
<td>How may the spatial complexity of urban sites be captured? What may be defined as ‘spatially complex’ in a Dublin context?</td>
<td>Investigate graphical and video methods of visual representation of spatial complexity, incl. geo-located video, timelapse, etc</td>
</tr>
<tr>
<td><strong>How is spatial complexity of urban sites understood through comparisons, correlations of composition, configuration and system properties?</strong></td>
<td>Link spatial data to social (desktop) data. Explore and test different compositional, configuration and system indices.</td>
</tr>
<tr>
<td>Which spatial measurements have a high level of significance for intensity or concentration of spatial complexity? Which indicators suit, or need to be weighted, for which urban sites?</td>
<td>Use methods that show how spatial complexity levels are distributed through space at different ‘intensities’ and scales, across urban sites. (descriptive case studies)</td>
</tr>
<tr>
<td>How can uneven spatial complexity conditions (evaluated differently at multiple scales) be evaluated?</td>
<td>Correlate across scales where necessary, qualifying evaluation as less precise with move upwards towards ‘whole city unit’</td>
</tr>
<tr>
<td>How can potential and deficiencies of urban sites be revealed for ‘descriptive’ ‘prescriptive’ and ‘design’ application?</td>
<td>Evaluate one site in each of ‘descriptive’ ‘prescriptive’ and ‘design’ situation, assess usefulness, pros and cons.</td>
</tr>
</tbody>
</table>

Source: Author, (adapted from Legeby, 2013:134)
In summary, three main phases are proposed (see Table 3-1) as the methodological framework in this study. Firstly, a theoretical development phase is needed to distinguish spatial complexity exploration and evaluation requirements for urban analysis and design. Secondly, an exploratory phase is needed to distinguish context from object, and types of relevant urban site. Thirdly, an evaluation phase is needed to apply indices of evaluation to demonstration sites, to test the theory, and describe and compare within, between and across cases.

3.2.4 Theory and this research design

Theory has been defined in scientific (quantitative) terms as ‘a set of interrelated constructs (variables), definitions, and propositions that presents a systematic view of phenomena by specifying relations among variables, with the purpose of explaining natural phenomena’(Kerlinger, 1969:64). This definition covers already established hard-sciences studies of spatial complexity of cities, for example (Hillier, 2008, 2009), (Batty, 2009) although applying to man-made rather than natural phenomena. However, the definition of theory can also be broadened for mixed methods research to include theory as ‘guiding perspective’ (Creswell, 2009:73), the approach adopted in this study. The use of theory in this way is directed by recommendations on how this aspect may be used as a ‘lens’ through which the entire study may be guided (Creswell, 2009:59). In this study a complexity theory lens guides exploration and extension of existing theories of spatial complexity for urban analysis and design of urban sites, as described in Chapter Two (Section 2.2).
The guiding perspective approach adopted means that theory is not only introduced in the start of the research, but also guides the focus of the study, the questions asked, and also conclusions. The theory of spatial complexity in the CTC, urbanism and architecture fields proposes certain variables for those fields (see Chapter Two) so purely deductive research could be appropriate for research in those fields. However, as urban design has not yet developed generally agreed variables within a theory of spatial complexity of urban sites for urban analysis and design, as has happened in landscape for example (Laterra, 2012) (Cushman, 2009, 2016) (Leitão et al, 2012), it was decided that inductive research would also form a part of the adopted research strategy.

Furthermore, as spatial complexity theory encompasses both quantitative (eg. modeling and science of cities, and qualitative aspects (eg. visual/environmental complexity understandings) (Rapoport, 1971), (Relph, 1976), theory is employed in this thesis both deductively, in quantitative testing and verification, as well as inductively, as part of an emerging (qualitative) theory or pattern-related explanation of spatial complexity of urban sites (Creswell, 2009:73). In this respect, pattern theory (Lincoln & Guba, 1985) is relevant, as this contains an interconnected set of concepts and relationships, but does not require causal statements. Complexity theory, the overarching paradigm of this research, also suggests less reliance on causality than other world views. As regards presenting theories, three ways are suggested by Creswell : a series of hypotheses, a series of ‘if-then’ statements, and a visual model, (Creswell, 2009:61) and the last of these is chosen, as this allows clearest communication of variables and interconnections in understanding spatial complexity. In summary, a partly deductive approach within a primarily inductive strategy, with abductive aspects, has been adopted in this research.
3.2.5 Other research design criteria

As well as worldview, strategy and methods, three further criteria for selecting a research design are suggested: the nature of the research problem, the researcher’s personal experience, and the audience for the study (Creswell, 2009:35). The relationships of these criteria to the selected research design are now discussed individually, as part of the description of this research design.

3.2.5.1 The nature of the research problem

The ‘problem’ of this research is a failure to understand the importance of spatial complexity of urban sites, and this problem is of a spatial and urban design research nature, and as such existing theories do not apply, as outlined in Chapter Two. So while theories of spatial complexity have been developed in CTC, urbanism and architecture, and while the cognate (to urban design) field of landscape has generated useful theories of spatial complexity, within urban design (including urban analysis) itself, the theory is under-developed. Urban design research can benefit from an exploratory approach to the research design (Carmona, 2014b:10), and well as descriptive accounts in detail of selected case conditions (Carmona, 2002), and these aspects influence the research design chosen.

3.2.5.2 The researchers personal experience

The personal experience of myself as researcher is related to the selected research design, in that I am aware that previous research and practice in the realm of urban design has combined both quantitative and qualitative approaches. I also have an awareness of the time needed to conduct mixed methods studies in urban design, which tend to be large in scope. In particular, as a mid-career urban designer, with extensive experience of researching, analysing and designing for urban sites, I understand the
benefits of combining the rigid structure of quantitative analysis with the more flexible aspects of qualitative research in one mixed methods research design.

3.2.5.3 The audience for the study

Three audiences are identified for this research: those who seek to describe, prescribe and design in or for urban sites. Firstly, in relation to description of spatial complexity of urban sites for urban design, this means urban designers, spatial planners and architects (and possibly landscape architects) in the main, as the spatial scientists most likely to be guiding\textsuperscript{56} the urban design process. Other urban design researchers, whether for urban design theory and/or practice are also a particular audience for his research in this first category. The second audience identified, in relation to prescription of spatial complexity of urban sites for urban design, enables those prescribing the urban design process and design outputs of others, whether design teams, planning officials, project managers, or clients. The third audience identified is in relation to design uses, which means assisting urban designers, in the making of iterative, projective urban design proposals, by enhancing evaluation methods and guiding urban designers in their core practice of designing\textsuperscript{57}. The most appropriate research design for such a diverse audience includes a pragmatic worldview, and a mixed methods approach. This is because firstly description requires a qualitative as well as quantitative approach (for the first ‘description’ audience), secondly the usefulness to practice in a real-world context must be demonstrated, (for the second ‘prescription’ audience), and thirdly the evaluation methods require a mix of urban analysis methods (for the third, ‘design’ audience).

\textsuperscript{56} In relation to leading or guiding the urban design process, George (1997) suggests a possible ‘second-order approach’, especially in turbulent decision environments, where economic, political, social, and legal factors change and are unstable. Second-order urban design is described as one step removed from the designed object, and the decision environment includes stakeholders, public and private entities equally leading or guiding the generation of more abstract, and therefore more applicable, designs.

\textsuperscript{57} According to Biddulph, as regards thinking ‘about’ or ‘for’ urban design, “if you cannot design, then you are not embracing urban \textit{design as a field}” (Biddulph, 2012:1)
3.3 Specific research methods

From the comparison of alternative research methods above, it is clear that a case study approach is considered to comprise a strategy in some readings, while in other descriptions there is no formal categorization. While certain distinct aspects of the possible research methods described above are relevant to particular elements of the research (e.g. historical interpretative, modeling), from assessing the available research methods, it is clear that case study provides the best method of doing an exploratory and descriptive study of this nature. Case study method is also widely used and recommended for its explanatory power in urban design research (Carmona, 2014:79). For these reasons, a case study approach is adopted. Both quantitative and qualitative elements within the overall case study strategy help to develop exploratory aspects, and others clarify and demonstrate evaluation methods and variables of spatial complexity, thus covering both aims of the research.

3.3.1 Case study

Yin advises that a case study design may be appropriate when: ‘(a) the focus of the study is to answer “how” and “why” questions; (b) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and context’ (Yin, 2003). All of these conditions are relevant to the research design here. In relation to ‘how’ questions, the research question\(^\text{58}\), of how the theoretical concept of spatial complexity can be constituted and operationalised for urban design, is asked through multiple-case study unit analysis, and more specifically, evaluation of urban sites. The (subsidiary) ‘why’

\(^{58}\) The research question of this study is: ‘how can a combination of complexity theory and urban design theory contribute to an increased exploration and understanding of the theoretical concept of spatial complexity (composition, configuration and system properties) for urban analysis and design, as well as to development of practical urban design evaluation tools for urban sites?’ (See Chapter One, Section 1.3.4).
questions include ‘why do different evaluated urban sites manifest distinct and contrasting levels of spatial complexity?’. As regards contextual conditions, the context and case evaluations of spatial complexity described in later chapters are relevant to both the theory and practice aims of this thesis. Lastly, the spatial boundaries of the urban sites measured are multi-scalar and not clear, and the social and spatial overlaps are also complex. In order to respond to theory which considers that observation of change over time in complex systems is key (Foster, 2005) three evolving unit case study sites within a single context of Dublin city are selected for further detail analysis. The benefits of multiple units include the fact that data can be analysed within the units separately (within case analysis) between different units (between case analysis), or across all of the units (cross–case analysis), to better illuminate the cases and context (Yin, 2003). The case study type in this research can be described as being exploratory, in that this type of case study is used to explore those situations in which the intervention being evaluated has no clear, single set of outcomes (Yin, 2003). Also there will be a partly descriptive element of the case studies, in the sense that this type of case study is used to describe an intervention or phenomenon and the real-life context in which it occurred (Yin, 2003). The multiple case study design will be instrumental, in that this type of case study approach is used ‘to accomplish something other than understanding a particular situation. The case helps the researcher pursue the external interest’ (Stake, 1995). In this thesis, the instrumental aspect of the situations of the multiple units is useful for demonstrating phenomena related to spatial complexity.

\footnote{Stake further elaborates: ‘It provides insight into an issue or helps to refine a theory. The case is of secondary interest; it plays a supportive role, facilitating our understanding of something else. The case is often looked at in depth, its contexts scrutinized, its ordinary activities detailed, and because it helps the researcher pursue the external interest. The case may or may not be seen as typical of other cases. Its contexts are scrutinized, its ordinary activities detailed, because it helps the researcher pursue the external interest. (Stake, 1995)}
which also occur in urban sites elsewhere. The external interest being pursued in this thesis is a theory of spatial complexity for urban design.

3.3.2 This case study design

Five components are considered key to a good case study research design (Yin, 2003:21). Three are related to the data to be collected: a study’s questions, its propositions, if any, and its units of analysis. A further two components are related to how to proceed after data has been collected: the logic linking the data to the propositions, and the criteria for interpreting the findings (Yin, 2003:21). The approach of this research design to these components is outlined in Figure 3-2. Briefly, the research question as outlined in Chapter One, is a ‘how’ question, a type of question considered appropriate to a case study research strategy (Yin, 2003:22). Propositions are considered less likely in exploratory cases, but in this research a core proposition is stated, in order to address the primarily quantitative aspects of the research question (ie. evaluation). The major proposition of the research (as stated in Chapter One, Section 1.3.3, The Research Hypothesis) is that evaluated levels of spatial complexity in urban sites depend on compositional, configurational and system properties.

In this study, and having stated the major proposition, the following three detailed propositions can be specified, based on previous complexity theories of cities and urban design theory:

Evaluated levels of compositional complexity of urban sites depend on three factors (criteria): urban form characteristics (Salat, 2011), sufficient land-use mix (Van Den Hoek, 2009) and optimal urban density (Berghauser Pont, 2010)
Evaluated levels of configurational complexity of urban sites depend on three factors (criteria): integration (Hillier, 1998, 1999) (Bafna, 2003:616), choice (Krafta, 1997) (Marcus, 2015) and intelligibility (Hillier, 2005)

Evaluated levels of system complexity of urban sites depend on three factors (criteria): street (pattern) network complexity (Marshall, 2005), path network complexity (Wei, 2015) (Peponis et al, 2008), (Ellis et al, 2016), and pedestrian movement network complexity (Ewing et al, 2009)

The implication of the main proposition is that evaluated levels of spatial complexity of urban sites can be derived from combining evaluations of compositional, configurational and system properties. The weighting aspects of this are dealt with in Section 7.2.4.

Figure 3-2 PhD Study Propositions Chart

The reason to state these propositions clearly in advance of data collection is so that they can form the structure of the case study report. Baxter provides three options for the structure of the case study report: telling a story, a chronological account, and
returning to the propositions (Baxter, 2008:555). The last of these, a return to the initial propositions, is the chosen method in this study, as it develops the theoretical aspects of the research question most clearly.

In exploratory cases, unlike other case types, a purpose of the study is recommended to be stated in advance (Yin, 2003:22). In this study the purpose is to define and operationalise the concept of spatial complexity for urban design theory and practice. The reason to have a clear stated purpose in advance of data collection is so that the purpose can be referred to for criteria by which the study will be judged successful (Yin, 2003:22). In this case, the two assessment criteria are:

Does the study define the concept of spatial complexity for urban design theory and practice?

Does the study operationalise the concept of spatial complexity for urban design theory and practice?

In relation to selected units of analysis, the ‘urban site’ is the chosen unit, that is, an urban area roughly equating to neighbourhood size. Clear definitional boundaries are advised in specifying the unit, and previous authors in compositional analysis (Carmona, 2010:305), configurational (Hillier, 1993) and system (Healey, 2007) analysis have examined the urban site as an analysis unit. In the case of composition, Carmona discusses the urban ‘site’ of urban design as a spatial unit for understanding the extent of possible design intervention. ‘Site’ is also a common description of a land unit in architectural, landscape and urban design disciplines. In configurational analysis, Hillier analyses the King’s Cross site in London as a recognizable unit of the city for analysis and redevelopment (Hillier, 1993). In spatial systems analysis, Healey defines
relational concepts of spatial planning partly through consideration of ‘places’ and sites (Healey, 2007:3). The designation ‘urban site’ is selected as a definitional unit, rather than the allied concept of ‘neighbourhood’ because spatial definition of the latter unit is more ambiguous (Jencks, Dempsey, 2007:153), more associated with planning (Perry, 1929) and bound up with particular urban design theories (Moughtin, 2003) and definitions (Rogers, 1999), whereas urban sites are considered here as primarily spatial units. The term urban ‘centre’ was also ruled out as a case description term, as the concept of centrality has a specific and sometimes contested meanings in the geography (Christaller, 1972) and spatial sciences literatures (Van Nes, 2007) and has a more specific planning disciplinary focus than this study, which concentrates on urban design. In conclusion, as regards defining what is to be included within the meaning of ‘urban site’, this study is primarily concerned with compositional, configurational and system aspects of these spatial units of analysis.

Specific time boundaries are recommended for binding of cases and definition of units of analysis (Stake, 1995) (Yin, 2003), and in this study, although the years 1988-2008 are important in considering spatial change in Ireland (as discussed briefly in Chapter One) the time boundary of the cases is the ‘static’ and only current manifestation of the urban sites as evaluated (in 2014-15).

Yin also advises that there should be no idiosyncracies in key definitions (Yin, 2003:26). The concept of the urban site is clarified above, and in the case of the core topic, spatial complexity, previous researchers around the field of urban design have defined the concept for CTC (Batty, Hillier) landscape (Laterra, Cushman), architecture
(Venturi, Dai) urbanism and urban design (Krafka, 2007:2) (Haghani, 2009:293) so this research is comparable with previous research in the relevant literatures.

The further two components of a good case study research design are related to how to proceed after data has been collected: the logic linking the data to the propositions, and the criteria for interpreting the findings (Yin, 2003:21). In this study, the logic linking the data to the propositions includes three of Yin’s suggested five possible analysis techniques: pattern matching, explanation building, and cross-case synthesis (Yin, 2003:115). These techniques are useful in developing internal validity and external validity associated with case studies (Yin, 2003:115), and are returned to in more detail in the next section. The final component a good case study research design, setting out the criteria for interpreting the findings, has been addressed above.
3.3.3 Type of cases

In this research, exploratory aspects of the case studies can uncover information about different ‘issues’ or variables which influence evaluated levels of spatial complexity. Weighting of the variables in an exploratory fashion also helps to develop urban design specific focus of aspects of spatial complexity of urban sites. Therefore, an ‘exploratory’ case study approach is adopted in this research.

It is argued in this thesis that the theories of spatial complexity related to urban analysis and design are not established (Chapter One), and it was demonstrated in Chapter Two that the extent of tools and methods for evaluation of spatial complexity for urban analysis and design are not well developed or proven in previous urban design research. Furthermore, as a complete description of a phenomenon as encompassing as spatial complexity is beyond the scope of this research, it would be difficult to ensure that a complete description has been provided at the conclusion of this research. An ‘explanatory’ case study is described as ‘presenting data bearing on cause-effect relationships- explaining how events happened’ (Yin, 2003b:5). In this study, there is no ‘program implementation’ as such, and no definitive way to judge effects. Also, in relation to causal effects, and as argued in Chapter Two (2.1) it is suggested in the complexity literature that: ‘we will do far better if we think about causal processes which are neither linear nor indeterminate, but are instead complex’ (Byrne, 1997: 49).

In this thesis it is argued that this proposal to treat causality with caution can be

---

60 Yin’s definition of ‘exploratory’ case study: ‘is aimed at defining the questions and hypotheses of a subsequent study (not necessarily a case study) or at determining the feasibility of the desired research procedures’ (Yin, 2003:5). It is considered justifiable where the goal is to ‘to discover theory by directly observing a social phenomenon in its raw form (Glaser & Strauss, 1967)’ (Yin, 2003b:6). The exploratory case study type has been considered ‘a prelude to other social research, not just to other case studies’ (Yin, 2003b:6). This is in contrast to a purely ‘descriptive’ case study design, which presents a complete description of a phenomenon in its context.

61 A further description of the explanatory case describes it as answering a question that seeks to: ‘explain the presumed causal links in real-life interventions that are too complex for the questionnaire/survey or experimental strategies. In evaluation language, the explanations would link program implementation with program effects’. (Baxter, from Yin, 2003)
extended to the spatial sciences, and especially for this thesis, to the exploration and evaluation of spatial complexity for urban analysis and design. Although this thesis involves retrospective cases, where past events are related to current circumstances, direct causal inferences are not made, as the influencing factors are too numerous, and contested.

In conclusion, this thesis involves an ‘exploratory’ case study approach, as this encompasses exploration of theory, and a partly ‘descriptive’ evaluation of three particular cases, without extending to full description of all complex urban sites. Yin points out that descriptive studies typically fail to specify a priori the critical ingredients of the phenomenon to be described (Yin, 2003b:25), so the next Chapter concentrates on describing the components of spatial complexity to be considered and evaluated in this research.

### 3.3.4 Number of cases

This section outlines the options considered and the detail decisions taken in this study as regards numbers of cases to choose in the case study research design. In this study, while Dublin is considered as an appropriate background to an investigation of spatial complexity (See Chapter Five, Section 5.2) many potential units of study were examined within the background context for this exploratory case study approach. The literature on case study unit selection has no clear recommendations of numbers of cases which it is appropriate to select. For example, it is suggested that the ‘individuality or specificity of a single case can be either lost in the multiplicity of cases, or its significance overstated’ (Mc Farlane, 2010). In this thesis, the objects of study are multiple urban sites within the context of the spatially complex unit of the city of Dublin. Five types of ‘unit’ of case study were considered as options. There were,
firstly, in a single case research design approach: a single ‘holistic’ case (1), a single case study unit with multiple embedded subunits (4), a single case study unit with multiple embedded subunits (7), and in multiple-case research design approach: multiple-case study units (6), and the selected design, multiple-case study units (3).62

As the selection of a multiple case study unit structure has impacts on the further selection of research strategies, tactics and techniques, a discussion of the selected option is outlined in more detail here. The selected option involves three conventionally understood large units of urban design (a character area, an urban centre, a future neighbourhood). In this multiple-case research design, three geographically separate evaluation case study units within three exploratory contexts against the overall background of the city of Dublin emphasises a multi-scalar complexity frame as structure for the study. This decision also concentrates the focus into a small and manageable number, of three urban sites. As noted above, the number of case study units to select is undecided in the case study literature. Three case study units are chosen for a pair of reasons. Firstly, in order to consider themes of temporal progression, and secondly, in order to clearly demonstrate contrasting results of high, medium and low evaluated levels of spatial complexity of urban sites. As regards the first reason for example, more historic cases could manifest results of high evaluated spatial complexity which had emerged over time, whereas recently developed areas could be shown to have lower evaluated levels, within an overall background of the ‘whole city unit’ of Dublin. The aim is to show, by chronological progression through the three units, from historical, present and future urban site types, how a theoretical replication approach (defined as a case study that produces contrasting results but for

62 A longer textual description of the definitions, advantages and disadvantages of each option, considered as a demonstration of the exploratory nature of this study of spatial complexity for urban analysis and design, is part of Volume Two, Appendix H, ‘Case study research design options’.
predictable reasons) to each case in turn, can show how evaluated results of analysis demonstrate contrasting results, but for predictable reasons in each case, which may relate to history for example. In complexity terms, the ‘linkages’ between the cases are considered to be as important as the individual cases, so these linkages also are a feature of the individual and multiple case study reports.

This study expands and develops theories of spatial complexity for urban analysis and design by demonstrating firstly that spatial complexity can be explored in contexts of precise units of study, and secondly by demonstrating that spatial complexity can be evaluated through an integrative process combining compositional (morphological) configurational (space syntactical) and system aspects of urban sites. It is not intended to predict the same results in the evaluation of spatial complexity for urban sites across cases (a literal replication), but it is of interest to predict contrasting results for predictable reasons (a theoretical replication) across different themes of scale, time geography, or policy. For example, comparing multiple cases could predict contrasting levels of spatial complexity in a between-case analysis because of different urban site size (scale), different historical path dependancies (time), different topography or urban densities (geography), or a lack of urban design frameworks in some cases but not others (policy). As regards the second reason to select three cases, in describing contrasting results, (and as described in Section 3.3.8, Weighting of findings) it is decided to confine the final quantification of evaluation to three evaluated levels of spatial complexity: high, medium and low.

In this study, exploration of spatial complexity is limited to the scales of urban design, and an important argument of this study is that criteria for evaluating spatial complexity
in future studies may vary depending on composition, configuration, and system properties of each urban site. For example, a factor of importance (in the consideration of spatial complexity for urban analysis and design) in the Liberties area of central Dublin is the historical urban prominence of compositional qualities at this site in overall Dublin terms. A factor of importance in Ballymun is the configurational properties of this New Town, especially as it relates to surrounding neighbourhoods. A factor of importance for Sandyford is the system nature of the site, particularly in relation to its planning designation as a regional hub for future development. Deciding on three exploratory contexts and three evaluation cases also allows emphasis on the importance of linkage between units in complexity terms, as discussed later in this Chapter. In this regard, it is considered that ‘every case should serve a specific purpose within the overall scope of enquiry’ (Yin, 2003a) and this study complies with this requirement for a robust research design.

3.3.4 Theory and the cases

As already described in Chapter Two, (Section 2.2.5) since the first significant association of organised complexity with life and design in cities (Jacobs, 1961), numerous synthesizing theories of urban design (Hillier & Hanson 1984, Alexander 1987, Salingaros, 2005, Shane, 200563) have considered complexity to be an important component of urban design. In very broad terms, urban design seeks complexity as an attribute of ‘optimal’ designed urban environments, which brings many benefits. Optimisation in these terms has been described in one account as optimal perceptual

---

richness, functional capacity, and ‘synergy’, or heterogeneity, whereby ‘a whole entity is judged to be greater than the sum of its parts, seen as qualities of a complex object or system’ (Marshall, 2012a: 192). In order to operationalise this theoretical matrix, research outputs by twelve selected authors associated with ‘spatial’ or urbanism understandings of complexity were reviewed for the Urban Design Complexity Classification Table set out below (Table 3-2). In terms of urban sustainability and quality for example, Salat argues that the complexity of the urban structure of cities has a direct impact on urban structural efficiency and resilience (Salat and Bourdic, 2012: 26) and that complexity classification criteria could include quantification of urban form complexity. However, no clear classification system of evaluated spatial complexity for urban analysis and design appears in the literature. In summary, while there are often mixed methods approaches to theory and research in this area of urban design, quantitative and qualitative criteria vary and there is currently no one agreed upon set of complexity classification criteria for urban sites.
As regards prior existing theories of spatial complexity, and as outlined in Chapter Two⁶⁴, previous researchers around the field of urban design have discussed the concept for complexity theories of cities (CTC), landscape, architecture, urbanism and importantly, urban design (Krafta, 1999:2),(Haghani, 2010:293). As a result, this research is comparable with previous research in the relevant literatures, although a

---

**Table 3-2. Urban Design Complexity Classification Criteria Table**

<table>
<thead>
<tr>
<th>Author</th>
<th>Discipline/Field (exact definition)</th>
<th>Relevant Complexity Classification Criteria of author</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Jacobs, 1961)</td>
<td>Urban Design ‘organised complexity’</td>
<td>Diversity: (small blocks, mix of primary uses, aged buildings and concentrations of people)</td>
</tr>
<tr>
<td>(Montgomery, 1998)</td>
<td>Urban Design ‘the city is a phenomenon of structured complexity’</td>
<td>(Three ‘principles’: Activity (vitality and diversity), Image, Form and “12 physical conditions”)</td>
</tr>
<tr>
<td>(Hillier, 1998a, 1998b)</td>
<td>Space Syntax (‘spatial complexity’, ‘physical complexity’)</td>
<td>Configurational complexity, integration, choice, intelligibility</td>
</tr>
<tr>
<td>(Salingaros, 2000)</td>
<td>Urban Design ‘complexity and urban coherence’</td>
<td>‘the complexity of a coherent (urban?) system is proportional to its size’ (Pg 309) Size, fractal relations, etc</td>
</tr>
<tr>
<td>(Marshall, 2005)</td>
<td>Urban Design ‘street network complexity’</td>
<td>‘no. of routes present less value of max. depth’ (Pg 148)</td>
</tr>
<tr>
<td>(Ewing &amp; Handy, 2009)</td>
<td>Urban Design ‘complexity’ (a ‘subjective measure of urban form’)</td>
<td>‘Significant physical features observed: people, buildings, colours, outdoor dining, public art’ (Ewing, 2009:72)</td>
</tr>
<tr>
<td>(Batty, 2011a:3, 2011b:4)</td>
<td>CTC * ‘spatial complexity’ *Complexity theories of cities</td>
<td>evidence of ‘scaling, self-similarity and fractals’ (Batty, 2011:?)</td>
</tr>
<tr>
<td>(Salat, 2011)</td>
<td>Urban Design ‘urban form complexity’</td>
<td>(a) Analysis power law distribution streets (b) Geometric analysis urban block passive volume ratio</td>
</tr>
<tr>
<td>(Marshall, 2012:198)</td>
<td>CTC * Planning / Urban Design</td>
<td>‘four types of organised complexity: artefactual, biological, ecological, system’</td>
</tr>
</tbody>
</table>

---

⁶⁴ See Chapter Two, Section 2.1.2, ‘Complexity, design, and cities’.

135
primary aim of this research is to introduce a spatial complexity frame more fully to the theoretical discourse on urban design. In this study, following the literature review and assessment of existing theories of spatial complexity, three rival theoretic patterns, portrayed as alternative scenarios, are briefly described here:

High levels of evaluated spatial complexity are associated with high levels of compositional, configurational and system complexity.

Medium levels of evaluated spatial complexity are associated with medium levels of compositional, configurational and system complexity.

Low levels of evaluated spatial complexity are associated with low levels of compositional, configurational and system complexity.

A further proposition, related to synthesizing the outputs of separate evaluations of urban sites, can also be set out as part of this section on the relationship of theory to the cases. The proposition is that optimal spatial complexity is a relative value, both in terms of high and low evaluated levels, but also spatially related to the centrality or spatial hierarchical structure within which the urban site is contained. Gell-Mann’s claim that: ‘It is probably safe to say that any measure of complexity is most useful for comparisons between things at least one of which has high complexity by that measure’ (Gell-Mann, 1995:2) encapsulates the complexity theory perspective on the issue. This would correspond to Salingaros’s (1997:3) claim about the relative nature of complexity of design in architecture, and to Bachman’s four distinct ‘modes of complexity’ (Bachman, 2012:24) as discussed in Chapter Two. The review of the literature for this study discusses prior theories of each of compositional, configurational and system
complexity separately (in Chapter Four), before combining these under an integrative frame of spatial complexity of urban sites. The statements above serve as the detailed and prior development of the rival theoretic patterns, portrayed as alternative scenarios, in advance of data collection and analysis. The review of these scenarios (or descriptive theories) is the theory-generated background against which the actual data will be compared in the findings and discussion section of this study.

3.3.5 Replication logic of cases

As regards multiple-case design, the choice of number and type of case should reveal distinct and contrasting conditions, for comparison purposes (Yin, 2003b:25). Multiple cases, in this respect are treated like multiple experiments in scientific experimental research, whereby ‘analytical generalization’ applies (Yin, 2003b:32), in which a previously developed theory is used as a template with which to compare the empirical results of the case study. If two or more cases are shown to support the same theory, replication may be claimed. If two or more cases support the same theory but do not support an equally plausible rival theory, then the empirical results are considered even more potent (Yin, 2003b:33). In a replication logic approach, each case serves as a distinct experiment that stands on its own as an analytic unit, while ‘like a series of related laboratory experiments, multiple cases are discrete experiments that serve as replications, contrasts, and extensions to the emerging theory’ (Eisenhart, 2007:25). In this research, the contrasting nature of the cases is key to developing a theory of variations in evaluated levels of spatial complexity of urban sites. Development of ‘idealized’ descriptive scenarios is recommended for descriptive case studies in advance

---

65 In Yin’s example ‘the case study analysis followed a pattern-matching procedure’ (Yin, 2003b: 23, Box 5) between cases, and ‘the case study design, even for a descriptive study, followed a replication logic’ (Yin, 2003b: 23).
of data collection, to specify *apriori* the critical ingredients of the phenomenon to be described\textsuperscript{66}.

In conclusion, the three case study sites are seen in this study as exploratory cases, which follow a theory explored in the literature review stage of the research, and during particular research design stages, such as development of descriptive scenarios (Yin, 2003b:25) as set out in Section 3.3.4 above. In terms of the resulting descriptive analysis, theoretical replication\textsuperscript{67} following prediction is adopted in this thesis. In summary, the second section has described the specific research methods adopted, including case study, the overall methodological approach.

### 3.4 Data collection

Three options are suggested for data collection: sequential, transformative or concurrent (Cresswell, 2009: 120). In a sequential data collection approach, findings from the first qualitative and exploratory (theoretical) phase could be used to test a theory of spatial complexity in the later two phases. However, although qualitative data is generated in the primary phase of this research related to theory and conceptual framework definition, this is not the core of the overall study, so this approach is not selected. In a transformative mixed methods research design and data collection approach, primacy is given to value-based, action-orientated research, aspects which are not directly related to the aims or objectives of this study. A 'concurrent mixed methods’ strategy of inquiry (Cresswell, 2009: 31) is one in which the researcher converges or merges quantitative and qualitative data in order to provide a comprehensive analysis of the research

\textsuperscript{66} In the cases Yin cites, the descriptive scenarios ‘were intended to recapture the essence of what constituted’ one or other of the (two) ‘systems’ being studied (Yin, 2003b:26).

\textsuperscript{67} *A theoretical* replication is defined as a case study that produces contrasting results but for predictable reasons (Groat, Wang, 2002:357), as further described in Section 3.4.7 of this Chapter.
problem (Creswell, 2009:31). Both forms of data are collected at the same time, and the advantages of a concurrent approach include the potential to embed a smaller form of data within a larger data collection in order to analyse different types of questions (eg. the qualitative addresses the process, and the quantitative the outcome). This concurrent mixed methods data collection approach has been selected over the other two options (sequential or transformative) (Cresswell, 2009: 120). Described as a concurrent triangulation strategy (Cresswell, 2009: 193), this allows comparison and triangulation of results from both qualitative and quantitative data to be compared after data collection, in the data analysis stage. The data are compared in order to discern whether there is convergence, difference, or some combination. In this study, the quantitative data is seen as predominant, while the amount of qualitative data, though less, helps to provide an overall comprehensive assessment of the research problem.

3.4.1 Data analysis

Following a consideration of options in the research design literature (Creswell, 2009:200), (Yin, 2003a) a total of six selected (four ‘evaluatory’ and two ‘exploratory’) data analysis procedures are outlined here. In general data analytical strategy terms, Yin suggests three possibilities: relying on theoretical propositions (‘follow the propostions that led you to your case study), thinking about rival explanations, (try to define and test rival explanations) and developing a case description (Yin, 2003a:113). Of these options, the selected approach is to mainly rely on the theoretical propositions inherent in the research question (that evaluated levels of spatial complexity are related to compositional, configurational and system aspects). However, Yin also describes a sample case analysing complexity which benefited from a rich case description, so the strategy will also include detail description of the multiple cases. This includes for
example, a historical interpretative and urban morphological analysis (text report) account of the case sites. So the reliance on theoretical propositions in analysing the exploratory cases will also contain descriptive elements.

Four selected ‘evaluatory’ data analysis procedures are identified in this research design, following from the research strategy. Certain concurrent data analysis and validation procedures are suggested for concurrent data collection using mixed methods (Creswell, 2009:200). These are:

**Data transformation** (Creswell, 2009:200): quantification of qualitative data (eg. periodization in morphological analysis, numbering plan complexes in urban form analysis, and quantifying pedestrian observation data), or vice-versa. In this case, qualification of quantitative data involves interpretation of mathematical measures of spatial complexity (for example ‘integration’), broadening descriptions into high, medium or low.

**Instrument development** (Creswell, 2009:200): this involves developing themes in the early stage analysis of urban sites which may form the evaluation instrument in a later stage of data collection. So, for example, from the urban morphological analysis (qualitative) of an urban site, a geometrical analysis of urban blocks and plots emerges as relevant to an evaluation tool. Also, development of compositional instruments can concurrently direct the questions for the configurational and systems related data gathering.

**Examining multiple levels** (Creswell, 2009:200): in this procedure, within the concurrent mixed methods model, a quantitative survey of an urban site is
undertaken at one scale (level), while at the same time more qualitative data is being collected at another level, for example in one street.

**Matrix preparation** (Creswell, 2009:200): A matrix is recommended in data analysis for comparison of quantitative and qualitative data. In this research, the evaluation tool takes the form of a matrix.

The reasons for selecting these four data analysis procedures are as follows: data transformation enables comparison between the quantitative and qualitative data. Instrument development focuses questions of other thematic strands in the research towards the main question. In this study, the thematic strands are the compositional, configurational and system properties of urban sites. Examining multiple levels involves collecting data about one scale of urban sites (eg. street network complexity), but also concurrently collecting data about another ‘level’ or scale, (eg. individual pedestrian observation). A matrix adds a visual communication element to data analysis, thus clarifying relations between variables. These four data analysis procedures are included in this research design, as they improve the robustness of the data collected (Creswell, 2009:200).

As part of the reliance on theoretical propositions in analysing the exploratory cases, two of Yin’s five suggested techniques for data analysis (Yin, 2003a) are also employed to some degree as part of this research design, and are used in this study as ‘exploratory’ data analysis techniques. The distinction between the four ‘evaluatory’ techniques described above and these two ‘exploratory’ techniques can be seen as the distinction between more quantitative (the former) and more qualitative (the later) analysis. Yin’s five suggested techniques for data analysis are: pattern matching, explanation building,
time-series analysis, logic models, and cross-case synthesis. Logic models and time-series analysis do not apply, as the time boundary of the cases has been restricted to a contemporary ‘static’ evaluation of the urban sites. Explanation building involves iterative theory building, whereby theoretical positions are revised, and is mainly beyond the scope of the research question of this study, which seeks primarily to be useful for urban analysis and design.

The first of the two selected techniques for data analysis, pattern matching, is now described. A pattern in research design terms is defined as ‘any consistent and characteristic form that is by definition non-random and potentially describable’ (Cao, 2007:447) and pattern matching is defined as ‘to compare an empirically based pattern—the “pragmatic reality”, with theoretical patterns—the “theoretical ideals”, or “systemic patterns”’ (Cao, 2007:447). Pattern ‘theories’ (Lincoln & Guba, 1985) are defined as explanations that develop during naturalistic or qualitative research. Of three pattern matching ‘logics’ or techniques presented by Yin (alongside ‘rival explanations’, and ‘simpler patterns’) (Yin, 2003a:116) one is selected for this research design: ‘non-equivalent dependent variable as a pattern’. This technique is described as one which can be used in quasi-experimental research designs, whereby: ‘the quasi-experiment may have multiple dependent variables- that is, a variety of outcomes. If, for each outcome, the initially predicted values have been found, and at the same time alternative ‘patterns’ of predicted values (including those deriving from methodological artifacts, or ‘threats’ to validity) have not been found, strong causal inferences can be made’ (Yin, 2003a:116). Hak et al further define the strength of ‘non-equivalent dependent variables design’, working from (Cook &Campbell, 1987) as: ‘the variables
that constitute the pattern or configuration are non-equivalent, i.e., not substitutable’ (Hak, et al, 2009).

The second of the two selected techniques for data analysis, cross-case synthesis, is now described. Cross-case synthesis as a technique applies specifically to the analysis of multiple cases, and is one reason findings can be more robust that only selecting a single case. In this approach, each case must be treated as a separate study, and findings are aggregated across the cases. Yin’s suggestion of creating ‘word tables’ to display data from across the cases according to some uniform framework (Yin, 2003b:134) is employed in the Databox and Toolbox approaches described later, in Chapter Four, Section 4.5. An argumentative interpretation is part of this approach (Yin, 2003b:137), and strong, plausible and fair arguments that are supported by the data are developed in the discussion and findings section of this study.

Use of these last two selected techniques for data analysis is particularly useful in developing internal validity and external validity associated with case studies. A return to the propositions in the final discussion and findings text also allows a focused analysis of the data within the scope of the research. Also, by returning to this process the confidence in the ultimate findings can be verified. In conclusion, the selected overall data analysis approach is to mainly rely on the theoretical propositions inherent in the research question (that evaluated levels of spatial complexity are related to compositional, configurational and system aspects). Within this approach, six data analysis techniques are employed in this study: data transformation, instrument development, examining multiple levels, matrix preparation, pattern matching and cross-case synthesis.
3.4.2 Representation of findings

This study integrates three distinct approaches to study of urban phenomena – compositional analysis (Marshall, 2005), space syntax analysis (Hillier, 1984), and spatial system analysis (Wilson, 2000), aiming at better understanding and description, through exploration and evaluation of spatial complexity of urban sites. Two spatial levels or scales are concentrated on: the case context and the case, (at the scale of the urban site), all against the background of the whole city unit of Dublin. Representation protocols and standards are established in each of the distinct approaches, and different scalar resolutions and emphases can apply depending on the research question. For example, while urban compositional analysis tends towards a local and three dimensional focus, space syntax has a multi-scalar approach to the urban environment, while spatial systems analysis can span across an entire developed region. Therefore integrative representation and visualisation of results have a central role in the study.

3.4.3 Weighting of findings

In a mixed methods study, qualitative and quantitative data can be either equally emphasized, or weighted towards one type of data, in collection, analysis and interpretation. As the concept of spatial complexity is considered to encompass both qualitative and quantitative aspects, the weighting in this study will be even across both datasets. Equal weightings are recommended for most mixed methods studies (Creswell, 2009:195) and often quantitative results appear first, followed by qualitative results that support or disconfirm the quantitative results. In this study, as the qualitative results are sometimes embedded within quantitative categories of indicators, (eg. morphological analysis within compositional complexity analysis, and pedestrian observation within system analysis) results of both data are compared after a category of
indicator data has been presented in full, in a concurrent embedded strategy (Creswell, 2009:197). As the final evaluations in this study provide flexible values and not fixed numbers (Gil, Duarte, 2013) all three issues of spatial complexity, as well as each of three criteria within each issue, are considered to have equal value in weighting terms. The indicators of evaluated spatial complexity, arrived at by testing the urban sites under three criteria for each issue, are of only three types: low, medium and high.

3.4.3 Interpretation of findings, and conclusions

In reporting on studies using concurrent mixed methods research designs, it is recommended that analysis and interpretation combines the quantitative and qualitative data in order to seek convergence or similarities among the results (Creswell, 2009:201). The structure of this type of study does not make a clear distinction between the quantitative and qualitative phases. In this case study research design, the matrix format is the location of the combination of data, and visualisation techniques related to a Toolbox and a Databox (introduced in the next Chapter) enhance data analysis and interpretation.

In this respect, Yin (Yin, 2003b:137) proposes that there are four principles underlying all good social sciences research, and which can demonstrate a high quality analysis. These are, firstly, attending to all the evidence, secondly, addressing all major rival explanations, thirdly, addressing the most significant aspect of the case study, and lastly, use of the researchers prior, expert knowledge in the case studies. In the case of multiple cases, the most significant aspect of each case is concentrated on in this research. These four principles are returned to in Chapter Seven, and it is demonstrated that each of these principles has been applied.
In relation to criteria for judging quality of case study research designs, four tests are suggested for establishing quality in case study research: construct validity, internal validity, external validity and reliability (Yin, 2003b:33). Construct validity is tested by success in establishing correct operational measures for the concepts being studied. In this study, operational measures adopted include using multiple sources of data, and establishing a chain of evidence. Each of these is reported on in the findings section of the study. Internal validity is established in this study by use of pattern matching in the data analysis stage. External validity, which involves establishing the domain to which a study’s findings can be generalized, is demonstrated through use of replication logic in the multiple cases, each of which relate data gathered to urban analysis of urban sites for urban analysis and design. Establishing reliability of the study, in this study, includes the use of case study protocols for each of the nine methods of analysis and measurement proposed. The protocols are implemented in the data collection phase, and a case study database is compiled for each case, which further enhances reliability by minimizing errors and biases in the study. To summarise, in this third section about the selected research design, concurrent triangulation data collection strategy is proposed, and six data analysis techniques employed in this study are described: data transformation, instrument development, examining multiple levels, matrix preparation, pattern matching and cross-case synthesis.
3.5 Comparative and correlational research approach

Having described the overall research design, and then the research method chosen, (a case study approach using mixed methods), this section outlines two key aspects of the further development of the research design adopted in this thesis. These are: firstly, a consideration of a comparative research approach to the multiple cases, and secondly, an outline of the relevant aspects of a correlational research approach to detail evaluation in this study.

3.5.1 Comparative research approach

Comparative research has been defined for urbanism as: ‘the systematic study of similarity and difference among cities or urban processes. It addresses descriptive and explanatory questions about the extent and manner of similarity and difference.’ (Nijman, 2007:1). Mc Farlane (2010) considers that a comparative research methodology is driven by particular research objectives and deployed for a variety of possible reasons, and he cites four of these: ‘in order to fill a gap in understanding; to reveal the distinctiveness of a case; to place a case in a broader context; or to reveal the generality or particularity of a process or theme’ (Mc Farlane, 2010:730). In relation to geography, time and comparative research, Harootunian (2005) considers that time has receded from historical and social analysis, to be replaced by spatial divisioning into units and categories, and suggests this has negative consequences for comparative study. In geography, Soja argued that time has traditionally dominated in accounts of places, to the exclusion of space (Soja, 1989:2). As regards a theme of this thesis research, that of scale and relations between resolution, comparison, and methodology, DeLanda (2011) (complexity, philosophy) and others (Brenner, 2009) (critical urban theory) have discussed the primacy of understanding a researcher’s decisions on
‘boundedness’ (which requires scalar decisions), in order to investigate phenomena thoroughly. By this decision-making process (what to include, where boundaries are ‘drawn’, which patterns are sought at which scales) conscious bias is evident, but also acceptance into agreed or commonly used categorisations of other researchers in the same field. In this research, the case study approach is of an ‘exploratory’ and ‘descriptive’ nature, for urban design (composition, configuration, systems). As selected, the types and categorisations of the case units (in a historic neighbourhood, a ‘New Town’, and a Regional ‘Hub’) reflect an exploratory approach and range across time, scale and geography. By consciously positioning this research at the disciplinary intersection of complexity framings and spatial/urban design and analysis understandings, commonly accepted sets of scalar categorisations in some disciplinary fields (whole city unit/science of cities, region-urban unit/geography, neighbourhood unit, ‘public space’ focus/urban design) are challenged, in order to extend both exploration and evaluation theory for urban analysis and design. In this research, after many interim iterations of scalar definition, it is decided to fix the spatial definition of the three case units at a broadly comparable size. This means, for example that approximate population densities, land coverage and urban form composition indices can be directly compared within, between and across cases. Therefore, in describing and reporting on these units, a more exploratory approach is adopted, including comparisons of evaluated issues in each site. In summary, following consideration of the advantages and disadvantages, it is decided to adopt a comparative research approach in relation to the analysis of the contexts and issues of the case units in this research, but to adopt a more descriptive approach, including a focus on correlations across criteria and indicators, for the analysis of the case units. In this way, both exploration and evaluation requirements of the research question are addressed, and useful observations
can be made across case contexts as well as within, between and across three distinct and contrasting urban sites.

3.5.2 Correlational research aspects of this research

Correlation studies are associated with quantitative research strategies of inquiry (Creswell, 2009:29). In correlational research, each study (case) seeks ‘to clarify patterns of relationships between two or more variables, ie. factors involved in the circumstances under study’ (Groat, Wang, 2002:206). The correlational research strategy has general characteristics, combining: ‘a focus on naturally occurring patterns, the measurement of specific variables, and the use of statistics to clarify patterns of relationships’ (Groat, Wang, 2002:206). In a prominent example for urban analysis and studies, Whyte charted urban plaza use in New York as a function of certain physical variables, leading to the identification of several key design elements in the spaces which affected public life and use (Whyte et al, 1980). After the advantages and disadvantages of a correlational study were examined for this research, it was decided that correlational study suits the observation of patterns across criteria and indicators of spatial complexity of urban sites (but not issues of spatial complexity, which are more related to comparative, qualitative study). In this research, correlational analysis is therefore undertaken following the results of the evaluations of the cases. The reason for this research design decision is now briefly outlined. The three case units chosen, all described here as ‘urban sites’, (in a historic neighbourhood, a ‘New Town’, and a Regional ‘Hub’) generally encompass Yin’s requirement that: ‘key definitions and units of analysis should be either similar to those previously studied or innovate in clear operationally defined ways’ (Yin, 2003b:26). The units of analysis are sufficiently formally distinct in definitional terms (description, history, planning/policy) so as to
clearly indicate an exploratory and descriptive case study approach, which seeks primarily to firstly explore a concept for a disciplinary field (spatial complexity for urban analysis and design) and secondly, give a full description of the distinctly differing phenomena studied (exploration and evaluation of spatial complexity levels in sites of differing types). The role of correlational analysis is therefore to examine relationships in data collected on criteria and indicators of spatial complexity within, between or across the three urban sites.

However, this is not an exclusively correlational study. A wholly correlational study could have chosen three equally categorised and sized sites for example, and looked for variables in these sites across issues, criteria, indicators and benchmarks, something which it is decided would yield less benefits for urban analysis and design. This is partly because prior theory in the field of spatial complexity in urban design terms is underdeveloped, so for example, benchmarks have not so far been developed. The reason to select a range of case types, (distinct and contrasting in description, history, and planning/policy) is to demonstrate the range of urban analysis/design conditions considered relevant in a complexity frame understanding of the contemporary spatial conditions in Ireland. The need for spatial complexity understandings of urban sites in this range and these types of locations can be described as including the lack of previous focus by spatial research on these types of location, the dynamically changing character of these site types, as well as the claim that these types of sites demonstrate conditions of cultural definition and international relevance. Another study could extend and elucidate the exploratory and evaluation findings of this research to compare and correlate data from other (less studied, similar sized) urban sites similar to those studied in this thesis.
The distinction between comparative and correlational aspects of this research, within an overall case study approach are also related to scalar levels of understanding of the urban sites. Whereas architectural understandings of spatial complexity tend towards considering one single building, CTC theories of spatial complexity are often related to large and abstract scales of the city. Meanwhile, spatial planning/urbanism understandings of spatial quality can range as far as a national policy (e.g. Belvedere Policy for Holland, 2005) and landscape analysis/design scale understandings of spatial complexity range across entire ecosystems. Jencks’ (1997) understandings of complexity as related to architecture come from the perspective of an architectural theorist, writer and critic. However, architectural criticism in particular has been heavily criticised in other literatures for over-emphasis on images and styles, added to the claim that: ‘The only representative of spatial order in the armoury of the (architecture) critic is the plan’ (Hillier & Hanson, 1984). For urban design, bridging as it does such a set of disciplinary contexts, this thesis can demonstrate the usefulness of ‘open’ scalar unit definitions and linkages by concentrating on more qualitative, exploratory and comparative analysis for the issues of spatial complexity of the urban sites, which in turn can add to comprehensive knowledge at multiple scales of the designed environment, linking spatial complexity for urban design to architecture, planning and landscape scales. Meanwhile, at the lower, more focused scales of criteria and indicators of spatial complexity of urban sites, a more quantitative and empirical set of data analysis techniques can uncover more precise correlational readings of spatial complexity. Therefore, this study is a mixed methods, multiple-case study unit research design, which includes aspects of comparative and correlational research.
3.6 Chapter conclusions (Summary of this research design)

This chapter advances the overall argument of this study through demonstrating the appropriateness of a case study approach to explorations and evaluations of spatial complexity. The first section has outlined the overall research design, describing the adopted research philosophy as a pragmatic worldview, and the strategy of inquiry as a combined (mixed methods) strategy approach. The mixed methods case study approach is argued to suit explorations and evaluations of spatial complexity of urban sites for urban design for four reasons: suitability to architecture (urban design) types of research, correspondence to a complexity research approach, responding to an aim of this research to be relevant to urban design practice, and usefulness in reducing bias.

The second section has described the specific research methods adopted, including case study, the overall methodological approach. This part outlined how the case study design was arrived at in detail, as this aspect determines all subsequent decisions on numbers of cases, types of analysis and reporting procedures. This section refers to a fuller description of all the case study (units of analysis) research design options considered, in order to demonstrate the exploratory nature of this research. This is followed by an explanation of the selected approach, a multiple case research design.

The third part of this Chapter deals with data collection and analysis. A concurrent triangulation data collection strategy is proposed, and six data analysis techniques are described as employed in this study: data transformation, instrument development, examining multiple levels, matrix preparation, pattern matching and cross-case synthesis. The fourth section describes the consideration of a comparative approach to the research topic, and an outline of the correlational aspects of the selected research
design. This section explained how the definition of spatial complexity of urban sites is derived for this research, and the research methods employed to investigate this aspect of urban sites, (including a mixed-methods, comparative and correlational case study approach). It is shown that these can be used to compare evaluated issues and criteria of spatial complexity between three distinct and contrasting urban sites (the exploratory aspect), and to correlate data relate to these issues and criteria of spatial complexity (the evaluation aspect) for urban design theory and practice. It is demonstrated that this mixed methods research approach can be used to define urban sites in terms of evaluated levels of spatial complexity. The chapter concludes that this study is a mixed methods, multiple-case study unit research design, which includes aspects of comparative and correlational research, in advance of introducing the conceptual framework of the study, the subject of the next Chapter.
Chapter Four  Conceptual framework of spatial complexity

“The world is complex, dynamic, multidimensional; the paper is static, flat. How are we to represent the rich visual world of experience and measurement on mere flatland?” (Tufte, 1990: 5)

4.1 Introduction

While relevant theoretical concepts from complexity and urban design theory have been reviewed in Chapter Two, with the conclusion that aspects of both are useful in deepening the concept of spatial complexity for use in urban design, and whereas Chapter Three described the research design and methodology, concluding that a case study approach is adopted, this Chapter develops a conceptual framework for understanding spatial complexity in an urban analysis and design context. This framework includes fully describing a proposed matrix of evaluation of spatial complexity for urban sites. This Chapter seeks to answer some additional exploratory questions about spatial complexity. The three questions of this Chapter are, firstly: how can a useful conceptual framework of spatial complexity be developed for urban analysis and design? Secondly, from a theoretical perspective, which issues are most important to consider in devising a conceptual framework of spatial complexity for urban analysis and design? And lastly, how can different issues of spatial complexity be weighted in importance, and how can this weighting be visually accessible for use in practice?

The main driver of this chapter is the description of the response to these questions, in order to fully outline a conceptual framework of spatial complexity. Chapter Four therefore develops one overall aim of this research, which is to investigate the
relationship between spatial complexity, urban sites and evaluation by proposing a new evaluation tool which is useful for urban design practice. This is done in advance of the next exploratory chapter on Dublin, before a detail evaluation for urban design of multiple urban sites in the following Chapter. This Chapter is therefore dealing with the second part of the research question, which asks how spatial complexity can be evaluated for urban description, prescription and design. The implementation of this is dealt with in later Chapters, after the conceptual framework has been described. This Chapter advances the overall argument of this thesis through exploration and development of a conceptual framework, in the first section, and describing a practical tool for evaluating spatial complexity in subsequent sections of the Chapter. In this way, the exploratory questions around spatial complexity at macro scales, above and around urban design scales, are deepened within urban design through development of a tool. The discussion draws then on a short literature review (related to evaluation theory and visual representation methods) before outlining the visualisation strategy of this study.

The main driver of this chapter is demonstrating the importance of the development of a conceptual framework and tool for evaluation of urban sites. As described, this is useful in the description, prescription and design of urban sites. The task of visualizing spatial complexity, and how this can assist understandings of urban sites, is also outlined.

---

68 This Chapter is therefore linked to the previous description of the research design, in the last Chapter, in that as part of an ‘exploratory’ case study approach, encompassing exploration of theory, a partly ‘descriptive’ evaluation of three particular cases will also undertaken, and this Chapter describes the framework of that evaluation, without extending to full description of all complex urban sites in Dublin.
4.2 Conceptual framework

Miles and Huberman suggest three purposes of a conceptual framework: to identify who will and who will not be included in the study, to describe what relationships may be present based on logic, theory and/or experience, and providing the researcher with the opportunity to gather general constructs into intellectual ‘bins’ (Miles & Huberman, 1994:18). In order to frame this outline of the conceptual framework of this research, these three purposes are summarized as scope, relations and paradigms. Firstly, as regards scope, and as outlined in Chapter One, urban sites as research object are concentrated on, and the boundaries of the enquiry include scalar (the scale of urban design) and disciplinary (urban design) limits. As regards relations, the proposed relations are between urban sites and evaluated spatial complexity, argued to be constituted primarily of three aspects. More specifically, the three aspects of spatial complexity concentrated on are the compositional, configurational, and system characteristics of urban sites. These relations are indicated graphically in the image titled ‘Conceptual framework chart’ (Fig. 4-1), adapted from Baxter (2003:28). In this chart, the relations between expected high, medium and low evaluated spatial complexity of an urban site are graphically linked. In this way, it is proposed for example, that an evaluated aspect of configurational complexity like integration is one of nine selected criteria for evaluation of spatial complexity, and examining this measure individually can help to describe and refine the evaluation.
Figure 4-1  Conceptual framework chart

Source: Author, adapted from Baxter, (2003:28)
4.2.1 A visual model

The concept of a visual model is suggested to assist in describing a conceptual framework for a study (Baxter, 2008:553) by allowing for all major constructs of the study to be displayed together in one format. As regards the gathering of general constructs into intellectual “bins”, while the overall theoretical frame of this study is a complexity theory approach, the particular emphasis is on complexity theories of cities, as outlined in Chapter Two. Within this frame, three particular paradigms converge in the conceptual framework of this research, especially in relation to data analysis: the compositional/urban form paradigm, the space syntax paradigm, and the systems analysis paradigm. A visual model of a proposed theory of spatial complexity for urban analysis and design is illustrated in Fig. 4-2. Each of these contributes to the development of the concept of spatial complexity of urban sites. The particular importance of the conceptual framework in case study research at a certain stage is emphasized (Baxter, 2008). This is considered to be at the point where the relationships between the proposed constructs emerge as data are analysed. At this point it is suggested that propositions that initially formed the conceptual framework are returned to, in order to ensure that the analysis is reasonable in scope and so that it provides focus for the final case study report (Yin, 2003b).
Figure 4-2  Visual model of theory of spatial complexity
4.3 Structure around an evaluation tool

Gil’s review of contemporary tools to evaluate urban design (Gil, 2013), as already discussed in Chapter Two, is now returned to and employed as a proposed structure around an evaluation tool of spatial complexity. The format for reviewing sustainable urban development evaluation tools used by Gil for urban design is considered appropriate to this study, because the structure around these tools which he devises (See Fig 4-3), (Figure 1, from Gil, 2013:313) can be easily developed and extended for spatial complexity evaluation. In discussing the general structure of sustainable urban development evaluation tools, one of Gil’s conclusions is that: ‘no single tool stands out, and that there is room to improve existing tools and develop new ones’ (Gil, 2013:327). It is apparent from reviewing the literature that there is a lack of commonly agreed criteria for evaluation in urban analysis and design. For example, sustainability ‘indicators’ have been criticised in the planning literature, (Briassoulis, 2001) as have broader definitions of ‘sustainability’ itself (Frey, 1999), including for an Irish ‘New Town’ site, Adamstown (Hunt et al, 2012,), and ‘resilience’(Chandler, 2014). Other relevant contested terms include ‘‘good’ urban form/ design’ (Talen, 2000), and ‘spatial quality’ (Moualert et al, 2013). Concurrently, there is increasing ‘measurement’ in an entrepreneurial sense and increasing scalar reach of commercial forces of urban measurement, including ISO69 for neighbourhoods. Another discourse argues for evaluation and prioritisation of ‘aesthetics/visual complexity/beauty’ in designed environments (ResPublica, 2015) pointing towards a broader culture of relational evaluation, and thus the increased shared valuing of these aspects of urban sites in particular.

___________________________

69 ISO (International Organization for Standardization) standard 37120:2014 is titled ‘Sustainable development of communities- Indicators for city services and quality of life.'
The concept of a ‘structure’ around a tool is developed by Gil as follows (See Fig. 4-3). In relation to the characteristics sought in a workable evaluation tool to enhance urban design, Gil considers that ‘a hierarchical structure supporting the selection and development of meaningful (sustainability) indicators’ is an essential characteristic of a ‘sustainable urban development evaluation tool’. He categorises tools for evaluation (at early design stage) of urban design aspects of sustainable urban development into five categories, and in a hierarchical structure from top to bottom: ‘dimensions’ (top), ‘issues’, ‘evaluation criteria’, ‘design indicators’ (indices), and ‘benchmarks’ at the bottom of a pyramid. ‘Dimensions’ (top) in this sense, are defined by Gil in relation to sustainability as ‘the core goals’ and he further describes these as often based on the three pillars of sustainability, that is, environment, society, and economy. In considering a structure for evaluation of spatial complexity, dimensions here would fit within environment, and more specifically, urban and spatial aspects. ‘Issues’, in the sense used by Gil, are defined as ‘themes that need to be addressed to achieve core goals’ (Gil, 2013:313). In this study, composition, configuration and system aspects are proposed as the ‘issues’ which are most important for evaluation of spatial complexity of urban sites (the objects of this study), as discussed later in this Chapter. ‘Evaluation criteria’, in the sense defined by Gil are ‘aspects that need to be assessed in order to verify the response of the plan to the issue’. Whereas Gil is reviewing sustainable urban development evaluation tools for usefulness as decision and design support tools to urban design practice and in the ex ante evaluation of design proposals (ie. in advance of completion and implementation of urban design processes), in this study evaluation criteria are seen as constituent measurable aspects of the three issues related to spatial complexity of urban sites as defined above.
In this study’s evaluation structure, each issue has three constituent measurable criteria: composition (urban structure/form, land use mix, density) configuration (integration, choice, intelligibility) and system (street network, path network, and pedestrian network). The concept of ‘variables’ arises in describing these criteria. The term ‘variable’ is associated with quantitative studies and measurement in the social sciences (Cresswell, 2009:59). A variable can be defined for this study, adapting from Cresswell (2007) as a characteristic of an object or environment that can be measured, and that varies among the objects or environments being studied. A variable will generally vary in two or more categories or on a continuum of scores, and it can be measured on a scale (Cresswell, 2009:59). As described in Chapter one, spatial complexity is examined as the independent variable in this study, that relates to dependant variables of compositional, configurational and systems aspects of urban sites for urban analysis and design. The dependant variables are arrived at from a review of prior theories and claims in the literature about how these aspects affect cities and urban sites. However, as these variables include qualitative and quantitative features, and this is a mixed methods study, carried out in a complexity frame, the term ‘criteria’, used to denote both qualitative and quantitative characteristics, is used throughout.

‘Design indicators’ in Gil’s definition are seen as ‘measurements that are indicative of the performance of the design, with specific measurement units and methods (e.g. percentage of residents within 400 m walking distance of a public transit stop, average distance in meters to the nearest doctor)’. This meaning would equate to the meaning of specific evaluation measures in this thesis (e.g. Network complexity varies between 0 and 1). High level concepts of sustainability are linked by Gil at lower level to the specific project being evaluated and to objectives which can be measured (Gil,
Categories at the lower end have increased levels of definition, detail and specificity. The hierarchical arrangement is considered to ‘provide compatibility with evaluation standards and theory, provide a clearer understanding of the issues, and give greater relevance to the result (Carmona and Sieh, 2008)’ (Gil, 2013:313). Gil’s view is that large frameworks of indicator systems and aggregate indices, in particular, are associated with positivist, quantitative planning policy and practice, and considers that they ‘have limited use in practice’ (Gil, 2013:312) partly due to ‘complexity of implementation and information gathering required’ which ‘reduces their ability to function in a quick, iterative and interactive fashion’. Serious difficulties are cited in assessing the results of indicators (Briassoulis, 2001) across scales and disciplines. Disaggregate indicator systems, combined with multi-criteria analysis (MCA) are considered by numerous authors (cited by Gil, 2013:312) to have become the preferred level of evaluation at the more local and detailed level of planning, such as neighbourhood development and design.

**Figure 4-3  Hierarchical evaluation pyramid and proposed toolbox**

Fig. 4-3 indicates Gil’s proposed hierarchical pyramid around evaluation, (l) Fig 1, (Gil, 2013:314) and proposed structure for a spatial complexity evaluation toolbox for this study (r)
In discussing specific selected urban design indicators, Gil states: ‘it is important that
the indicators make the consequences of design actions directly observable and
understood by the stakeholders to facilitate the interaction and iteration processes.’
(Gil, 2013:314). This emphasis on relevance of indicators to stakeholders and designers
is incorporated in the proposal of this research to evaluate three indicators only, in an
integrative manner, employing robust, testable, transparent and easy to use methods
(See Fig. 4-3). The results of evaluation are also considered important to easily access
and discuss, so a visualisation ‘databox’ is devised in this thesis to facilitate
dissemination and visual communication of results. The remaining parts of this Chapter
concentrate on the full description of the proposed issues, criteria and indicators of
evaluation of spatial complexity of urban sites, and the development of the resulting
‘toolbox’ and ‘databox’ of evaluation. The primary focus here is demonstration of
‘issues’ and within those ‘criteria’ and consequent measurement indicators or indices.
‘Benchmarks’, as the lowest part of the hierarchical structure around evaluation, are not
arrived at in this thesis. Benchmarks are defined in Gil’s analysis as ‘target values to
achieve specific quality levels’ (Gil, 2013:313). This is because, as Gil states,
benchmarks derive from reference values arrived at over time, and ‘come from a
baseline assessment of similar cases’. As described in Chapter Four (Sect. 4.4,
Screening the cases), the cases examined in this thesis are distinct and contrasting
examples of conditions of spatial complexity in urban sites, so the generation of
benchmarks of ‘optimal’ spatial complexity is beyond the scope of this study. This
section has answered the first question of this Chapter, in describing how a useful
conceptual framework can be developed for urban analysis and design.
4.3.1 Three issues of spatial complexity

In this section, a proposal is made for selecting three particular issues as those most usefully constituent of spatial complexity of urban sites, for urban design practice. In practice, the relative emphasis on certain ‘issues’ of spatial complexity would vary for different sizes and types of urban site. In this sense, urban sites differ to rural ones for example, and highly dense urban sites are distinct from suburban type sites, but all sites can be evaluated, though not all are within ‘urban design’ scales. In the science of cities domain for example, Batty considers fractility analysis of large sections of the city to be important to evaluate in considering spatial complexity, while in urban design, Hillier considers configuration to be important to evaluate for understanding levels of spatial complexity, at local and global scales, as outlined in Chapter Two\(^70\). The theories on which both Batty and Hillier rely are mostly applied to current evaluation or survey of urban environments\(^71\). Separately, a systems approach to evaluation of complexity of

\(^{70}\) Hillier considers that the study of ‘configuration’ has the ability to ‘bring the elusive ‘pattern aspect’ of things in architecture and urban design into the light of day’ (Hillier, 1996) which suggests an emphasis on local scales and highly urban sites.

\(^{71}\) Batty’s Phd Thesis, ‘Pseudo-Dynamic Urban Models’ (Batty, 1984) which brings together mathematical social sciences and urban modelling, was followed by extensive fractility analysis and other broad complexity science of cities research. Recent research related to spatial complexity for urban sites includes ‘Characteristic Visual Complexity’, (Oswald, 2013) and ‘Spatial accessibility to amenity in fractal and non-fractal forms’, (Tannier et al, 2012). One of Hillier’s earliest publications (in conjunction with Adrian Leaman) ‘How is design possible? (Hillier, Leaman, 1973) included discussion of the complexity of the environment, and the relative ‘simplicity’ of design. A whole field of spatial analysis (space syntax) including analysis methodologies, a peer
cities emphasises that change in cities is dynamic, and can only be modeled and predicted to a limited degree (Allen, 2008:5).

The specific issues of evaluation are selected for the following three reasons. Firstly, the three constituent issues have already been extensively used in evaluation for urban design either separately, or in combinations of methods related to either one, two or three of the issues. (See Figure 4-5). This means that results of evaluations can be easily compared with prior studies. Secondly, each of the three selected issues capture unique aspects of an urban site, which neither of the other two selected issues would describe, and the combination of the three issues evaluated reveals a rich account of the evaluated spatial complexity of an urban site. Thirdly, none of the selected issues (or criteria) have been tested for Irish urban sites previously, so new understandings and particularities of Irish spatial and formal units can be uncovered. Other issues of evaluation which were also considered and ruled out are included in notes to Figure 4-5.

The three constituent issues within the spatial complexity evaluation method proposed in this study are now described, firstly by brief description of separate urban design theoretical underpinnings, and then by outlining separate methods employed of each in practice to evaluate urban sites. Then an integrative approach is explained, as this seeks to combine and encompass all three issues within one evaluation context.
### Precedents in Evaluation Methods of Urban Sites for Urban Design

<table>
<thead>
<tr>
<th>Author</th>
<th>Composition</th>
<th>Configuration</th>
<th>System</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Hillier, 1998)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>(Hillier, 1999)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>(Read, 1999)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>(Hanson, 2000)</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Talen, 2003)</td>
<td>*</td>
<td>*</td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>(Marshall, 2005)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>(Stahle, 2005)</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Ewing et al, 2006)</td>
<td>*</td>
<td></td>
<td></td>
<td>B</td>
</tr>
<tr>
<td>Marcus (2006)</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marcus (2007)</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Hillier, Vaughan, 2007)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>(Elsheshtawy, 2007)</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Gil, Duarte, 2008)</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Dempsey, 2008)</td>
<td>*</td>
<td></td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>(Ewing, 2009)</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Berghauser, Haupt, 2009)</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Forsyth, 2010)</td>
<td>*</td>
<td></td>
<td></td>
<td>D</td>
</tr>
<tr>
<td>(Salat, 2011)</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Vaughan, Palaiologou, 2012)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Marcus (2012)</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Gil et al, 2012)</td>
<td>*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Van Nes et al, 2012)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>(Oliveira, 2013)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>(Gil, Duarte, 2013)</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ye et al, 2013</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Kickert et al, 2014)</td>
<td>*</td>
<td>*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Van Nes et al, 2014)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>(Dai et al, 2015)</td>
<td>*</td>
<td></td>
<td></td>
<td>E</td>
</tr>
<tr>
<td>Oliveira, Partenen, 2015</td>
<td>*</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>Marcus, Berghauser, 2015</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

**Notes**

Scales of focus: 1. Region, 2. Whole city or district, 3. Urban Site (emphasis on complexity, spatial complexity)

A- (Talen, 2003) discusses many ‘new approaches’ to urban built environment evaluation, including ‘visual enclosure’, ‘lost space’, ‘transect’, ‘centres & edges’ etc, but these are considered to be untested in practice, and therefore results are unlikely to be comparable across urban sites.

B- (Ewing et al, 2006) develops operational definitions and measurement protocols for five perceptual qualities of the urban environment that may influence walking behaviour: ‘visual enclosure’, ‘complexity’, ‘imageability’, ‘human scale’, and ‘transparency’. These definitions were considered too intangible for testing in urban sites, and comparing with prior evaluations.

C- (Dempsey, 2008) considers land use, density, building type, accessibility, mobility infrastructure, and street layout, many contained within the selected issues and criteria (though sometimes differently categorised)

D- (Forsyth, 2010) also considers an overlapping set of issues and criteria to those selected, in a communicative rationality approach (less purely spatial and formal focused)

E - (Dai et al, 2015) is focused on evaluating spatial complexity of architecture

---

**Figure 4-5** Precedents in evaluation methods of urban sites
4.3.1.1 Compositional analysis theory and methods

Figure 4-6 Relevant compositional analysis theories

Compositional analysis deals with primarily compositional and geometrical aspects of form as represented, for example in scale plans of urban sites, featuring ‘absolute position, lengths, areas and orientation’ (Marshall, 2005: 87) (Box 4) (Marshall & Çalışkan, 2011:416). In employing a compositional analysis approach to evaluating spatial complexity of urban sites, the interest is in identifying and describing relevant formal and geometric aspects of urban sites which neither configurational nor system analysis would capture. Research suggests that urban design is different to other forms of design, and more allied to science, in that it often needs to concentrate on ‘emergent morphological phenomena, rather than the study of design precedents’ (Marshall &
Çalişkan, 2011:420). As this is an exploratory investigation of spatial complexity for urban design, one aim is to explore alternative theories and methods of understanding and evaluating compositional complexity. Three aspects of composition of urban sites are concentrated on: morphology, land-use mix and density. Each is now discussed briefly in turn.

The guiding ‘paradigm’ in urban compositional analysis in this study is the urban morphology analysis paradigm (Gauthier, 2006). Urban morphology is defined as “the study of the physical or built fabric of urban form, and the people and processes shaping it” (Larkham, 2015). Urban morphology is employed as a research method to examine time-dependant changes in urban form in the urban built environment, though it has been described as “not well understood or used in planning or urban design practice” (Kropf, 2014: 70). As this study focuses on a static evaluation of urban sites, the urban morphological description of development of the urban sites has been recorded in a separate Appendix (A), to provide background to the more empirical evaluation of urban morphological complexity in Chapter Six.

In order to answer the part of the research question of this study which relates to evaluation of urban sites for urban design, the first aspect of compositional complexity concentrated on is urban morphological complexity. In defining the concept of urban morphological complexity, Conzen’s historico-geographical approach to town-plan analysis is relevant, as this seeks to uncover the morphological complexity of the town, based on an analysis of the plan, and especially the development of the settlement over time, regarded as a ‘time sequence’ (Conzen, 1960). This is in turn connected to the concept of ‘map regression’, (as discussed in Appendix A). However, Conzen does not
expressly define the concept of urban morphological complexity. Adolphe (2001) investigates urban morphological complexity in relation to environmental performance of cities, and develops mathematical equations related to the indicators, dimensions and classes, concluding that a model based on indicators of environmental performance can uncover the influence of urban morphological complexity on outdoor climatic conditions. Haghani (2009) studied urban morphological complexity, arguing that the uniqueness of each urban form can be identified by measuring the level of complexity that it exhibits (Haghani, 2009:271). Haghani investigated urban morphological complexity using fractals (2009) and later discussed the concept in relation to urban investigation methods (Haghani, 2013:60) but fails to define the concept. He does however agree with Ley (2012) that both quantitative and qualitative indicators are necessary in the evaluation of urban morphological complexity. Cooper explores urban morphological complexity through fractal-based townscape evaluation techniques including analysis of street vistas, street elevations, skylines and building lines (Cooper, 2000). In this study, seven urban morphological complexity ‘metrics’ are selected to evaluate the urban sites. Each is described in the next Section of this Chapter (see also Fig 4-4), results are in Appendix A (Morphology of Cases), and Appendix B sets out the protocols for implementing each method. In conclusion, the concept of urban morphological complexity is employed here for urban analysis and evaluation.
The second method employed to evaluate compositional complexity of urban sites is Van Den Hoek’s theory of land-use mix (Van Den Hoek, 2008, 2009). The concept of land-use mix analysis involves study of the different functional uses of land, and the relative occurrence of certain types of use (eg. housing, commercial uses, etc) in a given location. High land-use mix at the scale of a neighbourhood or urban site is associated with urban quality (Jacobs, 1961), diversity (Montgomery, 1998:97), and positive social usage or overall perception of the built environment (Dempsey, 2008:254). Urban design and planning policy supports high land-use mix for improving the built environment and making it more attractive, together with improved public transport and density which supports local services (Urban Task Force, 1999:5). The Irish Retail Planning Guidelines (Dept. of Environment, 2012:12) promote a mix of ‘often interdependent land uses which contribute to a sense of place and identity’, stating that these can enhance vitality and viability of town and city centres. The study of land-use mix is a feature in urban analysis (Hoek Van Den J, 2008) (Song, Knapp, 2007), evaluation (Dempsey, 2008), and design (Francis, 2012). Nedovic-Budic et al (2016) measure urban form of Dublin at community scale, analysing eleven indicators of different land uses on a 1km x 1km grid (CORINE, 2006), including continuous and discontinuous urban fabric. Many quantitative methods of evaluating land-use mix in the urban environment treat this as a primary variable in seeking optimal urban design.

The third method employed to evaluate compositional complexity of urban sites is a measure of density. The predominance of the issue of density of urban form is a feature of the urban analysis (Glaster et al, 2001), (Dempsey, 2008) design (Dovey, 2014) and evaluation (Ewing, 2009) literatures, and density is primary component in urban description, prescription and design (Berghauser Pont, Haupt, 2009). It is claimed that
density is ‘the dominating variable in the geographic analysis of urban space’ (Marcus, 2007). The co-incidence of density, urban intensity and urban complexity have been linked, but it is argued that conditions for these may be changing in the networked city (Porqueddeu, 2015). At urban site scale, neighbourhood density is considered to be a highly important ‘urban design quality’ in evaluating walkability (Ewing et al, 2006). Berghauser Pont & Haupt’s research on ‘space, density and urban form’ evaluation (Berghauser Pont and Haupt, 2010) is considered most relevant to this study, because it develops workable evaluation tools. A related method of evaluating plot ratio and site coverage of urban sites is adopted in this study as the third relevant measure compositional complexity. In conclusion, within the issue of compositional analysis, three criteria of compositional evaluation of urban sites are considered important for this thesis: urban morphological complexity, land-use mix and density.
4.3.1.2 Configurational (space syntax) theory and methods

Figure 4-7 Relevant configurational analysis theory

Configurational urban design theory deals with topological analysis of urban sites, ‘including ordering (relative position, but not necessarily metric distance) of urban elements, adjacency and connectivity’ (Marshall, 2005: 86) (Box 4). The primary configurational theory considered here, space syntax, sees buildings, urban areas and cities as continuously connected space, which can be understood as one whole complex entity, but also through a focus on any one or part of its constituents, and the connection or relations, between it or them and the whole system of space. The comprehensiveness of this scalar reach is one reason to select configurational analysis as an ‘issue’ of spatial complexity evaluated in this thesis. Hillier, one of the founders of space syntax
as a method, theory, and business, describes the configurational approach to (urban) analysis as:

using the basic ideas of spatial relation built into language (including syntax) to create more general tools for describing and comparing forms of spatial complexity (Hillier, 2008:224).

The specific reference above is one of the relatively few occasions when analysis methods of space syntax are directly connected to the concept of spatial complexity. Hillier then continues, and defines a core concept of space syntax, the ‘configurational approach’:

This was called the configurational approach. Configuration was defined as relations which take into account other relations (as the prepositions do), and methods developed to measure the relations between each space in a complex and all the others, and in this way to assign ‘configurational’ values to individual spaces describing the links of each to all others. A key example was the ‘integration’ value, which indexed how topologically close each space in a complex was to all other spaces (Hillier, 2008:224).

In employing this configurational theory approach to evaluating spatial complexity of urban sites for this study, the interest is in identifying and observing relevant global and local configurational aspects of the urban built environment, which neither of the two other issues (compositional and system) would capture (See Fig 4-6). Space syntax has been described as ‘a term that is used to describe a family of theories and techniques concerning the relationship between space and society’ (Dalton et al., 2012). It began in the 1970’s as a theory and method of analysing urban spatial layouts, connecting the physical attributes to the social aspects, and proposing that space was the strongest base

---

72 Space Syntax Ltd. is a consulting firm specialising in ‘the science of human behaviour for cities, human behaviour and buildings” (http://www.spacesyntax.com/ accessed 050216)
for consideration of both together. The first book to bring together the theory, ‘The Social Logic of Space’, (Hillier & Hanson, 1984) co-authored with Julienne Hanson, is seen as ‘the key theoretical –methodological statement of space syntax’ (Griffiths, 2014: 158). The book is regarded as one of only four attempts to ‘synthesise the entire field of urban design’ (Cuthbert, 2006: 14). In another account, space syntax is considered to be “one of the most important contributions to urban design over the last 25 years” (Carmona, 2007: 212).

Space syntax as theory and method has been criticized for an overly-mathematical emphasis (Cuthbert, 2007: 202), and a lack of three dimensionality /reality (Ratti, 2004) (Varoudis, 2014). It is also seen to have a perceived weakness as socio-spatial theory (Soja, 2001: 3), and to involve a ‘spatial determinism’ (Till, 2013). Many other responses to criticism are also in defence, including a public rejoinder to Ratti (Hillier, 2004b), though urban design practice increasingly is supported by the method. For this thesis, the proven applicability of space syntax theory and methods in relation to observed phenomena in urban sites, in particular ‘geometric complexity’ (Hillier, 1999:170), and the opportunity to draw from extensive space syntax literature for application in devising a new tool for practice in urban design, makes this theory and methods appropriate. Within the issue of configuration, three criteria of configurational evaluation of urban sites are considered important: integration, choice and intelligibility. Each is described in the next Section (4.4).

---

73 However, the extensive literature on the merits or otherwise of space syntax do include for example supporters of the mathematical aspects as the strongest feature Derix C. (2012) Digital masterplanning: computing urban design. Proceedings of the ICE - Urban Design and Planning, 165.

74 Other configurational analysis techniques related to urban sites were ruled out for this part of the study, including a method for analysing street patterns in relation to complexity (Marshall, 2005: 148-9). This method is employed later in this study, but categorised as a system criterion (See ‘Note on Nomenclature’, Chapter Four, Section 4.3.1.4). A separate approach, based on a network analysis of streets in a complexity frame (Porta, 2006), was ruled out as it concentrates on geographic network analysis (Porta, 2006:705), at scales larger than the urban site scale as understood in this study. A third approach to configurational analysis of urban sites, related to raster analysis of urban form, involves digital elevation models. However, this method was ruled out as it was unlikely to be used in conventional urban design practice. (See Appendix E, ‘Other configurational analysis techniques’).
4.3.1.3 Systems theory and methods

Figure 4-8 Relevant system theory

Systems theory for urban design engages with systems complexity of urban sites. In defining system complexity, Marshall states that this type of organised complexity: ‘is different from artefactual complexity in that the parts are not necessarily assembled with respect to the whole, and the whole is in practice unknown by any agency’ (Marshall, 2012a). In employing this systems theory approach to evaluating spatial complexity of urban sites, the interest is in identifying and describing relevant ‘non-object’ aspects as well as physical aspects of the urban built environment, which neither of the two other indices (compositional and configurational) would capture adequately. For this reason it is decided to select system analysis as one of three issues of spatial complexity evaluated in this thesis. Theoretical and practical guidance exists on
evaluating the complexity of particular physical aspects of urban sites which may form part of a system, such as of individual streets, (Tucker, 2005),(Cooper, 2010) or perceived complexity of individual facades (Heath, 2000). However, system aspects of urban sites themselves have not been evaluated for levels of spatial complexity. Within the issue of systems analysis, three criteria of systems evaluation of urban sites are considered important for this thesis, here described for convenience as ‘patterns’ (street network complexity), ‘paths’ (pedestrian path network complexity) and ‘people’ (pedestrian movement network complexity) (See Fig 4-6). Each is described in the next Section (4.4).

4.3.1.4 Nomenclature and the three issues

While the naming or classification of the three issues for evaluation of spatial complexity in this study is open to question, it is undertaken to facilitate a certain simplification of many diverse methods available across sub-disciplinary fields around urban design. The current discourse in morphology includes multiple interpretations of the disciplinary ‘homes’ of the different methods employed. Three examples are now described, in order to recognize the diversity, and clarify the position of the thesis in this regard. Firstly, it has been argued that ‘space syntax models cities as spatial systems’ (Marcus, 2012:8074:2) and therefore it might be mistakenly understood that the third approach to indices, system evaluation, resembles the second configurational approach, (space syntax). The distinction between the ‘whole systems configuration’ approach of space syntax, which models configurations of real street and road configurations, and a systems approach as understood in this thesis, which investigates non-physical or ‘mobile’ attributes of urban sites, is that the configurational method investigates fixed
topological attributes, while the systems related method investigates movement and temporal attributes.

A second example of categorization is street network complexity, here classified as part of a system analysis issue. Street network complexity is described by Marshall as a configurational analysis method for urban design. This includes a study of street patterns in relation to complexity, and Marshall defines this quality as a route structural property, and a heterogeneous feature, relating numbers of distinct types of routes present in an area, with a finding that often complex, characteristic structures are found in traditional street layouts (Marshall, 2005: 148). This combination of structural and network analysis, while not incorporating systems analysis methods in a purely scientific sense, contributes to the diversity of understandings of networks, seen here as composite elements in complex system analysis.

A third example of multiple interpretations of methods is the categorization of space syntax as a morphological approach (Oliviera, 2015:73)\(^\text{75}\). However, in this thesis, it is the cross-scalar topological potential of the space syntax analysis method which suggests it should sit as a separate category, as a configurational issue related to spatial complexity for urban design. In summary, the classification issues as set out here are categorized in this thesis in order to inform multiple, cross-scalar cumulative and abductive evaluations of spatial complexity\(^\text{76}\).

\(^{75}\) The debate on categorization of the syntactical approach to analysis is ongoing. See for example, (Pinho et al, 2009:118).

\(^{76}\) This concept of spatial complexity, as demonstrated in Chapter Two, is currently ill-defined and emergent in urban design, and claims made in this study are considered to be abductive in nature. This situation leaves open the possibility that categorization of issues around spatial complexity for urban design could be extended in future by others.
4.3.1.5 Integrative urban design theory and method

Having proposed a conceptual framework and three components of an evaluation tool, this description now advances to proposing a synthesis of the exploration and evaluation, as well as issues and criteria of spatial complexity. Integrative urban design theory is recommended for the particular “multifaceted field of urban design” (Inam, 2011). An integrative approach to urban design would best approximate, in urban design theory terms, to a complexity ‘approach’ seeing urban design as an ‘integrative art of place’ (Marshall, 2015). Buchanan proposes ‘integral’ theory in response to contemporary urban design approaches, which he sees as “still inflected with modern functionalist thinking” (Buchanan, 2013: 6). Marshall & Çalışkan (2011) consider that Trancik addresses most closely the need for an integrated design approach, taking this
to mean ‘figure-ground, linkage and place theories of urbanism’ (Marshall & Çalişkan, 2011:411). An integrative approach is also considered in this thesis as any interdisciplinary (Dalton et al., 2012: 10), or ‘transcending’ (Carmona, 2014b) urban design research practice in relation to the spatial disciplines, related to urban sites. This includes mixed methods research and approaches in urban design (Xerez, 2011). A mixed methods approach is associated with enrichment of theoretical and empirical urban research (Batty, 2009; de Roo, 2012c). Dyrssen considers that heterogeneity inherent in architectural thinking which seeks to “construct, perceive and conceptualise complex situations” (Dyrssen, 2011) opens new possibilities for art-based research, including creative modeling and simulation of information, and this discourse has recently been extended for urban design (Sorkin, 2014) (Marshall, 2015) (Louie et al., 2015).

Current literature associates integrative spatial quality in urban design and planning with a relational epistemology and transdisciplinarity, and complexity is seen as one of many cited ‘experiential quality attributes’ of the built environment and landscapes (Khan et al., 2014). Marcus (2014) associates integrative theory with urban design, urban morphology and resilient urban systems. Recent research in this integrative urban design area is described later in this chapter. (See also Fig 4-8). Perceived lacks of crossover and contact between urban morphological, and urban design research and practice, and the potential negative implications, have been highlighted in the literature (Marshall & Çalişkan, 2011), (O'Connell, 2013).

One aim of this thesis is to contribute to an enriched interface between classic syntactical measures (space syntax) and other morphological and system descriptors of
urban form. A recent example of a combination of syntactic and quantitative morphological analysis approaches argues that increasingly more complex generators of town form in small towns ‘act on the seeds of prior small aggregations, generated by simpler rules of adjacency’ (Lim et al, 2015:144). This association of urban formation over time with a kind of path-dependancy, a concept originating from complexity sciences (Bontje, Musterd, 2012)(Manson, 2006), suggests that a complexity theory approach, together with mixed methods tactics of urban analysis, can uncover useful new knowledge about urban sites.

**Integrative Method**

A practical complexity sciences approach to research in the social sciences proposes integrative method as an appropriate ‘toolkit’ for understanding urban and other systems (Byrne, 2001:64). This is derived from methods developed at the International Ecotechnology Centre (IERC) at De Montfort (formerly Cranfield) University, Leicester, UK, to study, diagnose and manage environmental change. In relation to ‘understanding the urban’, Byrne defines integrative method as having five characteristics: historical, exploratory, mixed methods, reflexivity, and a focus on action (rather than simply aiming to develop a set of prescriptions)(Byrne, 2001:71). Four processes are argued to be involved in a practical complexity sciences approach and integrative method : exploring, classifying, interpreting and ordering (Byrne, 2001:67). This study seeks to extend Byrne’s concept of integrative method from the social sciences field to exploration and evaluation of urban sites for urban design by implementing Byrne’s four processes, and foregrounding his five characteristics of a practical complexity sciences approach.
This third part of Chapter Four has outlined evaluation methods for urban sites with emphasis on three areas of the literature, compositional, configurational and system aspects of urban design, within an integrative frame. It can be added that compositional (morphological) research is associated primarily with dense historic urban sites, configurational (space syntax) approaches vary from historic environments to regional scales, while systems analysis approaches can combine the two others with specific observational fieldwork, and so cross the urban design scales well. The importance of an integrative frame is also emphasized. The three literatures are collected here in order to demonstrate the broad range of temporalities, scales and urban sites which can be analysed under a complexity frame. In summary, an integrative ‘three-issue’ and ‘nine criteria’ approach to evaluation of urban sites and a practical complexity sciences approach is proposed for exploration, evaluation, and visualisation, to extend and deepen the concept of spatial complexity for urban design.
4.4 Proposed criteria of spatial complexity

This section describes the relevant criteria of spatial complexity selected to explore and evaluate urban sites (for urban analysis and design) in this thesis. As described above, evaluation criteria are seen as constituent measurable aspects within the three issues related to spatial complexity of urban sites as defined in Section 3.2. In this structure, for both exploration and evaluation, each issue has three constituent measurable criteria: composition (urban form, land use mix, density) configuration (integration, choice, intelligibility) and system (street network, path network, and pedestrian movement network). These features are considered in so-called ‘static’ evaluations, that is, based on a fixed ‘once-off’ assessment of the physical environment, unlike ‘dynamic’ or longitudinal evaluation, taken in stages or reviewed over time. The sequential nature of the exploration and evaluation methods employed here can be seen as a cumulative process, whereby information gathered to explore and evaluate compositional properties in the first instance, is supplemented by information gathered to explore and evaluate configurational properties, and in turn both are assembled in advance of considering system properties of urban sites. Availability of data, site type and size are important considerations in specifying criteria to be applied in this urban site analysis. The combination of desktop, secondary and fieldwork sources and data are also significant in the selection of particular analysis methods within criteria of the three issues of spatial complexity described. Also, different site types (e.g. inner urban vs suburban) suit different criteria and methods to analyse urban sites though all are applied uniformly across the three cases of this study, in order to provide a baseline set of measures, from which benchmarks of spatial complexity of Irish urban sites could be derived in the future, following further studies. The three different criteria selected within each issue are now individually defined and described in detail. Included in these
descriptions are the advantages and limitations of considering each of the criteria, and discussion of possible analysis methods for each, associated with urban design research and practice.

4.4.1 Exploration and evaluation criteria

<table>
<thead>
<tr>
<th>Issues</th>
<th>Composition</th>
<th>Configuration</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>Urban form</td>
<td>Land-use mix</td>
<td>Density</td>
</tr>
<tr>
<td>Exploration</td>
<td>Protected buildings and historic sites</td>
<td>Building Address points</td>
<td>Residential and Employment Population Density mapping</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Urban morphological complexity sub-indices of urban sites</td>
<td>Mixed-use Index, MUI (Van Den Hoek, 2007) of urban sites</td>
<td>Plat Ratio/Site Coverage of urban sites</td>
</tr>
</tbody>
</table>

Table 4-1. All proposed issues and criteria of spatial complexity

The proposed separate exploration and evaluation criteria of spatial complexity of urban sites are set out in Table 4-1. The aim is to explore at larger city scales, and to evaluate at urban site scale, that of urban design. Therefore, different criteria, input data and assessment methods apply at two different scales. Each of these are now described in more detail, under headings of the three component issues of spatial complexity to be explored and evaluated: composition, configuration and system. In summary, two scales are examined, (case context and urban site), three issues are concentrated on, and three criteria apply to each issue, so a total of nine criteria of spatial complexity are analysed.
4.4.2 Compositional criteria of spatial complexity

<table>
<thead>
<tr>
<th>Issues</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>Urban form</td>
</tr>
<tr>
<td>Exploration</td>
<td>Protected buildings and historic sites</td>
</tr>
<tr>
<td>Evaluation</td>
<td>7 urban morphological complexity sub-indices of urban sites</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attributes Summary</th>
<th>Urban form (urban morphological complexity)</th>
<th>Land-use mix MXI</th>
<th>Density</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metric indicators</td>
<td>Triangle</td>
<td>Correlational graph</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highest</td>
<td>High trifunctional</td>
<td>3.0</td>
<td>90%</td>
<td>Red</td>
</tr>
<tr>
<td>Average</td>
<td>Average bifunctional</td>
<td>1.5-2.0</td>
<td>67%</td>
<td>Green</td>
</tr>
<tr>
<td>Minimum</td>
<td>Minimum monofunctional</td>
<td>0.5</td>
<td>45%</td>
<td>Blue</td>
</tr>
</tbody>
</table>

Table 4-2. Issue (top) and proposed compositional criteria (bottom)

Indicator bands for evaluation of compositional complexity: urban form, (source, Author), land-use mix, (Van Den Hoek, 2008, 2009), density, Author (from highest and lowest pilot case measures)

The compositional criteria considered most important to explore and evaluate spatial complexity of the urban sites of this thesis are firstly, urban form, secondly, land-use mix and thirdly, density. Each is set out in Table 4-2, and proposed relevant accompanying indicator band measures of urban sites are shown. Each is now defined and described. Indicator bands are numeric or other measures of high, medium and low evaluated status.
Urban form

Urban form has been defined widely in the literature (Schwarz, 2010:30), from the all-encompassing definition as ‘type of urban environment’ (Berghauser Pont, 2010:22) to focusing more specifically for urban design on aspects including ‘size, density, grain, outline, pattern’ (Lynch, 1954:17). In this study, the term urban form is used to refer to physical structure of urban sites, the objects of the study.

<table>
<thead>
<tr>
<th>Issue</th>
<th>Criteria</th>
<th>Method</th>
<th>Source</th>
<th>Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>Urban form</td>
<td>Power Law Distribution</td>
<td>(Salat, 2012:29)</td>
<td>low-medium-high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passive Volume Ratio</td>
<td>(Salat, 2012:34)</td>
<td>%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Street type</td>
<td>(Marshall, 2005:84)</td>
<td>ABCD</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plot Type</td>
<td>*(Song, Knaup, 2008:9)</td>
<td>Own door v mixed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Plots per hectare</td>
<td>(Jacobs, Appleyard, 1987:117)</td>
<td>/ha</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Blocks per hectare</td>
<td>(Dempsey, 2008:255)</td>
<td>/ha</td>
</tr>
<tr>
<td></td>
<td>Land Use Mix</td>
<td>Junctions per km sq</td>
<td>**(Song, Knaup, 2008:9)</td>
<td>/km</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Montgomery, 1998:107)</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>Plot Ratio/Site Coverage</td>
<td></td>
<td>Van Den Hook (2008, 2009),</td>
<td>percentage</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Steadman, in Carmona, 2014:205)</td>
<td>Ratio</td>
</tr>
</tbody>
</table>

Table 4-3. Literature on compositional criteria

Indicator bands for evaluation of compositional (urban morphological) complexity

An important part of the morphological analysis is a text driven account of the urban site, including hisotrical development, which in this study includes Conzenian and Scheer’s methods (See Appendix A, Morphology of Cases, Volume Two). Seven additional selected measures of urban form, and more specifically urban morphological complexity, are now briefly described: firstly, ‘power law distribution’ of streets (Salat, 2012), secondly, ‘passive volume ratio’ of urban blocks (Salat, 2012), thirdly ‘ABCD street type analysis’ (Marshall, 2005). The fourth, fifth, sixth and seventh measures are:
plot type, plots per hectare, blocks per hectare, and junctions per km sq. Each is set out in Table 4-2, and accompanying methods and indicator bands applicable to evaluate various urban site types are shown. In relation to the first measurable aspect of Salat’s two methods adopted in this research for evaluating complexity of urban form, ‘power law distribution’ of streets is one of Salat’s stated ‘toolbox’ of methods aimed at assessing the ‘structural efficiency of urban structures’ (Salat, 2012)\(^\text{77}\). In this reading, an evolving power law distribution is seen as contributing to more energy efficiency and ‘structural complexity’ over time, which the author argues includes a ‘scale free complexity’, meaning that regarding complexity ‘there is no one predominant scale’ (Salat and Bourdic, 2012) (Salat, 2012:30). This evaluation method is chosen because of its clear applicability for urban design practice. In relation to the second measurable aspect of Salat’s two methods adopted in this research for evaluating complexity of urban form, passive volume ratio builds on work by Ratti on energy consumption and urban texture (Ratti, 2005:768). Passive volume ratio in a building has been defined by Salat as ‘the ratio of the volume of passive zones within a building (normally 6m) over the total volume of the building’ (Salat, 2012:34). Salat states: ‘the more complex the urban tissue, the higher the passive volume ratio. By ‘urban tissue’, Salat means the general urban morphological pattern of the area. This evaluation method is chosen because of its clear applicability for urban design practice. This is based on the claimed links between complexity of urban form and resilience, efficiency and sustainability of urban form.

In relation to the third proposed method of evaluating urban morphological complexity in diverse urban environments, ‘ABCD typology’ analysis is part of Marshall’s wider

\(^{77}\) Salat states: ‘open complex systems tend to be structured in the most energy-efficient way that is based on a power law distribution. In an open complex system, energy considerations impose a relationship between the different scales of the system. It imposes a mathematical relationship between the size of a given element and the number of elements of this size: few big elements, more medium-size elements, and a big number of small elements. (Salat, 2012:29).
aim to develop a system of pattern classification of streets, ‘relating to desired formations of urban streets’ (Marshall, 2005:83). ABCD typology is described as having been developed ‘with the intention of reflecting typical street patterns that are encountered in different kinds of urban analysis’ (Marshall, 2005:84). It is further described by its originator as ‘one of a series of qualitative descriptors that culminate in a systematic classification system’ (Marshall, 2005:84). This method is chosen for direct applicability to practice, and has recently been used in a useful mixed methods approach to an analysis of urban typology and configuration (Berghauser Pont, Marcus, 2015). Another of Marshall’s descriptors of street patterns, street network complexity analysis, is defined and discussed later as one of the selected system issues of spatial complexity. Plot type analysis, the fourth aspect, has been used to measure quantitative characteristics of neighbourhoods (Song, Knaap, 2008:9) and in this study the geometric character of plots is concentrated on. Plots per hectare (Jacobs, Appleyard, 1987:117), blocks per hectare (Dempsey, 2008:255), and junctions per km sq. (Montgomery, 1998:107) (Song, Knaap, 2008:9) are other commonly used measures in urban analysis and design, selected to help to define a comparable difference in these compositional characteristics of urban sites. In line with the overall practice and evidence related aims of this study (See Section 1.4.1), which are firstly to investigate the relationship between spatial complexity, urban sites and evaluation, and secondly to demonstrate an evaluation tool, distinct, contrasting and comparable evaluated conditions of urban morphological and spatial complexity are sought, through use of these seven measures of urban form78.

78 In this study, for exploration of compositional complexity related to urban form, secondary sources are used to identify clusters of protected structures and historic sites, seen as locations of ‘artefactual’ or compositional complexity at city scale. For evaluation of compositional complexity in this study, primary data is generated by testing the seven selected measures of urban morphological complexity for the case urban sites.
Land-Use Mix

The selected method of evaluating land-use mix in this study is based on a tool developed to measure various types of multifunctionality of land use by Van Den Hoek (2008, 2009), which he called the ‘Mixed Use Index (MXI)’. The originator of the tool argues that ‘different MXI’s represent different types of urbanities’ (Van Den Hoek, 2009:83). This tool quantifies land area of the different functional uses, and the relative occurrence (in percentage terms) of certain types of land or functional use in a given location. The tool is useful to this study because commonly used measures of development in Irish urban design practice (plot ratio, site coverage) can be applied. The tool has been used in multiple relevant investigations of the urban environment, including one which showed high correlation between urban land-use mix, density and configurational integration (Van Nes, Berghauser Pont, Mashoodi, 2012). In employing land-use mix assessment to represent compositional complexity, some assumptions are made. These include the fact that the urban composition or ‘grain’ of urban sites of evaluated multifunctionality are assumed to be more compositionally complex than monofunctional ones. This is because of the resolution of the analysis, at area level, which captures individual buildings, (according to property ownership outlines) so for example mixed-use buildings are evident individually, and these would be expected to require more complex spatial composition than monofunctional ones. In this study, for exploration of land-use mix, secondary sources on address points of the city are studied, dividing uses into three use categories. For evaluation of land-use mix in this study, primary data is generated through attaining the ‘Mixed Use Index’ (MXI) for the case urban sites.

---

79 Van Den Hoek argues that, over time, the scale level of the physical mix and the grain size of working and living activities has increased, from function mix at the scale of the building to function mix at the scale of the region (Van Den Hoek, 2009:73).

80 Residential use (yellow), commercial (purple) and mixed residential and commercial buildings (green) are mapped at sufficient resolution to visually identify clusters of land-use mix at whole city scales.
Density

Urban density and compositional complexity are not specifically linked in the literature, though the broader concept of urban complexity and density are often associated (Jacobs, 1961)(Batty, 2008). In one relevant study, reductions in urban complexity are associated with less diversity in the Spanish context, and these changes are related to the ‘Anglo-Saxon urban tradition of low-density housing typologies’ (Munoz, 2003:385). In evaluating urban sites, high compositional complexity is considered in this thesis to be co-incident with high density, although it is accepted that this is dependant on the scale resolution of analysis.

One relevant tool of urban analysis, Spacematrix, defined as: ‘a model which demonstrates the relation between urban density, urban typology and performativity’ (Berghauser Pont, 2010), includes a three-dimensional box type visualization matrix of evaluation of urban density. In data visualization terms, this is described as a ‘data box’ (although this term is not defined). Spacematrix defines density as a multi-variable phenomenon and makes a correlation between density and the built mass (urban form). Spacematrix uses the following three measures: floor space index (FSI), ground space index (GSI), and network density (N) (Van Nes, Berghauser Pont, 2012:3). Other related research on density, which combines Spacematrix with other methods (Nes and Berghauser Pont, 2012), is shown to add a finer grain to strategic planning approaches. As described in Chapter One of this thesis, the SpaceMatrix authors outline three uses of their ‘Spacemate’ application (described as ‘one projection of the Spacematrix), described as follows: “prescriptive: guiding the urban design process, descriptive: analysing and comparing urban environments and monitoring spatial developments, and explorative: optimizing the relationship between urban density, form and performance
in research and design.” (Berghauser Pont & Haupt, 2009:179). Berghauser Pont and Haupt distinguish between prescription and description applications. In relation to description, the authors state: “form already exists and density is a descriptive outcome.” (Berghauser Pont & Haupt, 2009:178) This statement is interpreted here to mean that the authors of the study consider that the description of density according to their methods (including SpaceMatrix, Spacemate) is a useful description of this urban form for urban analysis and design. Prescription, in relation to density and (urban) design, is described by the authors of the study as follows: “Using density to prescribe, or being ‘forced’ to design under certain density conditions, implies that the density standard is first applied and then form emerges.” (Berghauser Pont & Haupt, 2009:178). A modified version of the Spacematrix tool, more directly applicable in urban design practice, is proposed for this study, and now described.

For the purposes of urban site density analysis in this thesis, the meaning of Floor space index (FSI) in the Spacematrix tool (Berghauser Pont, 2010) is equated with and substituted by ‘plot ratio’81, a common measure in planning practice which is argued to be its equivalent (Steadman, 2014:205). Ground space index (GSI) is equated with and substituted by ‘site coverage’82, another frequently used tool of evaluation of planning development proposal in urban sites. Among the advantages of the Spacematrix method is that the ‘resolution’ at which Spacematrix operates is claimed to be mid-way between the ‘statistical’ and the ‘subjective’ definitions of density, and also mid-way between the smallest unit of the built environment (‘cell’) and the largest (region) as indicated in

81 ‘Plot ratio’ is described by Dublin City Council as ‘a tool to help control the bulk and mass of buildings’ and defined as ‘the amount of floor space in relation (proportionally) to the site area, and is determined by the gross floor area of the building(s) divided by the site area’ (Chapter 16, Section 16.5, Pg. 160) (Dublin City Council Development Plan 2016-22, Written Statement).
82 ‘Site coverage’ is defined by Dublin City Council as ‘the percentage of the site covered by building structures, excluding the public roads and footpaths’ and described as ‘a tool particularly relevant in urban locations where open space and car parking standards may be relaxed’ (Chapter 16, Section 16.6, Pg. 160) (Dublin City Council Development Plan 2016-22, Written Statement).
a graphical image (Fig. 31) (Berghauser Pont and Haupt, 2010:140). The authors state that this position reflects the dialectical position of urbanism between planning and architecture. The theoretical and scalar focus outlined by Berghauser Pont and Haupt also coincides with that of this thesis research on evaluation of spatial complexity of urban sites. However, in an extension of the work of Berghauser Pont and Haupt, this thesis builds on Berghauser Pont and Haupt’s theoretical and methodological developments on considerations of density within one of three issues of spatial complexity, (density within compositional complexity), to be integrated with two other issues (configurational, system) which together constitute a useful conception of spatial complexity for urban sites and for urban design.

One potential limitation of Berghauser Pont and Haupt’s method of analysis of urban density is that it is potentially over-complicated. For example, the origin logic of the visual representation of the Radberg graph (Radberg, 1996) is not fully apparent in the Spacematrix tool. Furthermore, there seem to be extraneous aspects to the analysis, such as open space ratio, which Steadman does not consider important (Steadman, 2014:345). Also, there is possibly a cultural bias in favour of examining locations which have been highly urban historically, thus limiting usefulness for less urban locations, which are a feature of the Irish condition, for example. It is also unclear (despite interesting experiments by design students) how extensively this tool has been used in urban design practice since its initial development. In this study, for exploration of density, secondary sources of residential and employment density citywide are also studied. For evaluation of density in this study, primary data is generated by calculating plot ratio and site coverage for the case urban sites.
4.4.3 Configurational criteria of spatial complexity

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Integration</th>
<th>Choice</th>
<th>Intelligibility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exploration</td>
<td>Global Integration</td>
<td>Global Choice (Rn)</td>
<td>Whole city intelligibility</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Local Integration of urban sites</td>
<td>Choice (R400 metric) of urban sites</td>
<td>Intelligibility of urban sites</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attributes Summary</th>
<th>Integration</th>
<th>Choice</th>
<th>Intelligibility</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Global (HH)</td>
<td>Local (R3)</td>
<td>T1024 Choice R400 metric</td>
<td>Scattergram</td>
</tr>
<tr>
<td>Highest</td>
<td>0.813257</td>
<td>3.97927</td>
<td>3315</td>
<td>0.80063*</td>
</tr>
<tr>
<td>Average</td>
<td>0.558034</td>
<td>1.43858</td>
<td>106.881</td>
<td>0.585241</td>
</tr>
<tr>
<td>Minimum</td>
<td>0.301597</td>
<td>0.33333</td>
<td>0</td>
<td>0.309818*</td>
</tr>
</tbody>
</table>

Table 4-4. Issue (top), and proposed configurational criteria (bottom)

Indicator bands for exploration and evaluation configurational criteria of spatial complexity (from Dublin Axial Map)
*0.80063 is intelligibility reading of most intelligible axial line (top right of scattergram, Dorset Street, Dublin 1., while 0.309818 is intelligibility reading of least intelligible axial line (bottom left scattergram, Bailey Lighthouse, Howth.
** ‘Average’ Intelligibility locations Selection, Average 0.585241, Count 46 (axial lines selected)
*** X Axis, Integration (HH), Y axis, Connectivity

The configurational criteria considered most important to explore and evaluate spatial complexity in this study are firstly integration, secondly, choice and thirdly, intelligibility. Each is set out in Table 4-3, and accompanying methods and indicator bands applicable to various urban site types are shown. Although it is regarded that some locations are not ideal for analysis by Space Syntax methods (Marshall, 2005:111), in this research these methods have been calibrated to suit the low urban
density and character where appropriate, by varying radii and number of steps chosen as demonstrated elsewhere (Marcus et al, 2015). Space syntax theory states, in simple terms: ‘the form-function relation in buildings and cities passes through the structural properties of whole configurations’ (Hillier, 1998:37). The purpose of analysing configurational indices is to capture these characteristics of specific urban sites in a global, (or whole configuration) and local (urban site) context simultaneously. Hillier further states:

Nonlocal, (or extrinsic) properties (of spaces) are those which are defined by the relation of elements to all others in the system, rather than those which are intrinsic to the element itself. The method also leads to a powerful analysis of urban structures because cities are essentially nonlocal systems. (Hillier, 1999:169)

Hillier makes the following claim for the use of the axial map, the primary instrument of analysis:

‘However variable the precise spatial morphology of the city, we will usually find that it is constructed through consistent relations of some kind between the two prime geometric variables of the axial map: line lengths and angles of incidence.’ (Hillier, 1999:173)

In this thesis, analysis involves selected configurational properties of urban sites, which are examined using DepthmapX software, and those evaluated in this thesis are integration, choice and intelligibility, at both global and local levels or scales. (See Appendix E, Syntactic Analysis of Dublin). These are seen as especially relevant to understandings of spatial complexity for urban sites. Each is now individually defined and described.
Integration

In space syntax analysis the social patterns which, it is argued, are embedded in spatial configurations are tested through geometrical representations of the spaces, which are examined for levels of perceived ‘integration’ or ‘segregation’. The graph measures are used in order to inform configurational representations of space, including shallow graphs, indicating that spaces (like streets and squares) are integrated (have high accessibility between spaces) and deep graphs, indicating that spaces are highly segregated from each other. Integration is a defined in syntactical analysis as a static global measure in axial analysis. It describes the average depth of a space to all other spaces in the system. The spaces of a system can be ranked from the most integrated to the most segregated (Klarqvist, 1993:12). When an entire system is indicated in layout terms, it can be assessed for global integration (indicating the extent to which each space is ‘close’ to every other space measured) or for local integration (indicating the extent to which each space up to only a certain number of steps is measured). While these are quantitative measures, in response to analysis where inputs may vary, it is argued that these measures can reflect social patterns which are embedded in space (Hillier et al., 1993) (Hillier, 1996). It is further claimed that observation of movement through space (pedestrians, vehicles) can show correlations between the configurational analysis of spatial layouts and observed movement and activity, leading to potential for predicting aspects or effects of future changes in places (Hillier, 1997). Literature examining complexity and configurational integration includes analysis of housing type evolution and socio-spatial boundaries (Palaiologou et al, 2012), and a study of the need for co-presence as an aspect of urban complexity of public space (Marcus et al, 2012). Advantages of analysing integration include the fact that this attribute of a spatial network can be numerically represented, and so easily compared with other sites. Also,
it allows the ranking of spaces in a system from the most integrated to the most segregated, thus contributing in this thesis to evaluation, by helping to categorise urban sites. Integration, as a syntactic measure, is likely to predict how many people are in a space (Al Sayed, 2014:15) and so can contribute to evaluation of qualities of individual urban sites. The primary limitations associated with integration analysis include a two-dimensional focus rather than a three-dimensional representation of space, and a perceived over-emphasis on mathematical aspects, and ‘analytic computer exploiting techniques’ (Buchanan, 2013). In this study, for exploration of integration, a global measure is derived from the Dublin Axial Map. For evaluation of integration in this study, primary data is also generated about local integration for the case urban sites from the Dublin Axial Map.
Choice

Griffiths defines choice in syntactical analysis as follows: ‘Choice measures the extent to which one space rests on a path between two other spaces, relating to all other spaces in the system, within a given network radius’ (Griffiths, 2014:164). The analysis of (syntactic) choice is a feature of the analysis of large and highly urban sites (Hillier, Lida, 2005) as well as mixed urban and suburban locations (Chiaradia et al, 2013). As an indicator of configurational characteristics of urban form choice is (along with integration) one of the two most commonly used centrality measures in space syntax analysis (Marcus, 2015:6) and so has many comparison urban sites with which to compare findings. As regards a definition of choice for assessment of syntactical configuration, the following is relevant: ‘Like integration, choice has to do with the structural properties of urban form that make cities intelligible (centres will usually be high choice places), but it is more useful than integration in understanding the scale dynamics of urban growth processes’ (Griffiths, 2014:164). As regards limitations of this analysis method, it is relatively recent, and Griffiths considers that ‘choice is less well understood than integration, mainly because its widespread use is more recent and associated with segment angular analysis’ (Griffiths, 2014:164). Also, choice is associated with structuring the geographical scale at which urban-like space emerges (Griffiths, 2014:164) and so could be linked with a primarily abstract and ‘macro’ understanding of space. In this study, for exploration of choice attributes, global choice (Rn) is derived from the Dublin Axial Map. For evaluation of choice in this study, primary data is also generated about Radius 400 metric choice for the case urban sites according to the Dublin Axial Map.

83 One early encompassing glossary of terms in space syntax includes the following commentary describing choice: ‘Global choice is a dynamic global measure of the “flow” through a space. A space has a strong choice value when many of the shortest paths, connecting all spaces to all spaces of a system, passes through it.’ Klarqvist B. (1993) A space syntax glossary. Nordisk Arkitekturforskning 2. (Klarqvist,1993:12).
Intelligibility

Intelligibility is defined in the field of syntactical analysis as: ‘an axial graph measure that represents the relationship between streets that have high connections to other streets (connectivity) and streets that are more integrated in an axial system’ (Al-Sayed, 2014:174)\(^4\). In overall ‘whole city unit’ terms, intelligibility can be evaluated also, and it is claimed: ‘A gridiron urban system is ...highly intelligible...the highly ordered forest and the disordered one are both considered extreme examples in terms of intelligibility’ (El-Khouly, 2012). In this analysis, high intelligibility is considered to be ordered, and low intelligibility disordered. One stated advantage of assessing intelligibility is that ‘it helps identifying how easy it is for one in a local position to comprehend the global structure’ (of a spatial network) (AL Sayed, 2012:15). Another advantage of assessing intelligibility relates to Hillier’s claim that ‘an intelligible system is one in which well-connected spaces also tend to be well integrated spaces’ (Hillier, 1999: 194), which indicates that a system can be evaluated for levels of high or low intelligibility. This allows broad understandings of this configurational property of whole systems to be proposed, as well as evaluations of their constituent parts (for example, urban sites). Intelligibility as a concept has been associated with cognition and wayfinding, and it could be argued that the method represents populations who already know urban locations, rather than visitors, for example\(^5\). In this study, for exploration of intelligibility, a whole city measure is derived from the Dublin Axial Map. For evaluation of intelligibility in this study, primary data is also generated about intelligibility at local scales from the Dublin Axial Map for the case urban sites.

\(^4\) In defining intelligibility, the literature agrees that this second order measure or quality ranks prominently in the order of analytical terms used in space syntax. Another general glossary description states: ‘It is also possible to develop second order measures by correlating these four first order measures (The four first order measures are: ‘connectivity’, ‘integration’, ‘control value’, and ‘global choice’). Intelligibility, for example, is the correlation between connectivity and integration and describes how far the depth of a space from the layout as a whole can be inferred from the number of its direct connections, i. e. what can be understood of the global relation of a space from what can be observed within that space’ (Klarqvist, 1993:12).

\(^5\) However, it is claimed that space syntax research has shown that key elements of a good wayfinding environment are structurally (that is, configurationally) inherent to it (Bafna, 2003:28).
### 4.4.4 System criteria of spatial complexity

<table>
<thead>
<tr>
<th>Issue</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria</td>
<td>Pattern (Street network complexity)</td>
</tr>
<tr>
<td></td>
<td>Path (Path network complexity)</td>
</tr>
<tr>
<td></td>
<td>People (Pedestrian movement network complexity)</td>
</tr>
<tr>
<td>Evaluation</td>
<td>City Connectivity of road segments</td>
</tr>
<tr>
<td></td>
<td>City Walkability indices</td>
</tr>
<tr>
<td></td>
<td>City Pedestrian counts Data (DCC, BIDS)</td>
</tr>
<tr>
<td>Attributes</td>
<td>ABCD categorisation, street network complexity of urban sites</td>
</tr>
<tr>
<td>Summary</td>
<td>Metric reach of urban sites</td>
</tr>
<tr>
<td>Attributes</td>
<td>Gate counts, timelapse of urban sites</td>
</tr>
</tbody>
</table>

**Table 4-5. Issue (top), and proposed system criteria (bottom)**

Indicator bands for evaluation of system complexity: connectivity of road segments, (Nedovic-Budic et al, 2016:156) Fig. 5, walkability indices, (D’Arcy, 2013:213) Table 5-5, ‘Objective GIS results for method 4’, and pedestrian movement, various sources (see text this section).

The system criteria considered most important to explore and evaluate spatial complexity in this study are firstly ‘patterns’ (street network complexity), secondly ‘paths’ (path network complexity) and thirdly ‘people’ (pedestrian movement network complexity). Each is set out in Table 4-5, and accompanying methods and indicator bands applicable to various urban site types are shown. Patterns are seen here specifically as geometrical street network characteristics (Marshall, 2005)(Porta, 2006)(Nel, 2015)(Salat, 2011). Paths are understood as finer or more ‘capillary-like’
systems of pedestrian routes (Guerreiro, 2012)(Porta, 2008)(Guaralda, 2011) inscribed in land, whether formal footpaths, or less formal desire line paths in grassland, or alleyways and lanes embedded in urban fabric. The third aspect of system complexity assessment, ‘people’ here refers to human movement as a complex system (Wei, 2015) (ie. here, urban pedestrians) in urban spaces (Ozbil, 2011)(McArdle, 2014), and here specifically the movement of pedestrians in centres of urban sites is concentrated on. The three issues of system evaluation of urban sites considered important for this thesis are now individually defined and described.
Street network complexity (Patterns)

The first of three criteria of system complexity evaluated here is a measure of street networks system complexity. In particular, for Irish urban sites, where local distinctions in levels of urbanity⁸⁶ could be different to other European countries for example, it is possible that a finer resolution of the urban network could reveal information about the spatial nature of network complexity of urban sites. In this study, for exploration of street network complexity, secondary data on connectivity of road segments is analysed. Internal and external connectivity were measured for Dublin by Nedovic-Budic et al (2016), and defined for measurement at 1km x 1km grid cell resolution⁸⁷. For evaluation of street network complexity in this study, Marshall’s method of measuring street network complexity is employed for case urban sites. Primary data on street network complexity of case urban sites is generated. Described in his book ‘Streets and Patterns’ (Marshall, 2005), this is a directly applicable ‘test’ of constructed real system complexity, for urban analysis and design. One advantage of using this method is that measures derived for Dublin urban sites can be compared ‘like for like’ with other street networks studied in Marshall’s book. However, a possible limitation is acknowledged by its author (Marshall, 2005), who recognises that not all of the properties of complexity of routes and connections in the urban environment can be captured by the street networks system complexity measurement method, and that streets do not necessarily fit easily into a hierarchical ordering. However, in order to begin a collection of measured cases for Irish urban design practice use, this method is selected.

---

⁸⁶ In relation to discussion of ‘Irish urbanity’ characteristics of this could include less urban land, lower urban population densities, lower diversity of urban uses, more recently developed urban centres, and more ‘informal’ urban form than in the UK. For example, Eurostat estimates that as little as 1.3% of the geographical footprint of Ireland is ‘urban’. (Source: Eurostat Regional Yearbook 2013).

⁸⁷ A fuller description of this aspect is contained in Chapter Five, Section 5.2.1.3, ‘System overview of Dublin’.
Path network complexity (Paths)

To home in on some finer scales of the urban system, a second criterion of system complexity in this thesis is a measure of pedestrian footpath (referred to here as ‘path’) networks in the urban sites examined, following Wei’s definition of human movement as ‘a complex system’ (Wei, 2015:87). The term ‘paths’ in this description therefore refers to pedestrian path network complexity, as this shortened version conveys well the distinction with the other two aspects studied. In one research output, pedestrian networks are seen as connected to ‘opportunistic urban design’ (Guerreiro, 2012), evaluated through a combination of ethnographic and observation techniques, wherein pedestrian movement is considered a fundamental aspect of environmental performance within the study of the spatial form of the city. Hence, official and other path networks of urban sites are recorded and examined for evidence of complexity, seen as part of a ‘matrix’ of urban sites.88

In this study, for exploration of path network complexity, secondary data on city walkability is used, to indicate broad areas of difference at whole city scale. D’Arcy et al (2013b:5)(Fig. 1, ‘Final Shortlisted areas’) measures high and low walkability areas in Dublin as points on a map, and these can be assigned to a 1km x 1km grid cell for exploratory purposes. For evaluation of path network complexity in this study, primary data on metric reach of urban sites is generated for the case urban sites. Metric reach can be defined as ‘the network length that can be covered walking in all possible directions from a point of origin for a specified distance threshold, and is essentially a means of measuring the density of available footpaths’ (Ellis et al, 2016:141).

---

88 Scheer (2016) defines the concept of boundary matrix as ‘the subdivision of an area into bounded spaces including plot, and the space or rights of way of the streets and the delimited space devoted to other continuous paths (for example, highways railways, trails, canals, greenways)’ (Scheer, 2016:14). The boundary matrix concept has particular relevance in non-urban or edge sites in this study.
Pedestrian movement network complexity (People)

The term ‘people’ in this description refers to pedestrian movement network complexity as this shortened version also conveys well the distinction with the other two aspects studied, as described above. The human movement system is a complex system (Wei, 2015:87) revealing hallmark characteristics such as:

‘many interacting sub-systems, multiple interactions within and between levels of analysis, emergence of movement coordination modes, and the exhibition of varying levels of complexity of system output that continually evolve with the learning and development over the lifespan’ (Mayer-Kress, 2006:40).

McArdle et al (2014) suggests that pedestrian movement behaviour can be classified using visualisation and clustering, and that movement data can identify spatiotemporal patterns. Ozbil et al (2011) suggests a link between street connectivity, land use and pedestrian flows, and it is claimed that this link is useful in evaluating and development of designs, which in turn supports vibrant urban communities. In recognition of the fact that some complexity is dynamic, moving, and harder to capture, it is accepted that this evaluation method can only begin to record some more dynamically changing and ephemeral aspects of urban sites, like crowd surges at times of large events, moments of historic importance, or the temporary occupation of an urban site. One aspect which has established measurement methods, and which can function as a support for other evidence (like compositional and configurational readings) is observation data about people moving in urban sites. In this study, for exploration of pedestrian movement network complexity, three secondary sources of Dublin footfall databases are studied, as these are currently under-examined for urban analysis and design. For evaluation of pedestrian movement network complexity in this study, primary data is generated for the case urban sites.
Two complementary methods are used to collect primary pedestrian observation data: firstly, timelapse observation and secondly, gate counts. Timelapse observation is proposed to record movement of pedestrians in central point locations of the urban sites, using stop motion digital video, with a camera positioned to maximise viewing of expected busy centres of urban sites. Gate counts are proposed to gain an overview of pedestrian movement into and out of urban sites, as well as description of types of pedestrians moving. The core interest in combining these two observation methods is in identifying size (Batty, 2008), clusters (Gal, Doytscher, 2014:526) and diversity (Page, 2011) as indicators of complexity. Applied to the pedestrian movement system, these three indicators can indicate pedestrian movement network complexity. The protocols to undertake all of these tests are described in Volume Two, Appendix B, ‘Evaluation Protocols’.

In summary, this section has set out a proposed structure around evaluation of spatial complexity of urban sites, including three proposed ‘issues’ to evaluate in considering spatial complexity related to respectively, composition, configuration and system. Issues are understood in this reading as themes that need to be addressed to achieve core goals such as optimal or ‘preferred’ levels of spatial complexity in an urban site. This section answers the second question of this Chapter, by outlining the issues which are most important to consider in devising a conceptual framework around spatial complexity. This part of the study further describes in detail the proposed criteria of spatial complexity applying to each of the three issues, as urban structure/form, use, and density (compositional criteria), integration, choice, and intelligibility (configurational criteria) and patterns, paths and people (system criteria). Later Chapters will describe detail of so-called ‘indicators’ or exact measures of these criteria, in advance of urban site evaluations.
4.5 Toolbox and Databox: evaluating and visualising spatial complexity

This section begins by asking the third question of this Chapter, how can different issues of spatial complexity be weighted in importance, and how can this weighting be visually accessible for use in practice? Then a proposal is made to introduce visualization techniques which can enhance data analysis and interpretation, and two instruments, a Toolbox and a Databox. As regards cross-case synthesis, one of the two selected ‘exploratory’ techniques for data analysis for this study, Yin’s suggestion of creating ‘word tables’ to display data from across the cases according to some uniform framework (Yin, 2003b:134) is employed in the Databox and Toolbox approaches described here. Word tables help to illustrate patterns across cases, and in deriving cross case conclusions. Word tables depend on argumentative interpretation, and strong, plausible and fair arguments are recommended to be developed, which are supported by the data (Yin, 2003b:137). In the present study, this aspect is represented by the findings and discussion parts of Chapter Seven, which report on results of data analysis in relation to the single major proposition, and three minor propositions of this study.

The major hypothesis or proposition is that evaluated levels of spatial complexity in urban sites depend on compositional, configurational and system properties. It is demonstrated in this and the next two Chapters that this proposition can be tested, and that evaluation tools can be devised and applied to explore, evaluate and visualise current spatial complexity conditions.

89 The three minor propositions of this study, following from the major proposition, as described in Chapter One, ‘1.3.3 : The Research Hypothesis’, are related to composition, configuration and system aspect sof urban sites, and are described in Chapter Three, Section 3.3.2 ‘This case study design’.
4.5.1 Weighting

“Showing complexity is hard work.” (Tufte, 1990:50)

Complexity science, in one reading, is open to almost any definition of entities and relations between, but for any given area of study, certain kinds of entities and relationships are ‘more common, important, and necessary than others’ (Manson & O’Sullivan, 2006:681). In this study urban sites are the important entities, and relations between three constituent ‘issues’ of spatial complexity (composition, configuration and system) are the important relations. One objective in this research to compare and correlate within, between and across urban site cases, and the concept of weighting arises. In the measurement of urban environments, evaluation tools weigh criteria by assigning a score value (or ‘weight’) for each element, but in neighbourhood sustainability assessment for example, it is considered one of the most theoretically controversial aspects (Sharifi, 2013:80). This is partly because it is extremely difficult to compare and rank different elements, together with the often subjective nature of scoring and weighting different criteria, and the result is a vulnerability of this practice to ambiguity.

Urban design evaluation techniques have been outlined and reviewed in the literature (Gil, 2008) and are considered to help define the urban development strategy and set assessment criteria and performance targets. However, evaluation techniques and tools like SWOT analysis are considered to not intervene during the design and implementation process as they are more geared towards ‘static’ evaluation of results of development. Meanwhile, guidance like ‘By Design’ guidelines are considered helpful for reference, but cannot be applied to the urban design process (Gil, 2008:258).
Consistent and iterative evaluation is called for during the urban design process, with both quantitative and qualitative output, as well as a graphical user interface ‘to provide dynamic visualisations of complex urban phenomena to sustain meaningful stimulation of the urban (design) process’ (Gil, 2008:261). Gil calls for diagrams resulting from evaluation to be ‘operational’: i.e. “immediately usable in the design process without expert intervention for further technical manipulation or statistical analysis” (Gil, 2008:262). He describes urban design evaluation results as providing ‘summary diagrams of specific analytic parameters that usually take the form of charts, tables and maps’ but does not suggest weighting methods for clarifying the relationships between these varying outputs (Gil, 2008:262). In a more recent paper, Gil clarifies his opinion that urban design ‘scores’ and relative numerical weightings, while possibly of interest in final certification of a development, are not useful in the urban design process, and are part of the serious difficulties in assessing results of indicators for urban design (Gil, 2013:314). This study combines numerical and qualitative analysis with innovative cross-scalar visualisations to overcome this limitation of numerical evaluation of urban design.

In defining the approach adopted to criteria of spatial complexity earlier, and distinguishing these from the term ‘variable’, (which could be associated with an over-quantitative reading of phenomena), the idea of weighting has similar associations. In this study, weighting of the criteria is carried out in an exploratory fashion. As mentioned in Section 3.3.6, given that the concept of spatial complexity is considered in this study to encompass both qualitative and quantitative aspects, the weighting will be even across both datasets. In relation to validity and qualitative research, it is suggested
that stronger data should be given more weighting than weaker data (Onwuegbuzie AJ and Leech, 2007). Equal weightings are recommended for most mixed methods studies (Creswell, 2009:195). This study helps to develop exploratory information for urban design on aspects of spatial complexity of urban sites by giving equal importance to all factors, in the absence of prior theory. This aligns with the exploratory case study approach adopted in this research.

Figure 4-10  Relevant visualization images of urban environment evaluation
Sources, from top left: (Berghauser Pont, 2010; Ye and Van Nes, 2013), (Marshall, 2005), (Radberg, 1996), (Gil, 2013)
4.5.2 Spatial complexity exploration methods

While earlier in this study concepts and methods of representation of spatial complexity in landscape were reviewed (Chapter Two, Section 2.2.1, ‘Spatial complexity, spatial planning and design’), here the related idea of ‘complexity maps’ are described and preparation of these is proposed as exploratory outputs of this study. In selecting methods for spatial complexity exploration above the scalar level of urban sites for urban design, prior theory and research in landscape suggests that concepts of spatial complexity can be usefully extended for urban design at this ‘higher’ scale.

In this study, while it is beyond the scope to seek an overarching paradigm of spatial complexity of the urban environment, two exploratory scales are proposed as contexts for the case urban sites, the evaluated units. The two exploratory scales are the whole-city scale, and the case context scale. The aim of this aspect of the study is to present exploration level understanding of spatial complexity derived from a number of secondary sources. The theoretical proposition, building on concepts derived from the review of landscape literature above, is that this aspect of urban sites can be investigated at the scalar level of the whole city, as well as case contexts scale. A visibility cluster analysis approach is adopted, as one of the six data analysis techniques of this study, data transformation. (See also, Appendix B, Evaluation Protocols, Section 4.0, ‘Note on deriving exploratory complexity maps’).

Diverse data sources are combined in a compositional complexity map to illustrate explored alignments between morphological, land-use and density aspects of the city in order to identify clusters and absences of compositional complexity. Whole city level measurement of syntactic aspects of Dublin city are examined to identify high and low
instances of integration, syntactic choice and intelligibility, in order to identify clusters and absences of configurational complexity. Thirdly, multiple data sources are combined to prepare a system complexity map of Dublin, in order to identify clusters and absences of system complexity. Finally the three exploratory complexity maps, (composition, configuration and system), are overlaid and to derive a spatial complexity map of the city. The two objectives in exploratory mappings of spatial complexity in this study are: firstly, to visually identify clusters of spatial complexity at city scale, and secondly to explore spatial complexity aspects of urban site contexts for urban design, in advance of case evaluations.

4.5.3 Urban evaluation visualization methods

As described above, a graphical user interface for urban design evaluation is sought: ‘to provide dynamic visualisations of complex urban phenomena to sustain meaningful stimulation of the urban (design) process’ (Gil, 2008:261). In relation to seeking and demonstrating linkages between cases and indices, appropriate representation has the potential to bring visual clarity to quantitative assessment, and also allow for qualitative interpretation by a wide community around evaluation. One extensive review of urban evaluation methods and visual representation of results (related to sustainability) emphasizes the visual aspects of tools:

The visual feedback provided by the tools is also important because formal measurement and informal interpretation go hand in hand (Carmona, 2003). Effective graphic communication of the results allows the involvement of a wider group of stakeholders and can provide a clearer overview of the strengths
and weaknesses of a proposal, thus operationalizing the evaluation process (Becker, 2004). (Gil, 2103:315)

According to this analysis therefore, urban design-specific evaluation relies especially on visual aspects of tools, and clear representation of results. As a result, the reasons to employ visualisation in this study can be summarised as:

- to stimulate the urban design process
- to bring visual clarity to quantitative and qualitative assessment
- to allow for qualitative interpretation by a wide community around evaluation
- to allow formal measurement and informal interpretation of results to be combined
- to allow the involvement of a wider group of stakeholders around evaluation

The primary objective in reporting results of exploration, evaluation and visualisation in this study is to usefully represent the evaluation carried out of three separate issues within the dimension of spatial complexity, and nine separate criteria evaluated. Another aim is to examine relevant spatial complexity characteristics present in the case study urban sites in a coherent way. In relation to aspects of weighting, data analysis and interpretation, it is instructive to briefly review visualization methods in the field of urban evaluation. Emphasising a lack of all-encompassing ontology within its theory, it is claimed that: ‘Complexity focuses on entities and relations among them, a premise that directs attention to the kinds and strengths of relationships in a system’ (Manson & O’Sullivan, 2006:681). In Chapter Three the selected research design involving multiple case study units (3) rather than one city ‘holistic’ study unit is outlined. In this thesis, relevant case study units and are clearly identifiable in scalar and formal terms as urban sites of the mid-size. Though the underlying theories are emergent, and are founded on
holistic aspects of complexity theories, it is important for this research in a complexity frame to acknowledge that the theory applies to all scales or levels: global, intermediate and detail scales. Significantly, the *connections* or ‘linkages’ (Yin, 2003b:11) between the different ‘levels’ of generality, or ‘holism’ on the one hand, and the detail or focused ‘levels’ on the other hand, are considered in complexity theory to be equal in importance to the distinct units of study themselves. The context of each case study unit is also explored in relation to spatial complexity levels. The combination of three separate case study units creates a condition whereby in-case, between case, and cross-case analysis can be employed, to better illuminate the cases (Yin, 2003b), allowing triangulation of results, and effective visualisation reveals this complexity.

**Selected visualisation approach**

In case study research it is a primary strategy that data sources, data types or researchers are triangulated appropriately, in order that it can be established that phenomena have been explored and viewed from multiple perspectives. Clear and accessible visual representation of this multi-scalar and multi-criteria analysis is important in this regard. In this thesis, correlation and comparison of case study data enhances overall data quality based on the principles of idea convergence and the confirmation of findings (Knafl & Breitmayer, 1989). The data gathered converges to illuminate the cases as well as the conditions studied in a new way. The fact that indices of spatial complexity vary related to time, scale and geography, and that these necessarily vary in each demonstrative case study unit, means that linkages between cases and indices become a rich source of descriptive account of phenomena.
Following from the discussion of the difference between data visualization and infographics of Chapter Two (Section 2.4.4), where the former is associated with algorithmic generation and the latter with manually generated images, here the visualization approach of this study can now be described. Data visualization, in categorization terms, is considered to have two types, exploration and explanation (Iliinsky et al, 2011:7), and each suggests different approaches and tools. So while exploratory data visualizations are associated with high levels of granularity, where large amounts of data are in play, at the data analysis phase of a project, the narrative emerging from the data is still to be set. Explanatory data visualizations, in contrast, are seen as connected more to facts which are already known to the designer/researcher, and to reporting more concrete results, and as part of the presentation phase of a project.

However, Iliinsky (2011:7) also proposes a third category, which is useful to this study, the hybrid ‘exploratory explanation data visualization’, seen as ‘a curated dataset’ (Iliinsky et al, 2011:8), which is presented in a way that allows the reader to interact with the dataset in some way. Information, persuasion and visual art are also considered relevant and important in understanding concepts of data visualization (Iliinsky et al, 2011:7), and it is in this respect that the connection between data visualizations and urban design as art⁹⁰ becomes important to this study. Iliinsky (Iliinsky et al, 2011:7) suggests that there are three main categories of explanatory visualizations based on the relationships between the three necessary players: the designer, the reader, and the data, considered as three essential supports to effective explanatory (or hybrid) data visualization. However, the dominant relation between two of these elements will

---

⁹⁰ The concept of urban design as ‘art’ is discussed again in Chapter Eight, Section 8.1.3.4, in relation to outputs of this study, and how they relate to urban analysis and design practice. The ‘designer’ referred to above, while understood in Iliinsky’s terms as the graphic designer/creator of the visualisations, could also be the urban designer, who also employs explanatory visualisation as part of practice. However, the urban designer could also be the ‘reader’ (or recipient) in these cases, ‘reading’ images by others.
determine the type of data visualization needed. Informative, persuasive and ‘visual art’ data visualizations are considered the three types to consider in deciding on data visualization type or categorisation.

So while informative visualizations distill information into consumable form (eg. for a newspaper), persuasive type visualizations seek to change a readers mind about something, from a specific point of view. The third category, visual art, is considered to serve primarily the relationship between the designer and the data (Iliinsky et al, 2011:10). Visual art is considered to be ‘unidirectional’ in form, that is, the reader may not be able to decode the visual presentation to understand the underlying information (Iliinsky et al, 2011:10). So while ‘both informative and persuasive visualizations are meant to be easily decodable—bidirectional in their encoding—visual art merely translates the data into a visual form’ (Iliinsky et al, 2011:10).

From the review of the data visualization literature, it is concluded that the majority of the representations (ie. non-text) in this study can be defined as ‘infographics’. Exploratory infographics are especially employed in the exploratory ‘whole-city’ explorations of spatial complexity. However, exploratory data visualizations are also derived and employed. These are especially used in the case study evaluations, to further informative and persuasive aims of the overall study. Extensive data visualization is not a feature of this study, partly due to limitations on the skills base of the researcher, but also because the concept of spatial complexity is not relying on prior theory, especially in the spatial sciences around urban design.
Introducing a ‘Toolbox’ and a ‘Databox’

In this research, the visual and graphical interrelations between indices are key to understanding the linkages and overlaps between criteria and issues, and connections between the three issues of spatial complexity evaluated. In order to coordinate the representation of data and information gathered in three separate urban sites, related to three issues and nine criteria of spatial complexity, two instruments of visualization are proposed, a ‘Toolbox’, and a ‘Databox’. Nine sequential steps in the evaluation of spatial complexity for urban analysis and design are therefore proposed one related to each criterion (numbered in Table 4-5). Sequence is important because a cumulative picture of quantitative, qualitative, and visual evidence is collected as each step is completed, and the method is repeatable and testable by other researchers. Gil defines four tool types for evaluating sustainability of urban design: design guides, calculation tools, assessment tools, and ratings systems. Calculation tools are defined as those which ‘allow aggregations of indicators for visualization in simple charts and in some cases display thematic maps of individual indicators (Gil, 2013:313). The proposed ‘Toolbox’ in this thesis is of a calculation tool type. The development of the conceptual framework around visualisation of spatial complexity for this study, including discussion of relevant concepts of resolution, use of pixels, and visualisation theory, are discussed in in Appendix F. The importance of considering the role of colour is also discussed, and a ‘degrees’ of colour key for indicating levels of spatial complexity is also presented in this Appendix. (Appendix F, Visualising Spatial Complexity’, Volume Two).
4.5.4 Toolbox

<table>
<thead>
<tr>
<th>Composition</th>
<th>Configuration</th>
<th>System</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Urban structure (Form)</td>
<td>4. Integration</td>
<td>7. Patterns (Street network complexity)</td>
</tr>
<tr>
<td>2. Land use (Function Use Mix FUI)</td>
<td>5. Choice</td>
<td>8. Paths (Pedestrian network complexity)</td>
</tr>
<tr>
<td>3. Density Plot ratio (FSI)</td>
<td>6. Intelligibility</td>
<td>9. People (movement system complexity)</td>
</tr>
</tbody>
</table>

Table 4-6. Proposed spatial complexity evaluation Toolbox

Gil charts the evolution of planning evaluation tools from ‘simple calculation methods to complex assessment frameworks’, and relates this change to the progress of planning evolution theory from ‘a positivist stance of instrumental rationality to a dialectic stance of communicative rationality (Khakee, 2003)’ (Gil, 2013:312). In this thesis a range of proposed tools, together comprising a ‘Toolbox’, are proposed to measure indicators of spatial complexity (See Table 4-6). The concept of employing analysis tools has been used extensively in urban analysis for design, including cartographic analysis and GIS as tools for urban morphological studies (Pinho, Oliveira, 2009), Gehl’s eight tools employed to study public life and systems of pedestrian flow (Gehl, 2013:22), and Whyte’s use of timelapse and mapping tools to observe use of small public spaces in New York (Whyte, 1980).
The Toolbox is seen as operating below the identified criteria of spatial complexity, within the overall structure of evaluation as described above. The tools are seen not only as decision and design support instruments, but also as evidence towards arguments for optimizing levels of evaluated spatial complexity in urban sites. In this way for example, planners (and conservation specialists in particular), could be guided by use of these evaluation tools in seeking to preserve the context of a conservation structure of architectural complexity, by using evaluation tools to characterize the spatial context of the structure. In this way, clarity and quantitative meaning can be added to concepts in urban conservation such as ‘curtilage’, and ‘architectural conservation area’, as well as policy understandings of ‘historic urban core’. Each tool is seen as operating independently, but the combination of tools builds a mixed quantitative and qualitative frame of understanding across exploration and evaluation of spatial complexity.

91 In Irish conservation planning, the term ‘curtilage’ refers to the area of ground that is directly connected with the functioning or inhabitation of a structure (Murray, 2011). Architectural Conservation Area (ACA) and historic urban core also have accepted (but sometimes contested) meanings in the conservation fields and literature, related to preservation of urban environments.
4.5.5 Databox

Figure 4-11  Indicative Databox visualization method of urban site evaluation

Source: Author, concept adapted from ‘Pedestrian movement in Delft city centre’, (Kveladze, 2015:62), (Fig. 3.12.) (See Appendix F, ‘Visualising Spatial Complexity’)

The concept of a Databox is now proposed in this thesis to enhance data visualization of evaluation results. This derives from the model of a ‘data cube’, a visualization technique common in data mining fields. An indicative proposed Databox is illustrated in Figure 4-11, showing a possible visualization method to accompany urban site evaluation. Data mining concepts and techniques are explored by reference to the book of that title (Han & Kamber, 2006) including the concept of a multidimensional ‘data cube’ with the following characteristics: ‘A data cube provides a multidimensional view of data and allows the precomputation and fast accessing of summarized data’ (Han & Kamber, 2006:13). The steps involved in employing Toolbox evaluation and Databox visualization are indicated in Figure 4-12, and further developed as part of evaluation of
individual urban sites in Chapter Six. The fact that indices of spatial complexity vary related to time, scale and geography, and that these necessarily vary in each demonstrative case study unit, means that linkages between scales, cases and indices, as represented through appropriate visualization, become a rich source for a deep and descriptive account of phenomena. Timelapse video of the databox in four dimensions (including time) could in theory record historic and possible future changes in spatial complexity of an urban site, as well as zoom in and out from sites to whole city contexts, but this is beyond the scope of the present work. This study uses the Toolbox and Databox to develop findings of DeKay (2013)\textsuperscript{92} who demonstrated that a nested, lattice-like network of levels of spatial complexity could be uncovered for building scales through design strategy maps, at nine levels, from materials to neighbourhoods. DeKay describes his level structure as having the potential to provide ‘a graphic overview of the whole knowledge base’ (DeKay, 2013), although his scope is later limited to energy and architectural design at preliminary stages. The proposed Databox of this study in particular can uncover and visualise nested hierarchies\textsuperscript{93} between urban sites, case contexts and whole-city understandings of spatial complexity in a single image, improving on previous visualisations of spatial complexity.

\textsuperscript{92} DeKay describes his use of design strategy maps to chart the knowledge base of climatic design as follows: ‘Each strategy is both a whole and a part; each organises and is made up of smaller strategies, and also has a context within a larger strategy. More complex strategies organise patterns of smaller ones. The strengths of this organisation lie in linking strategies across scales, identifying strategies potentially critical to the success of another, and providing a graphic overview of the whole knowledge base’ (DeKay, 2013).

\textsuperscript{93} The concept of nested hierarchies is defined ‘a commonly accepted notion of scale’, and as ‘a set of areal extents in which it is assumed that the sum of all components at one level, such as counties or consumers, produces one component at a larger scale, such as states or households (Haggett, 1965)’ (Manson, 2001:408).
4.5.6 Proposed visualisation methods for spatial complexity

In conclusion, a Toolbox and Databox of evaluation are proposed together, as a dual means of evaluating and visualising spatial complexity, and as an enhancement of existing urban evaluation visualization methods for urban design. A Spatial Complexity Evaluation Form and spider plots are also used at the outset to support data analysis, pattern matching and visualisation. The Evaluation Form is the minimum reporting requirement, showing results in tabulated form. The spider plot visually accesses the relations between results. In defining the Toolbox, complexity, resolution, pixels, and visualization have been discussed above, before the importance of considering colour and visualization has been foregrounded. A further proposed spatial complexity ‘degrees’ colour key has then been presented, and the concept of spatial data cubes was introduced before a proposed Databox was described, to represent evaluations visually in more than two dimensions, and over time. This derives from the model of a ‘data cube’, a visualization technique common in data mining fields. The combined Toolbox evaluation and Databox visualization represent the third phase of this research, following exploration and evaluation in the first two phases. Figure 4-12 describes the indicative method of employing both the Toolbox and Databox in the evaluation of an urban site.
Figure 4-12  Indicative method: Toolbox evaluation and Databox visualization
4.6 Chapter Conclusions

Following an introduction and background to this thesis in Chapter One, a review of theoretical frameworks in Chapter Two, and a description of the proposed research design in Chapter Three, this fourth Chapter engages with core material related to the precise scope of this research: exploring, evaluating and visualising spatial complexity for urban analysis and design. The conceptual framework, including the use of a visual model, structure of an evaluation tool, and theory and methods related to three related issues of spatial complexity are described. Integrative theory and method are introduced, including the proposal to adopt a practical complexity science approach to evaluation. Synthesis across exploration and evaluation, and issues and criteria of spatial complexity is provided by the integrative method. Nine detailed criteria of spatial complexity are outlined. A Toolbox is proposed, as an enhancement of existing urban evaluation visualization methods. The concept of spatial data cubes is introduced before a proposed Databox to represent evaluations is described. This derives from the model of a ‘data cube’, a visualization technique common in data mining fields. The combined Toolbox evaluation and Databox visualization are tested in the third phase of this research, following theory and exploration in the first two phases. In order to coordinate the representation of data and information gathered in three separate urban sites, related to three issues and nine criteria of spatial complexity, nine sequential steps in the evaluation of spatial complexity for urban analysis and design are proposed (numbered in Table 4-5). This Chapter concludes that, although the three cases evaluated in this study are the core ‘object’ of this enquiry, the fact that indices of spatial complexity vary related to time, scale and geography, and that these necessarily vary in each demonstrative case study unit, means that linkages between scales, cases and indices as represented through appropriate visualization, become a rich source for a
deep and descriptive account of phenomena. The context of this evaluation in exploratory terms, the definition of the multiple cases themselves, the varying indices of evaluation and the linkages between all is the subject of the next Chapter.
Chapter Five Exploring spatial contexts of urban sites

5.1 Introduction

Optimal spatial complexity of urban sites is known to bring environmental, functional and social benefits, but methods of measurement of this characteristic of cities are under-developed. In this context, Chapter Five develops the overall aim of exploring spatial complexity of contexts of urban sites in macro-scale terms by linking general aspects of spatial complexity to specificities of one whole city unit, Dublin. This is done in advance of detail evaluation for urban design of multiple urban sites in the next Chapter. In focusing on exploration as well as evaluation, a multi-scalar approach of this study is made clear, as exploration in this study means analysis at larger geographic scales, and evaluation means closer measurement at finer scales associated with urban design at neighbourhood or urban site scale. This Chapter focuses on exploration.

While the theoretical background to the research question was set out in Chapter Two, and the selected research design was described in Chapter Three, the last Chapter put forward the conceptual framework of this study on spatial complexity. This first of two assessment Chapters seeks to answer two new, non-theoretical, exploratory questions about spatial complexity. Firstly, what is the usefulness to urban design of exploring the concept of spatial complexity for larger geographical units than urban sites, for example of an individual city? The first question is answered by describing in overview the

---

94 For example, functional benefits of optimal compositional complexity, (street pattern/typology complexity), (Marshall, 2005), (size/density), (Bettencourt, 2013), (land-use mix), (Van den Hoek, 2008, 2009), configurational complexity (Krafta, 1996), (Krafta, 1997), (Law, 2013) and system complexity (street network complexity), (Marshall, 2005), (pedestrian network complexity), (Hoogendoorn et al, 2005), (movement network complexity), (McArdle, 2014) are already separately described in the literature, and as this thesis proposes that the combination of these three aspects constitute spatial complexity, it follows that functional benefits of optimal spatial complexity are separately demonstrated in prior publications.
background spatial condition of Dublin city in overall terms. The second question asks: how spatially complex are the contexts of the case sites? This second question relates to the requirement in case study research to adequately describe the case context (Yin, 2003b:13)\textsuperscript{95}. A separate requirement in case study research is that each case should serve a particular purpose within the overall scope of the enquiry (Yin, 2003b:47), and this Chapter demonstrates that each of the three cases in this multiple case study is a distinct and contrasting example of an urban site type before evaluation of levels of spatial complexity in the next Chapter. In this study, a theoretical replication logic applies (Yin, 2003b: 47), whereby each case is selected so that it predicts contrasting results but for predictable reasons. Illuminating the spatial context of each case advances the descriptive theoretical claims in relation to varying spatial complexity of urban sites. In this sense Yin’s definition of descriptive theory is relevant: ‘A descriptive theory is not an expression of a cause-effect relationship. Rather, a descriptive theory covers the scope and depth of the object (case) being described’ (Yin, 2003b: 23). The scope and depth of the urban sites evaluated in this study in the next Chapter are foregrounded in this Chapter by a description of context.

This Chapter is linked to the previous development of methods, units and tools of evaluation of spatial complexity by the use of the ‘three issue’ structure developed in Chapter Four for this wider exploration at city scale. This chapter advances the overall argument of this thesis through a primary generation of visual representations of explored spatial complexity for the three contexts within the spatial unit of Dublin, including original mapping and graphical representation. The four exploratory

\textsuperscript{95} Given that the definition of a case study is ‘an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident’ (Yin, 2003b:13), and that selecting this method implies the researcher believes contextual conditions are highly relevant, this study concentrates this Chapter on contexts of the cases.
‘complexity maps’ which form the core outputs of this Chapter are comprised of three separate ‘issues maps’\textsuperscript{96}, composed separately, which are then combined into one ‘spatial complexity map’ of Dublin. The concept of a ‘complexity map’ of the city is discussed by Krafta in relation to defining and measuring urban configurational complexity (Krafta, 1997:11). Krafta proposes in the concluding part of his paper that this type of map should be an algorithmic possibility, but does not graphically illustrate the concept, so it is developed here, albeit in a less mathematical, and more abductive way. This is done in advance of detail evaluation for urban design of multiple urban sites in the next Chapter.

The second part of the research question is the main driver of this Chapter. This asks how spatial complexity of case contexts can be evaluated for urban description, prescription and design. This Chapter is also linked to the previous outline of the conceptual framework, in the last Chapter, in that as part of an ‘exploratory’ case study approach, encompassing exploration of theory, a partly ‘descriptive’ evaluation of three particular cases is also undertaken, and this Chapter describes the framework of that evaluation, without extending to full description of all complex urban sites in Dublin. In this way, the exploratory questions around spatial complexity at macro scales above and around urban design scales are deepened within urban design through demonstration of an exploration approach to site contexts.

\textsuperscript{96} The three ‘issues maps’ are the ‘compositional complexity map’, the ‘configurational complexity map’, and the ‘system complexity map’ in line with the described theoretical development of the concept of spatial complexity of urban sites in Chapter Four.
5.2 Introducing Dublin

Figure 5-1. The Greater Dublin Area and the Dublin Region

(l) The Greater Dublin Area is indicated in dark grey (the county of Dublin itself in light grey, and three adjacent counties, namely Wicklow, Meath, and Kildare), and (r) the Dublin Region (The four local authorities, with Dublin City Council area and historic villages in white, dotted).

The first question posed at the beginning of this chapter asks ‘what is the usefulness to urban design of exploring the concept of spatial complexity for larger geographical units than urban sites, for example of an individual city?’ In response, this section firstly demonstrates that Dublin is of sufficient complexity in urban terms to warrant attention in this study. Measurement of complexity for an entity in the real world has been argued to be context-dependent ‘or even subjective’, reliant on level of detail of description of the entity, on previous knowledge of the world that is assumed, and on the language employed (Gell-Mann, 1995: 1). In defining Dublin here, a general city level unit is described in planning terms, for the purposes of urban analysis and design. The County boundary is chosen, as it includes the Dublin city centre administrative area, together with the three adjacent local authority areas, also collectively known as the Dublin Region. The land area of the Dublin Region is 92,000 hectares approx, and had a
population of 1.18m people in 2006\textsuperscript{97}, which grew to 1.27m in 2011\textsuperscript{98}, a growth of 7.6%. The population of the Republic of Ireland also grew by a record 8.1% between 2002 and 2006, from 3.9 million to 4.2 million\textsuperscript{99}. Beyond the Dublin Region, the Greater Dublin Area, that is, the county of Dublin itself and three counties adjacent to Dublin County, namely Wicklow, Meath, and Kildare contain almost 40\% of the population of the country, on approximately 10\% of the state’s surface area (Hughes, 2015: 1) and accounted for 29\% of the growth in the national population between 2002 and 2006.

Dublin is a suitable context for case study research on spatial complexity and urban design because of three primary characteristics: history, size and diversity. Each of these aspects is associated in the CTC literature with the occurrence of complexity. A historical frame of reference is considered important in understanding complexity because growth over time is one way to measure relative levels of complexity (Byrne, 2001:67)(Byrne, 2005). Measures of complexity are considered to be related to size (Salingaros, 2000:309), and a minimum size (or number of components) is suggested for complexity in cities to exist (Batty, 2008). Diversity of components in a complex system like a city makes a fundamental contribution to structure, patterns and performance (Page, 2010).

Firstly, Dublin is one of the oldest European capitals outside the areas that were once part of the Roman Empire (Brady, 2001). The established urban historic structure of Dublin dates at least to the mid-ninth century, when urbanism was introduced from

\textsuperscript{97} Central Statistics Office (2008) CSO 2006 Volume 1 - Population Classified by Area; CSO Regional Quality of Life in Ireland 2008

\textsuperscript{98} Central Statistics Office (2012), Population Classified by Area Report, Table 4, Pg. 15, CSO, Dublin.

England to Ireland through the establishment of the city (Wallace, 2015: 11). Whereas Simms argues that Dublin is important in understanding urban origins in Europe (Simms, 1979), this study can demonstrate connections between history and spatial complexity with particular specificity by focusing on urban sites in the city. A focus on the established urban historic structure by previous researchers has been extended in this study to encompass a spatial focus on a globalised contemporary city-region containing a variety of distinct and contrasting urban sites, the Dublin Region.

A second reason Dublin is a suitable context for case study research on spatial complexity and urban design is that the contemporary city has a sufficient size, urban structure, and urban population density to warrant an urban design study. In relation to city size, Dublin is comparable to medium-sized European centres such as Edinburgh or Amsterdam when considered internationally for foreign direct investment (Williams, 2010: 23). Although recent growth of Dublin took place later than in most other European cities, which developed mainly in the post-WW2 period (Kasanko et al, 2006:116), the urban structure of the Dublin Region contained approximately 80,000 hectares of urban fabric in 2006 (McInerny & Walsh, 2009:212). However, Dublin is also categorised along with Dresden, Brussels, Helsinki, and Copenhagen as cities where discontinuous urban fabric predominates (Kasanko et al, 2006:119), though Dublin is considered in a medium range of European cities as regards density and compactness (Kasanko et al, 2006:128). Urban population density of the Dublin Region (1,380 pers/km sq), though considered in the lower end of the European range (Nedovic Budic et al, 2016:151), has an average population density of 3,498 persons per square kilometer (CSO, 2012:11) in the city. Planning literature suggests a contemporary reading of the ‘primate’ nature and ‘monocentric dominance’ of the capital city of
Dublin (Davoudi and Wishardt, 2005) (Davoudi, 2005:123), in relation to urban development on the island of Ireland generally, and Hughes’s finding is of an absence of a second tier of (urban) settlement in the (Irish) state (Hughes, 2010: 18), thus concentrating the urban activity of the island nation in one location.

Thirdly, sufficient diversity exists in Dublin to identify distinct and contrasting conditions of urban sites for urban analysis and design. While spatial diversity is manifested in urban sites of different historical and morphological character, economic and socio-spatial aspects of contemporary Dublin also suggest a sufficient variety of indicators. For example, as a site of rapid recent urban and spatial change, and following a period of low economic growth in the mid-twentieth century, contemporary Dublin displays a high degree of spatial and social segregation when examined in relation to relative affluence and deprivation. At particular scales, including and especially in the inner city for example, ‘each area (is) revealed as an amalgam of highly affluent and deprived neighbourhoods’ (Haase, 2009: 26). As regards immigration, Dublin is considered to be a city where this phenomenon is new and recent, and a study of Dublin in the years 1996-2006 found that new populations tend towards segregation and clusters in disadvantaged areas (Fahey and Fanning, 2010: 1625). Preliminary desktop analysis and fieldwork for this study of Dublin also established that incidences of high and low assessed spatial complexity do exist in the city. In this respect Gell-Mann’s claim that any measure of complexity is most useful for comparisons ‘between things at least one of which has high complexity by that measure’ (Gell-Mann, 1995:2) can be tested.
Long historic urban growth, which itself implies (but does not guarantee) a certain complexity developed over time, and medium size, suggests an appropriately sized research object as a ‘whole city unit’. This unit of study is not too large as a context in which to study spatial complexity of its urban sites, and not too simple, small or low density to be of interest for urban analysis and design. In this respect, enough distinct and contrasting urban site conditions exist within Dublin so that each case studied can be individually relevant to Irish and other cities, of both smaller and larger size, while consideration of all cases together can reveal spatial characteristics of the overall city unit in a new way.

In concluding this section on Dublin as a suitable context for case study research on spatial complexity and urban design, two observations can be made, based on the description of contemporary Dublin set out here. Firstly, the object of study in the evaluation of spatial complexity for urban design should be of sufficient complexity to warrant attention. Three aspects have been shown to make Dublin suitable: history, size and diversity. Secondly, Dublin is a manageable sized city to simultaneously examine and connect the larger, city level (exploratory) scales and smaller (evaluation) urban design scales in this study of spatial complexity.

### 5.2.1 Composition, configuration and system at city scale

The first question of this Chapter asks: what is the usefulness to urban design of exploring the concept of spatial complexity for larger geographical units than urban sites, for example of an individual city? Four aspects of usefulness are now briefly
propose\(^{100}\). Firstly, this is useful for urban design because this discipline and practice operates at increasingly larger scales and therefore needs new analysis tools, capable of operating across new and existing scales. While Swyngedouw (2002) argued that large-scale urban development projects are on the increase in Europe and promote new forms of governance, Biddulph (2011) focuses on the urban design implications, including potential of large schemes for increased privitisation of public realm, gentrification and placelessness (Biddulph, 2011). However, Biddulph employs rather vague urban design ‘principles’ and ‘objectives’ of urban design which he admits are ‘prosaic’ to evaluate his chosen case (Liverpool) and thus somewhat lacks quantitative and cross-scalar detail in his urban design evaluations of large-scale urban design interventions in the city.

Secondly, despite calls for more relational planning (Healey, 2000), ‘hierarchical alignment’ (Grist, 2012:7) between urban sites and other sites are still a fundamental of Irish and international strategic and forward spatial and urban planning and design practice. This hierarchical alignment can be supported (or could be contested) by evidence about relative evaluated levels of spatial complexity of urban sites. Thirdly, in line with international practice, it is likely that emergent international classification strategies in landscape and ecosystem studies (ES) will eventually point towards a standard of classification of spatial complexity for natural landscapes in Ireland. It seems appropriate in this context to align this already developing classification system with a future national system of spatial complexity classification of urban sites. In this way, a coordinated, evaluated cohort of urban and non-urban spatial units could be described across the state in a coherent fashion. A fourth reason that it is useful to explore the concept of spatial complexity for the large urban geographical units is that

\(^{100}\) These are as summary points from a larger discussion about city and national level issues around spatial complexity, edited out of the final document because of the scope of this study, on urban sites.
the ability to evaluate spatial complexity on larger scales could also enhance an evidence base of a national spatial strategy.

The second question of this Chapter asks: how spatially complex are the contexts of the case sites? This query relates directly to the spatial complexity of Dublin in whole city terms, as discussed in the last section, but also to more specific issues of spatial complexity as derived from the literature. One reason to ask this question is in order to screen potential case sites: that is, those contexts and sites which appear to demonstrate distinct and contrasting spatial conditions, in advance of focused spatial complexity evaluation of particular urban sites in the next Chapter. In framing an answer to this question, the three constituent issues of evaluated spatial complexity introduced earlier are used to structure the categorization of data sources for exploration of case context, that is: composition, configuration and system issues. In general terms, two separate relevant papers have considered evaluations of complexity in relation to whole cities, primarily from a landscape or planning viewpoint. Huang et al, (2007), in assessing (landscape) complexity of whole cities, employing spatial metrics and remote sensing, clusters cities of northern Europe including Glasgow, Hamburg, and Manchester, all of which are concluded to have low evaluated complexity. While this study does not include Dublin, two other authors have considered Dublin in relation to some of the urban form factors evaluated in Huang et al study, including compactness (Hughes, 2010: 164) and density indices (Williams, 2010: 149). These two studies showed that both compactness and density were dropping in Dublin over time, from a relatively low base, in European terms. As a result, Dublin could be considered as similar to the cities categorized in the Huang et al study as having low overall evaluated complexity. Schwarz (2010), in examining urban form indicators for characterising European cities,
concludes that Dublin is in a cluster of low complexity cities, categorized with cities such as Liverpool and Copenhagen (Schwarz, 2010: 41). However, the relevance of both of these studies is limited, since complexity as defined in these studies considers urban form in the abstract, geographical sense. This two dimensional reading implies complexity consists of irregularity of footprints of large scale ‘patches’ of city, assessed from large-scale aerial photography mapping, revealing fractal-related shapes, which appear to exclude the smaller geographical scales and three-dimensional resolutions of urban sites, the focus of this study. Song et al discuss ‘shape complexity’ of land patches, as one measure of neighbourhood form metrics (Song, Knapp, 2013), and define the ‘patch’ as the basic unit of landscape analysis. This is related to the perspective on urban form of landscape ecologists, who study appropriate patch size and type in relation to particular plant and animal species and habitats. A third, more relevant study (Nedovic-Budic et al, 2016) measures urban form of Dublin at community scale, and although many aspects of the urban environment measured by this thesis are also covered (land-use mix, density, street network connectivity) a single scale (a 1km x 1km grid) is concentrated on. This study argues that a comprehensive exploration of spatial complexity can be achieved by considering compositional, configurational and system criteria at macro- and micro- scales of the city, in a multi-dimensional frame (including 3d visuals) and by visualizing data using infographics methods (in advance of data visualization) so the next sections discuss these criteria for Dublin individually.

---

101 Song et al use the term ‘patch’ as defined by McGarigal as ‘a discrete area of homogeneous environmental conditions’ (McGarigal, 2004). See also Volume Two, Appendix F, ‘Visualising spatial complexity’, for fuller discussion of pixels and resolution around complexity.
5.2.1.1 Compositional overview of Dublin

Clusters of protected structures and historic sites (NIAH and NMS) indicating low, medium and high urban form complexity of Dublin (top), Density overlay mapping detail (middle), (Source, Author), and address points details clusters indicating low, medium and high land-use mix complexity (Source, www.myplan.ie) (top and bottom).

Figure 5-2. Dublin Compositional Complexity Map
Compositional complexity can be assessed at one scale, by considering ‘artefactual complexity’ (Marshall, 2012), in this case, urban form complexity\(^1\) (of buildings and historic sites), by using official protected or recorded status as a proxy for complexity. In assessing one criterion, street units are inappropriate, as street lengths vary, for example. Assessing by area, at a Irish Grid 0.5km x 0.5km grid cell was selected as the best mid-scale resolution at which to measure. Although data availability is uneven\(^2\), the grid cell in and around Temple Bar East, Dublin 2, is the most compositionally complex grid cell location (280 protected structures) in Dublin. Assessing how variations in official data, and differences in comparing grid cell units to urban site units for evaluation is assisted through abductive visualization. Also, other criteria of urban compositional complexity at larger scales, such as architectural conservation area status for example, is not recorded here, nor the three dimensional reality of extents of official designations, which can vary substantially and affect visual complexity.

---

\(^1\) Urban form complexity is the selected criterion of compositional complexity used for this exploratory test about location of highest compositional complexity in Dublin. Later, two other criteria of compositional complexity, land-use mix and density, are evaluated to give fuller account of these aspects of spatial complexity of urban sites.

\(^2\) Mapped data on National Inventory of Architectural Heritage (NIAH), and National Monuments Service (NMS ) sites is incomplete for Dublin city centre on www.myplan.ie in January 2017, and on Dublin City Council protected structures mappings (Map E Development Plan 2016-22), individual structures or sites are visually unclear.
An exploratory compositional description of Dublin is presented in this section as a background and context for the later urban sites to be evaluated at urban design scales. The primary data presented in this compositional overview of Dublin includes data about three criteria of compositional complexity, as proposed in Chapter Four: urban structure/form, land-use mix, and density of the city. As one of the research outputs of this study, this compositional data is overlaid in a graphical exercise to produce the documentary output of this Section, a compositional complexity map of Dublin city. This compositional complexity map is derived from multiple sources, and involves an overlay of the three indicator aspects of compositional complexity, as data inputs. Each is listed in Table 5-1 (Compositional complexity data inputs). Information on urban

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Criteria</th>
<th>Data Input</th>
<th>Source</th>
<th>Scale of resolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compositional Complexity</td>
<td>Urban structure/Form</td>
<td>Planning/Policy designations of ‘centre’, Morphological Regions characterisation mapping NIAH Sites, ACA’s, pedestrian areas, etc (city centre only)</td>
<td>Relevant Local Authority Development Plans, etc</td>
<td>1:5,000 approx. 1:20,000</td>
</tr>
<tr>
<td></td>
<td>Land-use Mix</td>
<td>Address points of building uses</td>
<td><a href="http://www.myplan.ie">www.myplan.ie</a></td>
<td>2km resolution (screenshot)</td>
</tr>
<tr>
<td></td>
<td>Density</td>
<td>Residential and Employment Population Density statistics/mapping and high buildings data</td>
<td><a href="http://www.aire.ie">www.aire.ie</a>, NTA, 2013, Dun L/Rathdown Co.Co.</td>
<td>1:25,000 still 1:10,000, 250 x 250 m grid (city centre only)</td>
</tr>
</tbody>
</table>

Table 5-1. Compositional complexity data inputs
structure/form consists of one dataset: locations of compositionally complex structures, (NIAH and NMS mapping on myplan.ie website). Input data on land-use mix consists of one dataset, address point data from www.myplan.ie, an official public spatial data source. This includes available mappings of ‘clusters’ of land-use mix in the city. Input data on density consists of three datasets: city-wide population density mapping, including residential population densities, (CASO/AIRO Small Areas), city centre employment population densities (NTA, 2013), and employment population densities of selected outer city locations where available.

In discussing the compositional overview presented here, three resulting observations can be made. Firstly, a limitation other researchers have observed is that spatial data available in Ireland can have wide variation in levels of resolution (Hughes, 2016:14). It is also primarily aggregate data, and therefore considered ‘coarse’ for some purposes (Haase, 2009:26)(Kitchin, 2014) and therefore difficult to interpret for graphical synthesis purposes. In this case, large scale resolution (eg. neighbourhood outlines) has been combined with small-scale resolution (eg. exact locations of address points) so some graphical decisions on output mapping were determined by eye, leading to a less precise reading than could be useful for the next stage of this study, urban case analysis and evaluation.

Secondly, the lack of compositional coherence of the city viewed at this scale of resolution is a feature of the mapped output. So while inconsistent urban residential population densities across the city have been noted by previous research (Haase, 2009) (Kearns, 2014), it is the lack of overall discernable graphical pattern of compositional complexity at city scale that emerges from this complexity map. In other words, urban
structure/form does not cohere in the city centre as a cluster, for example, while land
use mix varies considerably across small areas, and mapped densities of employment
and residential areas are not evenly spread across the city. An international comparison
for one indicator, of urban block density, reinforces this observation\textsuperscript{102}. Thirdly, it is
apparent from this graphical mapping output of the three cited criteria of compositional
complexity that a hierarchical arrangement of compositional qualities (e.g., most dense at
centre, less dense at edge) does not emerge in this city-wide analysis of Dublin. So, for
example, all tall buildings are not just located in the city centre, while unexpected land-
use mixes in certain sites, and some very high urban population densities are emerging
far from the city centre.

In concluding this Section on the observed compositional complexity of the city of
Dublin, a number of points can be re-stated. In theoretical terms, complexity can be
apparent at different levels of resolution without manifesting at all levels, and emergent
properties could be present at one level which do not appear at a higher or lower level
(Gershenson et al, 2012:31)\textsuperscript{103}. Also, the multiple criteria analysed could have included
other criteria, such as geographical and landscape variation in composition (height,
slope, presence of water, etc), so this result should be treated as a preliminary urban
design analysis output. As context for the selected case urban sites, the overall evaluated
compositional complexity of the whole city unit of Dublin is considered from the
evidence to be low and uneven, at this level of resolution\textsuperscript{104}.

\textsuperscript{102} Dublin, Glasgow, and Hamburg, as three cities which can be compared for urban desity levels, show patchy or uneven clusters in Dublin, while in Glasgow clusters are of larger size, while in Hamburg these larger clusters of density are even more evident. (See Urban Observatory image, Appendix F, 2.0 Visualising Case Contexts)

\textsuperscript{103} In this respect, a multi-scalar approach to observation is recommended as a complexity ‘frame’ (Byrne, 2005)(Chapura, 2009:466), so this preliminary reading of the city scale can be combined with the later attention to single and multiple case sites, which are of urban design scale.

\textsuperscript{104} Appendix F also contains a compositional overview of Dublin and a fuller description of the method of deriving the Dublin compositional complexity map.
5.2.1.2 Configurational overview of Dublin

This section describes an overview of one reading of the configurational complexity of Dublin, as represented through an axial map of the city. This study applies syntactic analysis to the case of Dublin city, based on a dataset referred to throughout this study as the ‘Dublin Axial Map 2012’\textsuperscript{105}, supplied to the researcher in May 2014 by Space Syntax Ltd. London. A fuller description is contained in Volume Two, Appendix E, Syntactic Analysis of Dublin. A strength of axial map analysis is the ability to encompass all 14,818 streets, as represented through individual axial lines, in one overview analysis, while simultaneously having a local focus where necessary, even down to the level of a single line (street). This overview sets a context for the later evaluations of individual urban sites. The result of this data analysis is an overall ‘configurational complexity’ map of Dublin. This configurational complexity map is derived from multiple sources, and involves an overlay of the three indicator aspects of configurational complexity, as data inputs. Each is listed in Table 5-2. In exploring the configurational complexity of one city, and as regards configurational complexity at ‘whole city scale’ of Dublin, more accurate information can be described than for compositional aspects, due to available data on the comparison between Dublin and international cities which have been studied by other researchers for particular variables: numbers of axial lines, connectivity, integration (global, local, integration core) syntactic choice (overall and local) and intelligibility. Appendix E describes the appraisal which has been undertaken to compare Dublin with other locations, with the result that Dublin appears to have an especially low level of configurational complexity at the scalar level of the whole city.\textsuperscript{106}

\textsuperscript{105} The supplied dataset is known to Space Syntax Ltd. as the Dublin Spatial Network Model.
\textsuperscript{106} Appendix E also contains a Configurational overview of Dublin and a fuller Description of the Dublin Axial Map.
Table 5-2. Configurational complexity data inputs (top) and Integration core as cells (bottom).
Figure 5-4. Dublin Axial Map 2012

Global Integration Rn (top) and Local Integration R3 (bottom)
Highest configurational complexity location, Dublin
East Essex Street, Dublin 2.

Configurational complexity is hard to be exact about, because levels of resolution ranging from single streets to entire city scales all give different readings of configurational complexity levels, so while M50 is the most globally integrated (and possibly complex) location in Dublin, a street in Temple Bar, East Essex Street, Dublin 2, is the most configurationally complex single street location (highest local choice\(^1\), 400m metric radius measure of 14,818 axial lines). Assessing how this type of variation affects evaluation at the scale of an urban site is assisted through abductive visualization.

\(^1\)“Choice” is the selected criterion of configurational complexity used for this exploratory test about location of highest configuration in Dublin. Later, two other criteria of configurational complexity, integration and intelligibility, are evaluated to give fuller account of these aspects of spatial complexity of urban sites.

Figure 5-5. Highest Configurational Complexity location
Syntactic parameters of Dublin

Hillier’s concept of ‘syntactic parameters’ which illustrate syntactic and geometric variations, are argued by Hillier to be expressions of what might be called distinctive spatial cultures of cities (Hillier, 2002:157). The three selected syntactic parameters described in this section are integration107 (global and local )(Serra, 2013), choice and intelligibility. Integration indicates the relative depth between spaces in a network, where depth between two spaces is defined as the least number of syntactic steps in a graph that are needed to reach from one to the other’ (Klarquist, 1993). Choice is a measure of ‘through’ movement potentials for areas and spaces108. Intelligibility is the correlation between connectivity (a static local measure) and integration (a static global measure) (El-Khouly, 2012). The literature on whole city analysis using space syntax methods repeatedly focuses on these as aspects of urban complexity of a city system (Hillier, 2007) (Marcus, 2015) (Read, 1999), but have not previously been directly linked to spatial complexity of urban sites.

Global and local integration

According to the global integration overview of Dublin, as illustrated in the Dublin Global Integration Rn Map 2012, (Fig. 5-4) concentrations of globally integrated areas occur in the centre, north and south of the Liffey river, but clustered to the east, with some high integration evident to the north and southeast of the city centre. Dublin postal code areas 1, 2, and 8 show high integration values, as well as around the inner part-ring road (North Circular Road and South Circular Road), and outer part-ring motorway

---

107 Integration is usually indicative to how many people are likely to be in a space, and is thought to correspond to rates of social encounter and retail activities (Hillier, 1996a)’ (Al-Sayed, 2014:14).
108 Through movement means the likelihood, for both pedestrians and vehicles, that they will pass through a space. Further definitions of syntactical ‘integration’, ‘choice’ and ‘intelligibility’ are contained in Appendix C, ‘Glossary of Terms’, and Chapter Four, 4.4.2, ‘Configurational criteria of spatial complexity’.
Other research has shown that highest to-movement potential in cities tends towards motorways (van Nes, 2012). According to the r3 Local Integration Map [HH], Dublin appears to have only a small number of local or neighbourhood level integrated cores, meaning places of particular importance for local users of the city, (or ‘centres’) and which connect to other places well in configurational terms. Local integration in this sense is defined by the ‘to’ movement potential which exist in surrounding public spaces, within the nearest three syntactical steps. Research indicates that these places should have high numbers of people passing through, as well as high possibility to generate public activities and retail (Hillier et al., 1993). Three different local integration cores are apparent in the city (and one in a historic suburban centre, Dun Laoghaire), in contrast to its single global integration core, which is in a different location. In the Dublin case, we also find that the most segregated locations are located on the end of routes, which do not in turn connect beyond the city limits, for example, at the sea coast, but also due to boundary effects of the decisions on geographical limits of the axial map. A comparative analysis of other cities and configurational measures of integration in (Appendix E), confirms low overall integration values for Dublin.

**Choice and the Dublin Map**

Two separate radii are applied to the syntactic choice measure of the Dublin Map. Firstly, a radius n measure, in order to highlight the ‘foreground network’ (Hillier, 2012:1) or the spatial structure of the overall city (See Figures 5-6, 5-7). In the Dublin case, a relatively clear set of connected ‘foreground’ routes emerge from the map, although the south-west and north-west inner city are both badly served by connections in this analysis. Secondly, a radius of 1km, (that is, between the two radii mentioned
above used in other relevant research), is applied to the Dublin Map, as the focus is on
the whole configuration complexity, as measured in choice terms, of a small city. In the
Dublin case, the city core is clearly visible as having high choice levels, especially a
cluster of high choice lines between the two canals, and in the south city centre.
Compared with the coherent framework of the overall city choice map, a more
dispersed set of clusters of choice appears at local (1km radius) level. Other prominent
clusters of global choice include historic suburban centres and villages (Dun Laoghaire,
Dalkey, Dundrum), one designed C20 garden city residential layout (Marino), and one
modernist housing estate (Ballymun). In this choice map, both the foreground and
background networks of the city (often associated with mainly residential space) are
made graphically clear. It is concluded from analyzing choice at whole city (Rn) and
1km radius level that in the Dublin case, the city in general has good configurational
‘choice’ levels for longer trips, but poor choice levels for shorter trips, at the scalar level
of the urban site.
Figure 5-6. Dublin Axial Map 2012, Choice Rn

Choice Rn (top), and city centre detail (bottom)

High choice  low choice
Figure 5-7. Dublin Axial Map 2012, Choice 1km radius

Choice 1km radius overall (top) with high choice urban sites circled, and city centre detail (bottom)
High choice 🟥  🟢  🟡  low choice
Overall Intelligibility, Dublin Map

Intelligibility can be represented by a scattergram\(^{109}\), showing overall (global) integration on the x-axis (HH) and overall connectivity on the y-axis. In this Chapter, the scattergram for the whole city of Dublin is described (Figure 5-8). From the angle of the regression line, (which would ideally be in a 45-degree angle), it can be seen that Dublin has a non-ideal relation between connectivity and global integration. Therefore, Dublin, in syntactic terms, is a not a fully intelligible system. An intelligible system is one in which well-connected spaces also tend to be well-integrated spaces (Hillier, 1996:94). Also, the points around the line do not form a tight scatter around the regression line, indicating poor correlation, and therefore non-ideal intelligibility. From the overall intelligibility score of the 2012 Dublin Axial Map (0.101) as indicated in Table 1 (Appendix E) Dublin has a much lower intelligibility than evaluated UK cities.

---

\(^{109}\) A scattergram is composed of a multitude of points marked on a graph with two axes, one axis for each variable (Al Sayed, 2014:58). Scattergrams are used to explore the relationships between two continuous variables. Each point represents a single convex space, or axial line, which in this case represents individual streets and roads of Dublin.
(0.232), and is well below European averages (0.266), so it is evident that Dublin has a very low intelligibility rating overall.

**Conclusions on configurational complexity of Dublin from analysing Axial Map**

In concluding this Section on configurational complexity of the city of Dublin, a number of points can be re-stated. Firstly, Dublin has a very low configurational complexity in international terms. As regards the three selected syntactic parameters described in this section, while global integration is high, local integration is low, and choice analysis shows a strong foreground network of routes, but a more dispersed set of clusters of 1km radius choice, at local level. It has been shown that overall intelligibility is very low in international terms. Therefore, it can be concluded from assessing all three syntactic parameters that overall, Dublin has very low levels of evaluated configurational complexity. Hillier (2002) discusses the concept of ‘discrete geometry’\(^\text{110}\) to describe what he considers a more ‘elementary’ way than metric distance to deal cognitively with complex spatial systems such as cities. In this respect the axial map can represent configurational complexity of Dublin in a way which is useful for describing spatial complexity, and which captures aspects not recorded in this study by the other two selected issues of spatial complexity, composition and system. This conclusion of a low explored configurational complexity of Dublin is important because high configurational complexity is associated with the ‘spatially successful city’ (Hillier, 2007).

---

\(^{110}\) Discrete geometry is described as: ‘the application of techniques of discrete mathematics such as graph theory to systems of discrete geometric elements, such as lines, convex spaces and visual fields’ (Hillier, 2002:177).
5.2.1.3 System overview of Dublin

This section describes an overview of one reading of the system complexity of Dublin, as represented through a map of the city. The result of this data analysis is an overall ‘system complexity’ map of Dublin. This system complexity map is derived from multiple sources, and involves an overlay of the three indicator aspects of system complexity, as data inputs. Each is listed in Table 5-3 (System complexity data inputs Table).

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Criteria</th>
<th>Data Input</th>
<th>Data Outputs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Street network complexity (Patterns)</td>
<td>Internal and external connectivity of road segments (Nedovic-Budic et al, 2016) Fieldwork Survey</td>
<td>SNC map (1km x 1 km pixel)</td>
<td></td>
</tr>
<tr>
<td>Path network complexity (Paths)</td>
<td>Walkability data (GIS) (D’Arey, 2013) Fieldwork Survey</td>
<td>Walkability map (1km x 1 km pixel)</td>
<td></td>
</tr>
<tr>
<td>Pedestrian network complexity (People)</td>
<td>Canal Cordon Pedestrian Count Locations Data, BIDS Pedestrian footfall locations, City Centre (bridges) Pedestrian Count (DCC, 2012),(BIDS, 2013)</td>
<td>Pedestrian Key Map (1km x 1 km pixel)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5-3. System complexity data inputs for exploration

The three criteria of system complexity, as proposed in Chapter Four (Section 4.4, Pg 185) are : patterns (street network complexity), paths (path network complexity/metric reach) and people (pedestrian movement complexity). The Protocols for description and measurement of each is contained in Appendix B, Evaluation Protocols, Volume Two.
Although urban system complexity could be argued to be in fact ‘unknowable’ (Marshall, 2012), due to large size, many moving parts and many scalar levels of operation, for this study, one particular aspect of the urban system, pedestrian movement network complexity can be abductively examined. Pedestrian movement flow is used as a proxy for analysing the urban system at local level, and although data availability is uneven, hourly footfall counts indicate that Grafton Street, Dublin 2, the busiest retail location in the city, has the highest hourly footfall in the city (5,000/hr approx.). However, a number of nearby locations have similarly high levels at different times, so these are also useful to join together to represent a ‘flow’, and this can be indicated graphically as static ‘snapshot’ of a changing spatial system.

Figure 5-9. Highest System Complexity location
A detailed explanation of the ‘Spatial Complexity Colour Key’ is contained in Appendix F, ‘Visualising Spatial Complexity’, Section 1.3, Pg 188, Volume Two.

While a system or network overview of Dublin could encompass the physical urban structure itself, transport, utilities, communications, or other physical or non-physical webs of connection present in the city, the most important system in relation to urban sites and urban design in this study is considered to be the pedestrian movement system or network within the city. So while the street as a fundamental component of the designed urban environment is promoted in the literature, (Jacobs, 1993)(Moughtin, 2003:127) it is the more specific detail of the system of footpaths and other pedestrian routes in the city, as well as pedestrian movement, which are evaluated in this study. One reason to choose this aspect of the urban environment to analyse for Dublin is because secondary data about movement on foot is available through public datasets for parts of the city, and is likely to be available in most of the city in the near future due to
technological advances. The primary data presented in this system overview of Dublin includes generated information about three criteria of system complexity, as proposed in Chapter Four: patterns (street network complexity), paths (path network complexity/metric reach) and people (pedestrian movement complexity).

Patterns

In exploratory terms, input data on patterns looks at city-scale connectivity of road segments. Related to street network design, connectivity of road segments has been studied related to urban form of Dublin, as this characteristic is associated with accessibility, more walking and cycling, better air quality, and better sense of community among residents (Nedovic-Budic et al., 2016:154). Internal and external connectivity were measured for Dublin by Nedovic-Budic et al, and defined for measurement at 1km x 1km grid cell resolution. Internal connectivity measures transportation route options within a neighbourhood (cell) as the sum of the number of sections intersecting within 1km$^2$ grid cell. The higher the number, the greater the internal connectivity. External connectivity measures route options between neighbourhoods (cells) as the number (density) of intersections of roads with the boundary of each 1 km$^2$ grid cell. The higher the number the greater the external connectivity. The external connectivity indicates how well a grid cell is connected with other cells. Highest connectivity is found for inner city areas, but also for recently developed outer areas along transport links. Internal connectivity is measured in quintiles of five bands, which run from 0-645. External connectivity is measured in quintiles of five bands, which run from 0-100. Connectivity is taken as an indicator of street network complexity for this exploratory analysis of Dublin at whole-city scale. Although Song Knaap, (2004) and Peponis (2007:4) use different measures, the latter paper does provide comparison numbers for ‘numbers of intersections (choice) per sk
km’ for 25 areas in Atlanta, USA, (Table 1) and it can be concluded that Dublin has similar levels of connectivity to Atlanta, that is, of low connectivity at whole-city scale.

**Paths**

While Dublin in overall terms has been considered a walkable city, (D'Arcy, 2013) the physical characteristics of the pedestrian system of Dublin has not been previously studied. In exploratory terms, walkability indices are selected, and a cross-check of ‘Walk scores’ is undertaken. D’Arcy measures high and low walkability areas in Dublin as points on a map, and these can be assigned to a 1km x 1km grid cell for exploratory purposes. A medium level of path complexity at overall scales can be concluded from the mapping of the walkability indices and WalkScore results.

**People**

Urban pedestrian places are associated with complexity in the environmental psychology (Purciel, 2009) and urban design (Isaacs, 2000) literatures, although this is primarily a visual attribute in these understandings, and therefore considered more related to purely qualitative methods than this study. Exploratory input data on pedestrian movement complexity in this section consists of three datasets: mapping of city centre Dublinked footfall numbers, overlay mapping of Canal cordon footfall numbers (DCC) and overlay mapping of BIDS footfall cctv numbers. Dublin footfall databases are currently under-examined for urban analysis and design. However, the limitations of the data also require brief explanation. Only Dublin city centre is patchily covered, because currently only Dublin City Council (one of four local authorities for the city) collects and releases public data on pedestrian behaviour, for example at bridges across the river Liffey. Furthermore, within this dataset, data collection

---

111 ‘Walk Score’ is an online website (www.walkscore.com) and tool that allows a user to test a location for walkability and receive a Walk Score assigned to that point on a map. The algorithm uses a score from 0 to 100, and calculates a score of walkability based on distance to various categories of amenities (e.g., schools, parks) that are weighted equally and summed. Scores above 50 are rated as walkable. Advantages include accessibility, international scale, and up to date data that is constantly being corrected, but research is limited on the validity of the tool (Duncan et al, 2011:4161).
techniques and quality vary widely, methods and protocols of collection are unclear, and choices of locations of measurement are biased in some cases. For example, in the inner city, the relevant BIDS (Business Improvement District) collects footfall data. However, their pedestrian activity data naturally concentrates on commercially active streets, to the exclusion of commercially quieter streets. Footfall data is available in only six grid cell areas in the inner city. Thus, an overall understanding of the citywide system is missing. However, because this pedestrian movement data has a high level of detail, the results from a contextual overview at this exploratory stage of this investigation of spatial complexity of urban sites can be linked to later evaluation in a meaningful way, to inform a more precise quantitative evaluation of this important system aspect of spatial complexity of case urban sites. For exploration of pedestrian movement network complexity it can be concluded that ‘hotspots’ of activity can be identified in the city centre only.

As one of the research outputs of this study, the three sets of system data (connectivity of road segments, walkability indices, and footfall counts) are overlaid in a graphical exercise to produce the documentary output of this Section, an exploratory system complexity map of Dublin city\textsuperscript{112} (Figure 5-10). It can be concluded from reviewing the primary data presented in this system overview of Dublin, which includes data about three exploratory criteria of system complexity: ‘patterns’ (connectivity), ‘paths’ (walkability) and ‘people’ (footfall), that although the overall system complexity of the city is difficult to measure, due to poor data availability, there are geographically distinct clusters of ‘high’ explored system complexity in certain locations within the inner city of Dublin at this level of resolution.

\textsuperscript{112} In the system complexity map, red (R), green (G) and blue (B) colouring of grid cells indicate high (R), medium (G), or low (B) explored levels of system complexity. In all exploratory maps prepared in this thesis, three levels of ‘colour transparency’ (33%, 66% and 100%) are indicated in colour terms, to graphically signal intensity of spatial complexity. A detailed explanation of the ‘Spatial Complexity Colour Key’ is contained in Appendix F, ‘Visualising Spatial Complexity’, Section 1.3, Pg 188, Volume Two.
Figure 5-11. Various Footfall counts combined, central Dublin

Sketch maps of overlaid source data of footfall from four sources, indicating ‘spatial gaps’ in the count locations, including one case site (Liberties character area) (top), and footfall number for retail core of Dublin, indicating ‘hotspots’ of activity (bottom). Source: Author
5.2.2 Conclusions on introducing Dublin

The question of weighting of variables in the evaluation of spatial complexity in this study, dealt with for urban sites in Chapter Three, Section 3.3.8, arises also in the wider discussion of Dublin and spatial complexity\textsuperscript{113}. While the standard environmental assessment tools for evaluating sustainable urban design, for example, are mainly designed for the local context, (Ameen et al, 2015:24) they derived originally from the expansion of single building assessment tools, (Haapio, 2012) for use in planning and design of the city. This exploratory study about spatial complexity and Dublin could seek to develop quantitative instruments of evaluation related to urban sites, or even build on previous approaches to considering and evaluating spatial complexity of a single building (eg. Venturi, Bachman). However, unlike other disciplines (eg. landscape), urban design has not yet developed prior theory and evaluation criteria of spatial complexity of urban sites and larger scales. As this study has a limited scope related to the case urban sites, the approach adopted to weighting of the cases applies equally for the context and background scales considered in this Chapter.

Therefore, as the final evaluations in this study provide flexible values and not fixed numbers (Gil, Duarte, 2013) all three issues of spatial complexity, as well as each of three criteria within each issue, are considered to have equal value in weighting terms. Hence the indicators of explored spatial complexity in this section, arrived at by considering the background of Dublin and the contexts of the case sites under three criteria for each issue, are of only three types: low, medium and high. In synthesising

\textsuperscript{113} In comparing explored spatial complexity of Dublin with other ratings of complexity at national level, the Observatory of Economic Complexity (OEC) is “is a tool that allows users to quickly compose a visual narrative about countries and the products they exchange.” http://atlas.media.mit.edu/en/resources/about/ Accessed 121015. The Atlas of Economic Complexity, produced by the OEC, “attempts to measure the amount of productive knowledge that each country holds” (Hausmann, Hidalgo et al, 2010:7). The Atlas of Economic Complexity rates Ireland as 16\textsuperscript{th} most economically complex country (of 186) in 2013. Research on governance and complexity has looked at Irish regeneration sites (Rhodes, 2008, 2011) including classifying Ballymun (one of the later case sites of this study) as a site of high complexity.
the results of the three issues of spatial complexity for the background of Dublin, and applying equal weighting to all three, it is evident firstly that the city unit has a lack of overall discernable graphical pattern in relation to explored compositional complexity, and is therefore assessed as of low and uneven compositional complexity. In considering urban form of the wider Dublin area, Nedovic-Budic’s analysis of development of urban form of Dublin is relevant. From a visual appraisal of the development of Dublin over five periods (Nedovic-Budic 2016), approximately one quarter of the 267 (1km x 1km) approx.\(^{114}\) cells of the Dublin Axial Map (2012), could be considered in the category ‘developed before 1966’ (first two quintiles). This is a useful input to quantifying spatial complexity of urban form in Dublin if the characteristic of historic urban form is to be associated with complexity of urban form.

Explored configurational complexity of the overall city unit, based on the axial map evidence, and comparison with international examples (See Appendix E), is considered very low. The explored system complexity of the overall city unit of Dublin is low at this level of resolution, although available data is scarce for the system complexity mapping exercise. In conclusion, a low level of spatial complexity of the city of Dublin is derived from combining the three exploratory mappings, in the form of the Dublin spatial complexity map. This result is important because for the first time, a relatively clear description of distinct and contrasting levels of spatial complexity can be discerned across four separate local authorities of Dublin County. So while each local authority has its own hierarchical planning and zoning divisions, the spatial relations between sites of varying levels of explored spatial complexity suggests new readings of established official local hierarchies across a whole city context. As part of this

\(^{114}\) The Dublin Axial Map area as introduced in Chapter Five, represents a 20km wide and 16km high footprint of the Dublin urban area, and 267 (1km x 1km) Irish Grid geolocated land cells (53 cells are water) have quintile colour indications of the year they were developed as urbanised areas (Nedovic-Budic, 2016:153) Fig.2.
exploratory investigation at whole city scalar level, certain urban site contexts can be identified on the completed complexity maps through visibility clustering analysis (Gal, Doytscher, 2014:526), as having high or low compositional, configurational and system complexity at whole city scalar level, indicating possible distinct and contrasting conditions of explored spatial complexity of urban sites. The visibility cluster analysis approach adopted is one of the six data analysis techniques of this study, data transformation. (See also, Appendix B, Evaluation Protocols, Section 4.0, ‘Note on deriving exploratory complexity maps’). The focus on the derived potential clusters of high and low spatial complexity identified through pattern matching between maps is the subject of the next Section.
5.3 Selecting case urban sites

This section outlines the screening process of candidate case study units, and the specific reasons that a particular group of cases are selected. The case study literature recommends that during the screening process of potential case study units, the selection process should outline the specific reasons that a particular group of cases might be selected. This could include exemplary instances of the phenomenon being studied or a group of cases that includes ‘contrasting outcomes’ (Yin, 2003b:10). It is stated: ‘The specific cases to be studied may be selected by following several different rationales, one of which is to select ‘exemplary’ cases. Use of this rationale means that all of the cases will reflect strong, positive examples of the phenomenon of interest.’ (Yin, 2003b:13). In screening candidate cases to investigate spatial complexity of urban

Figure 5-12. Dublin context and case sites locations
sites, it is conditions of distinct and contrasting spatial complexity which are sought, (as opposed to exemplary cases) for exploration purposes and evaluation.

Also, while the intensely complex locations of Dublin in compositional terms could be investigated further, this is only one issue in the theoretical framework of this study, to be balanced by an understanding of the other two issues of spatial complexity considered. As a result, while there is potential interest in looking in more detail at the evident local integration cores in the syntactical mapping, (identified in the previous section, Section 5.2.1.2) those locations mostly have established historical configurations, and therefore integration measures are likely to follow the pattern of the historic city, which is an already selected case. In system terms, while certain locations unexpectedly seem to be centres of the spatial system or network of the city, (in considering pedestrian network complexity) the data is uneven, so a full picture is difficult to achieve, and must be considered in an integrative way, together with compositional and configurational aspects.

While the cases selected are therefore not seen a ‘strong positive examples’, they are seen as strong demonstrative and contrasting examples, which illuminate the concept of spatial complexity through a number of degrees, types or orders. Exemplary case design is considered to fit replication logic well, because the ‘overall investigation may then try to determine whether similar causal events within each case produced these positive outcomes’ (Yin, 2003b:13). In this thesis, overall investigation does not seek evidence of causal events leading to outcomes, but seeks to describe contrasting spatial conditions in order to give a comprehensive account of a distinct range of spatial complexity conditions. Yin also states: ‘The use of exemplary case design, however,
also requires you to determine beforehand whether specific cases indeed have produced exemplary outcomes. Extensive case screening may be needed, and you must resist the case screening process to become a study in itself.’ (Yin, 2003b:13).

Here, although the case study design aims at contrasting rather than exemplary conditions, efforts have been made to determine beforehand whether specific case contexts display contrasting spatial complexity conditions. This is done through the whole city unit exploratory analysis described in Section 5.3. Then suitable examples of case conditions are selected for further study and evaluation. Baxter (2008) considers that although findings from a multiple case study design predicting contrasting results but for predictable reasons (a theoretical replication) are considered ‘robust and reliable’, they can also be extremely expensive and time consuming to conduct’ (Baxter et al, 2008:550).

A relevant example of case screening in the urbanism literature included three criteria: differences in morphological patterns, historical periods, and ‘geographical and cultural spread’ (Berghauser, 2010:110). Another relevant study (Read, 1999) considered three criteria in selecting neighbourhood areas to be studied in the Dutch city: (1) a representative cross section of neighbourhood areas, (2) that areas show internal consistency of visual analysis in geometrical properties of textures of grids, and (3) that the areas constitute commonly understood local areas or neighbourhoods with fairly clearly demarcated and commonly understood edges (Read, 1999:255). Whereas Dutch cities and areas, in spatial terms, are considered in the Read study to have developed historically as coherent units at both scales, this study of Dublin examines a spatially different pattern. While (1) can be satisfied, (2) and (3) are harder to ascertain than in
Holland, and would involve investigations beyond the scope of this thesis. Also, as described in the discussion on the meaning of ‘urban sites’ in this study (Section 3.3.2), in spatial complexity terms, part of the difficulty of defining urban sites in Irish terms can be geometric properties (2) and commonly understood edges (3).

5.3.1 Reasons for case selections

Given that the research design of this study is of a multiple-case type, the choice of number and type of case should reveal evidence of distinct and contrasting conditions, for comparison purposes (Yin, 2003b:25). (See Chapter Three, Section 3.3.5). According to the prior theory propositions described in Chapter Three (Section 3.2.2) the cases are predicted to demonstrate contrasting conditions of evaluated spatial complexity. The reasons\textsuperscript{115} for selection of cases are:

- All sites are officially designated as urban land
- Clear official planning boundaries and designations exist in each site
- Each site is a distinct urban form and morphology type: inner city, suburban and outer suburban
- All three sites are of broadly comparable land area
- Contrasting urban population densities exist in each site
- All three sites were identified through the exploration stage of this study, including mapping of compositional, configurational and system complexity at whole city scalar level, indicating possible distinct and contrasting conditions of explored spatial complexity of urban sites

\textsuperscript{115} The term ‘reasons’ is used here in preference to ‘criteria’ to avoid confusion for the reader in relation to the defined ‘criteria of spatial complexity’, as set out in Chapter Four, Section 4.4.
In defining the meaning of the term ‘urban’, the EU’s recent (2015) introduction of harmonized rules for defining cities and urban centres includes a requirement of a minimum sized cluster of 1km x 1km units of population density of 1,500 persons per km sq. (Hughes, 2016:12), and in overall terms Dublin city and suburbs satisfy this requirement by having an average population density of 3,498 persons per square kilometer (Census 2011 Report, Profile 1, Town and Country) (CSO, 2012:11). Clear official planning boundaries and designations can help avoid bias of the researcher in selecting a geographical limit on the definition of the urban site, so each urban site selected has a formal spatial definition\textsuperscript{116} and set geographical size.

In this study, all selected urban sites are also designated or otherwise foregrounded for future development in current local authority development plans. Distinct urban form and morphology types allow for contrasts in compositional aspects to be highlighted, and inner city, suburban and outer suburban morphological types represent a hierarchical range of urban intensity in morphological terms, from highest to lowest. Selecting sites of comparable land area has been done to some extent, but because of planning boundaries, no two spatial units in Dublin would be of exactly the same size. In this study, the largest unit is one and a half times the geographical size of the smallest unit. Lastly, contrasting urban population densities in each site help to illustrate, through comparison, the impact of urban population density on evaluated spatial complexity levels.

As regards definitions of ‘inner city’, ‘suburban’ and ‘outer suburban’ adopted here, Dublin City Council (DCC) defines a geographical outline of the ‘inner city’ which

\textsuperscript{116} Subject to detail description of Carmanhall later in this Chapter, in Section 5.5.
roughly follows the two Canals which encircle the historic city. The term ‘inner suburban’ is defined by DCC as ‘those areas beyond the inner city (see definition above) which comprise the 19th Century built up areas’\textsuperscript{117} while ‘outer city’ is defined as ‘those areas generally between the 19th Century urban areas/villages and the city boundary’\textsuperscript{118}. As the site of this study extends beyond the DCC boundary, the term ‘suburban’ here refers to areas of Dublin outside the inner city, and broadly adopts the official definition of ‘Inner suburban/infill’, which is: ‘proximate to existing or due to be improved public transport corridors’\textsuperscript{119}. The official definition of ‘Outer Suburban/Greenfield’ sites is used to define ‘outer suburban’ in this study, and refers to areas of Dublin including ‘open lands on the periphery of cities or larger towns whose development will require the provision of new infrastructure’\textsuperscript{120}. While official documents such as the NTA Planning and Development Report for Dublin (2013) adopt these official definitions, other authors diverge, including Kearns & Ruimi (2010:358) who define all areas outside their spatial ‘urban’ designation as ‘suburban’, and Redmond et al (2012:36), who use the term ‘outer suburban’ to refer to locations which generate commuters to the Dublin Region from outside that area. Having defined these three terms for the context locations of this study, (‘inner city’, ‘suburban’ and ‘outer suburban’) it may seem unconventional to employ the term ‘urban site’ when discussing the case sites. However, the term ‘urban site’ partly refers to the high urban development pressure on each of the three sites, as discussed in Section 1.3.5.3, Section 5.5\textsuperscript{121}.

\textsuperscript{117} See Glossary, Pg 192, Dublin City Council Development Plan 2016-22, (2016)
\textsuperscript{118} ibid.
\textsuperscript{119} Section 5.9 (d) Planning Guidelines, Sustainable Residential Development in Urban Areas, 2009, Pg 43
\textsuperscript{120} Section 5.11 (f) ‘Outer Suburban/Greenfield’ sites, Pg 45, Planning Guidelines, Sustainable Residential Development in Urban Areas, 2009, Pg 43
\textsuperscript{121} Section 8.2.3 has concluding remarks on the cultural definition and international relevance of these Irish urban site spatial conditions.
Figure 5-13. Distinct density resolutions

Above, screenshot from overall Dublin area CSO 2011 Small Areas map (Source AIRO) and below (1) Dundrum-Balally Electoral District (ED) map, (2) Electoral District also showing constituent Small Areas mapping, (3) One low density Small Area highlighted (4) An Adjoining high density Small Area highlighted, with view point indicated in plan (Images 1-4, Source www.Myplan.ie) (5) View of distinct Small Area densities at the urban site. This indicates highly distinct differences in residential density occurring in ‘point’ locations, which ED mapping does not convey graphically.
Above, Screenshot from Dublin area myplan.ie website, showing 'Address Points' only, from top, (1) Inner city, (2) Outer suburban (3) Suburban and outer suburban locations. Distinct mixed land-use clusters of address points are highlighted, and also contrasting single use clusters of address points in plan (Images 1-3, Source www.Myplan.ie). Other contexts are recorded in Appendix A.
Figure 5-16. Overall Dublin spatial complexity maps: composition, configuration, system

Overall explored Dublin spatial complexity map (highest) and three constituent maps (r): composition (bottom), configuration (middle), and system (top). Source: Author.

272
Figure 5-16. Exploratory Spatial Complexity Map of Dublin

Source: Author
Table 5-4. Three case unit descriptions

* CSO 2011 Small Areas geographical outlines do not exactly coincide with case site outlines, and population estimates have been slightly adjusted here based on spatial outlines of official units (eg. Liberties character area outline) and the researchers local knowledge and fieldwork.
5.3.1 The case urban sites

The three site contexts and selected case units are described in Table 5-4. The first case site is the Liberties Character Area, defined as such according to the Liberties Local Area Plan (2009). It is one of the eight character areas officially defined in planning terms as part of the wider historic inner urban neighbourhood also called the Liberties. The land use context is described as mixed, including tourism and institutional city centre use (DCC, 2009). The second case site is Urban Ballymun, defined in official planning terms as a Key District Centre (KDC) Area, in the Dublin City Council Development Plan (2016-22) within the context of Ballymun, a suburban town. This urban site is officially described as a primarily residential area (DCC, 2016). The third case is the existing condition of a proposed new neighbourhood area, at Carmanhall, defined in planning terms by the Sandyford Urban Framework Plan, (2011) in the

![Figure 5-17. City map showing case sites](image)

Ballymun (top), Liberties, (centre) and Sandyford (bottom) with Small Areas map outlines, CSO 2011, indicating relative clusters of density, as each Small Area contains 250 residents approximately.
context of a regional hub at Sandyford. The Sandyford area is officially defined in land use terms as primarily light industrial (DLRCC, 2012). The three case sites are described in more detail after a description of each context, in the next Section.

5.4 Three case context descriptions

This section concentrates on the descriptions of the contexts of the three case sites, focusing specifically on an outline description, historical overview and planning/policy context in each case. This part of the overall study serves to supplement the contextual overview of the city of Dublin earlier in this Chapter, and to foreground the material of the next chapter, which deals individually with case evaluations.
5.4.1 Liberties (context of the LAP Character Area)

This section describes the context of the case study site called the Liberties Character Area (an LAP Character Area), one of eight character areas defined in the current Local Area Plan document (See Fig 5-18). The geographical context of the case site is the wider Liberties, as defined in the same planning document. While the next Chapter will evaluate the case site, this Chapter concentrates on the description, history, and planning and policy contexts of the case, and description of the case itself. This Liberties is regarded in this study as one of a small number of origin sites of Irish urbanity. (See Appendix A, Morphology of Cases).
5.4.1.1 Context Description

The Liberties is a historic inner urban neighbourhood in the south west of Dublin city centre, which has undergone significant spatial change in recent times. The land area of the Liberties\(^{122}\) context is 1.36 km sq (336 acres) and has a total residential population of 14,599 persons (10,734 pers/ sq km).

5.4.1.2 History

The term ‘liberty’ refers to defined landholdings of medieval origin under ecclesiastical control, covering the whole south-west quadrant of the city of Dublin (McCullough, 2007:100). Originally a medieval suburb, located just outside of the original walled city, the Liberties area is west of, and close to, the crossing points of ancient routes leading from the rest of the country towards the walled city of Dublin, and also close to the first bridge over the main river of the city, the Liffey. The years immediately after Dublin’s Charter of urban liberties of 1192 are considered important in the genesis of the area, as one of its provisions was that citizens could build outside the town walls (Casey, 2005:15). Casey further describes a ‘medieval peak’ in city population around 1300, of 11,000 persons approximately, and relates this to the Henrician Reformation (c.1540) which ‘followed more than two centuries of morphological stagnation in Dublin (Casey, 2005:17). Craig describes a population growth of ‘at least five or six times, and perhaps more’, between 1660 and 1710, (from less than 15,000 to 75,000), and suggests this growth was associated with industrial development and expansion, which he argues took place largely in the ‘haphazard industrial suburb round Cork Street and the

\(^{122}\) The ‘Liberties’ site description here is taken to mean the designated Local Area Plan lands within the boundary of the LAP document, (see Pg 29, Draft Liberties LAP, 2009) which includes five electoral districts (ED’s) : Merchants Quay A, B and C, and Ushers Quay B and C, and CSO population figures of the 2011 Census of population are used here.
Coombe’, in other words, the Liberties. He then describes how ‘the large weaver’s colony’ to the south-west put a stop to fashionable interest in that quarter’ (Craig, 1952:84). A description of fast urban growth around this time by (O’Brien, Kane, 2012) paints a portrait of Dublin in 1800 as ‘the sixth largest city in Europe’, arguing that ‘it was growing too big to be visualised, imagined or designed as a complete entity (O’Brien, Kane, 2012:17). After this date, tenements in the Liberties are a feature of urban historical descriptions (McCullough, 2007)(Burke, 1972), right up to 1880, the date of the commencement of ‘social housing’ (DCT, 2008:7) in the Liberties quarter. Although the prevailing accounts of the Liberties in the early and mid-twentieth century have associations of overcrowding and poverty (Kelly, 1910)(Kearns, 1994)(Johnson, 1981), it is the spatial restructuring brought about by a combination of tenement clearances, large modernist social housing schemes and road widenings that define the contemporary urban structure of the area.

5.4.1.3 Current Planning/policy

The current local planning context of the Liberties includes a definition of ‘urban quarter’ designation by a Local Area Plan (LAP) published in 2009. The making of Local Area Plans (LAP) in Ireland is a primary planning tool for the development of local area planning schemes, defined as ‘the principal statutory instrument for setting out balanced understanding, vision and spatial strategies at local level’ (LAP Manual, 2012:2). The Liberties is also designated a Strategic Development and Regeneration Area (SDRA) in the city’s current Development Plan (Dublin City Council’s Draft City Development Plan 2016-22).
5.4.1.4 Spatial complexity of Liberties context

This section explores the spatial complexity of the Liberties quarter, the context of the case site, in advance of evaluation of the case site. In this way, the exploration of this Chapter is linked to the evaluation of the next Chapter. While exploration is less precise than evaluation, concentrating on the three issues rather than the nine criteria, and in advance of the use of the Toolbox and Databox, examining these three scalar levels (whole city, urban site context, and urban site) enriches a full description of the city, the contexts, and the cases.

Composition

The Liberties quarter is defined by the planning designated boundary adopted by the Liberties LAP, as described earlier, and comprises nine character areas within the inner city of Dublin. Evidence of compositional complexity is provided in three areas: urban morphological complexity, land-use mix, and density. Firstly, high urban morphological complexity is demonstrated by mapping the plan-units of the inner city, showing small size and relative diversity of plan-unit type in the historic city\(^\text{123}\). Secondly, high land-use mix is clear from 2km resolution images of address points in the south inner city\(^\text{124}\). Thirdly, high density is shown by reference to mapped Small Areas level Census of residential population data (2011) in the inner city\(^\text{125}\).

Configuration

Evidence of configurational complexity of the Liberties quarter is provided in one of three possible areas: global integration. While other evidence items could be described including local integration, choice, and intelligibility of this area, it is sufficient to review briefly the global connectedness of the inner city quarter to demonstrate that

\(^{123}\) See Volume Two, Appendix A, Morphology of Cases, Section 2.0, ‘Liberties character area’, Pg 8.

\(^{124}\) See Volume Two, Appendix F, Visualising Spatial Complexity, Section 11, ‘Visualisations of highest compositional complexity’, Fig. FF-13, Pg 197.

\(^{125}\) See Volume Two, Appendix F, Visualising Spatial Complexity, Section 2, ‘Visualising case contexts’, Fig. FF-6, Pg 191.
high configurational complexity exists in this inner city context. The image indicating the position of the Liberties area in the scattergram of Dublin overall, with a high global integration in city terms, shows high configurational complexity of the Liberties quarter.

**System**

Exploring the spatial complexity of the Liberties quarter by analyzing system criteria could involve analyzing street network complexity, path network complexity or pedestrian movement system complexity, and each is evaluated for the case site in the next Chapter. However, as the high pedestrian movement system complexity is already evident, as demonstrated through presence of footfall counts in the city centre, (Section 5.4.1.2, Fig. 5-11, Pg 260) an image which superimposes this aspect on the local choice analysis for the quarter is prepared and employed, to indicate both spatial proximity of the ‘system centre’ of the city to the Liberties quarter, and also to show how this is connected by integration qualities of the urban structure of the city centre.

**Spatial complexity of Liberties context**

From the three descriptions above, and applying the equal weighting principle to the three criteria of spatial complexity employed, and according the conceptual framework of this study, this exploration of the Liberties context suggests an inner city urban context of high spatial complexity, in Dublin terms.

---

126 See Volume Two, Appendix E, ‘Syntactic Analysis of Dublin’, Section 7, Figure EE-7, Dublin Axial Map 2012, Liberties highlighted, Pg 167.
127 See Volume Two, Appendix D, ‘Pedestrian Movement Fieldwork’, Section 1, Liberties character area fieldwork, Pg 135.
5.4.2 Ballymun (context of Urban Ballymun)

This section describes the context of the case study site called Urban Ballymun (a ‘Key District Centre’), located at the centre of, and surrounded by five neighbourhoods, defined in the Ballymun Masterplan (1998) (See Fig 5-19). Ballymun represents Ireland’s largest social housing and high-rise urban experiment. (See Appendix A, Morphology of Cases).
5.4.2.1  Context Description

Ballymun\textsuperscript{128} is located approximately six kilometres north of Dublin city centre, close to Ireland’s largest airport and the main motorway surrounding the city, the M50. Originally developed in the 1960’s, and described as a ‘low-density, decentralized community in the model of the self-sufficient post-war British New Town’ (Rowley, 2014: 415), it was later (1997-2015) the subject of the largest urban regeneration project ever undertaken in the Irish state. The regenerated ‘town’ of Ballymun contains five neighbourhoods and one major civic space, Ballymun Plaza. Connections to surrounding neighbourhoods are poor, partly as a result of the modernist, car-based design of the original estate, which focused on vehicle links to the city centre and the airport, and often contained roads with no footpaths.

5.4.2.2  History of Ballymun

Ballymun was conceived as a modernist social housing estate (1965-69) on agricultural lands, as described in detail by Power (Power, 2000) and others (Montague, 2008)(Power, 1993, 1997), which then underwent a period of notable social and spatial decline (1971-85), and a further phase of neglect and vacancy, the results of a surrender grant scheme in 1985, which facilitated many residents to move away (1986-97). The subsequent policy response, and ongoing physical, social and economic regeneration (1997-2015) could serve as a most recent, fourth phase in the spatial trajectory of the place (Boyle, 2005). Estate regeneration began in 1997 in response to social and economic decline. Five separate neighbourhoods were envisaged in the 1998 Masterplan for regeneration, although no neighbourhood plan was made specifically at the time for a neighbourhood to be located at the urban centre of Ballymun, to link the

\textsuperscript{128} Ballymun is defined here as the ‘urban site’ which has the geographical extent outlined in the Dublin City Council Development Plan 2011-2017, (Map K, Key Developing Area outline, coloured in orange).
surrounding residential neighbourhoods. Hence, residents of this part of the development are officially seen to belong to primarily low-density residential character neighbourhoods, but not to an emerging urban, medium density apartment dwelling community, which is defined in this study as urban Ballymun.

5.4.2.3 Current Planning/policy

Ballymun (in overall terms) is designated by Dublin City Council as a district centre, and is officially considered to be one of the fastest growing and most dynamically changing locations in the city, although still (in 2015) subject in planning designation terms to the urban design intentions of the 1998 Masterplan.129 It is currently earmarked for a new Local Area Plan, an objective of the Draft City Development Plan 2016-22. It is described as 3rd highest single 'area' for ‘estimated capacity’ of housing, and is considered to have future capacity for 3,000 residential units. ‘Extensive new neighbourhoods’ are planned by the city authorities, and a Local Area Plan will be prepared by the Council in the near future. It is designated as one of seventeen Strategic Development and Regeneration Areas (SDRA) and one of only eight Key District Centres (KDC) in the city, and is one of one of the top (13) locations in the city selected by forward planning for high buildings in the future. As part of the future planning context of Ballymun, a number of recent events are relevant. In order to incentivise development in the area, Ballymun is identified (by DCC) as one of nine ‘mid-rise’ locations in the city, which allows future building heights of ‘up to 50 m’, which means “equivalent to 16 storeys residential or 12 storeys commercial”. However, official

129 Dublin City Council’s Draft City Development Plan 2016-22, due for adoption on 211016, foresees preparation of a Local Area Plan for Ballymun, and illustrates Key Development Principles for the SDRA in Map 2-Ballymun, including increased connectivity and proposed land uses.
planning designations do not mention town status, as the area does not have the legally required components, such as borough status\(^\text{130}\).

### 5.4.2.4 Spatial complexity of Ballymun context

#### Composition

The suburban ‘town’ of Ballymun is defined by the official designated boundary adopted by Ballymun Regeneration Limited (BRL), the primary public body overseeing regeneration and development in the area since 1997. As described earlier, Ballymun comprises five neighbourhoods in the suburbs of Dublin. Evidence of compositional complexity is provided in three areas: urban morphological complexity, land-use mix, and density. Firstly, medium urban morphological complexity is demonstrated by mapping the plan-units of Ballymun\(^\text{131}\), showing large size and relative homogeneity of plan-unit type in this residential suburb. Secondly, low land-use mix is clear from 2km resolution images of address points in the north of the city\(^\text{132}\). Thirdly, medium and low density is shown by reference to mapped Small Areas level Census of residential population data (2011) in the area\(^\text{133}\). In summary, compositional complexity of the case context at Ballymun is evaluated as medium to low.

#### Configuration

Evidence of configurational complexity of Ballymun is provided in one of three possible criteria: intelligibility. While other evidence items could be described, for

\(^{130}\) The Planning and Development Act 2000, Section 84(6) defines a ‘town’ as a borough, urban district or a town having town commissioners that has a population in excess of 2,000.


\(^{132}\) See Volume Two, Appendix F, Visualising Spatial Complexity, Section 11, ‘Visualisations of highest compositional complexity’, Fig. FF-13, Pg 197.

global and local integration, and choice for this area, it is sufficient to review briefly the intelligibility of the development to demonstrate that medium intelligibility and therefore configurational complexity exists in this suburban context. The image indicating the position of the Ballymun area in the scattergram of Dublin overall, with medium intelligibility indicated by points both above and below the regression line in city terms, shows medium configurational complexity of Ballymun. A separate image indicates how intelligibility falls away from the main street rapidly. In summary, configurational complexity of the case context at Ballymun is evaluated as medium.

**System**

According to the conceptual framework of this study, exploring the spatial complexity of Ballymun by analyzing system criteria could involve analyzing street network complexity, path network complexity or pedestrian movement system complexity, and each is evaluated for the case site in the next Chapter. However, as street network complexity can reveal useful system characteristics of the overall ‘regenerated New Town’, this aspect is evaluated, data is prepared, represented graphically and employed, to indicate both low street network complexity of the suburban town, and also to show how this measure is lower than the street network complexity of the civic centre at urban Ballymun, which will be evaluated in the next Chapter. In summary, system complexity of the case context at Ballymun is evaluated as medium.

**Spatial complexity of Ballymun context**

From the three descriptions above, and applying the equal weighting principle to the three criteria of spatial complexity employed, and according the conceptual framework

---

134 See Volume Two, Appendix E, Syntactic Analysis of Dublin, Section 8, Figures EE-8, and EE-9, Dublin Axial Map, Ballymun highlighted, Pg 167.

135 See Volume Two, Appendix D, ‘Pedestrian Movement Fieldwork’, Section 2, Urban Ballymun fieldwork, Pg 139.
of this study, this exploration of the Ballymun context suggests a suburban context of medium spatial complexity, in Dublin terms.
5.4.3 Sandyford (context of Carmanhall)

This section describes Sandyford, the context of the case study site called Carmanhall (a future neighbourhood), one of five areas described in the current Urban Design Framework Plan for the Sandyford area (See Fig 5-20). Sandyford represents the first entry by Dublin City Corporation in the 1970’s into the field of development and sale of industrial sites, which could be connected to an entrepreneurial shift in Irish spatial governance. (See also Appendix A, Morphology of Cases).

5.4.3.1 Context Description

The context of the Carmanhall area, (the case site), ‘Sandyford’ in south Dublin includes two former separate entities in the area, the Stillorgan Business Estate and the
'former Sandyford Industrial Estate’, together commonly known as Sandyford\textsuperscript{136}. The Stillorgan Business Estate, formerly known as the Stillorgan Business Park, is the oldest of the numerous ‘industrial estates’ located in this area, developed in the early 1970’s by a private developer, Holmes Construction, and is described as a ‘very high density industrial estate’ including terraces of single storey light industrial sheds (McGibbon, 2006). The surrounding geographical context is mainly suburban residential housing in semi-detached estate form, and the major motorway around the city, the M50, is situated directly adjoining the area to the southwest. The former Sandyford Industrial Estate, developed by Dublin Corporation in the 1970’s, was laid out according to a single grid-like plan, geographically aligned to the pre-existing former railway line, recently reinstated as a tram line connection to the city centre. The land area of the context site at Sandyford is 1 km sq area approx (255 acres) and this has a population of 2,600\textsuperscript{137}, an average population density of 2,600 persons per sq km. This is a very low overall residential density for an emerging regional hub, and is unevenly spread over the 'site' with just a few high density apartment blocks, alongside unfinished developments.

\textbf{5.4.3.2 History}

Deriving its name from a small historic village situated in what was, until recently, countryside to the southwest nearby, the location commonly referred to as ‘Sandyford’ in south Dublin represents the entry by Dublin City Corporation in the 1970’s into the field of development and sale of industrial sites, which then evolved (in the 1980’s)

\textsuperscript{136} The historic village of Sandyford, which originally gave the name to one of the industrial estates, is located approx. 600m to the south-west of the centre of Sandyford Business District, geographically separated from this area by the M50 motorway, since the 1990’s.

\textsuperscript{137} In arriving at the residential population estimate for Sandyford, no information was available in the local authority document entitled ‘Sandyford Urban Framework Plan (2011), and the relevant electoral districts (ED) is much more spatially extensive than the context site considered here. Therefore, using a combination of researchers local knowledge and fieldwork, a spatial delineation of the two original Sandyford industrial estates was devised including nine small areas (SA) figures from the ‘Population by Area Census Report’ (CSO, 2011) and AIRO All-Island Census Atlas mappings (Source: http://airomaps.nuim.ie/id/AI_Atlas/?mobileBreakPoint=400/).
towards a more mixed-use site including offices and retail, and lastly emerging after 2000 as an unplanned, sharply mixed density, unfinished commercial and residential development zone, effectively stalled since the end of the economic boom in 2008.

5.4.3.3 Current Planning/policy

Sandyford, which was in farmland until the 1970’s, is one of only four proposed ‘primary growth centres’ in the medium term future of Dublin. According to The Regional Planning Guidelines (RPG) 2010-22: “The Dublin city region and a number of growth centres within the polycentric gateway- Swords, Blanchardstown, Sandyford and Tallaght- have been identified as drivers within the core of the GDA (Greater Dublin Area), for sustained international and regional economic development and growth” (Dublin Regional Authority, 2010: 67). Although this status is not pursued in the most recent Framework Plan for the area (See Appendix G), Sandyford can be regarded as a ‘primary economic growth town’ (RPG, Section 3.7.3) and regional hub in planning and urban design terms.

5.4.3.4 Spatial complexity of Sandyford

Composition

The outer suburban regional hub of Sandyford, as an existing case context, is defined by the official designated boundary adopted by the Local authority for the area, Dún Laoghaire Rathdown County Council, for the Sandyford Urban Framework Plan document (2011). As described earlier, Sandyford comprises a number of former industrial estates in the outer suburbs of Dublin. Evidence of compositional complexity is provided in three areas: urban morphological complexity, land-use mix, and density.
Firstly, low urban morphological complexity is demonstrated by mapping the plan-units of Sandyford\textsuperscript{138} (Appendix E), showing grid-like layout, large size and relative homogeneity of plan-unit type, as expected for what was originally a single owner development in this outer suburb. Secondly, low land-use mix is clear from 2km resolution images of address points in the this south east part of the city (See Figure 5-14, ‘Distinct land-use clusters’, Pg 271). Thirdly, a mixture at smaller scalar resolution between very high density and very low density is shown by reference to mapped Small Areas level Census of residential population data (2011) in the area\textsuperscript{139}. In seeking to derive an overall understanding of the compositional complexity for the context of the urban site at Carmanhall, it is evident that the first aspect evaluated, urban form, has a significant impact on the wider reading, due to the rapid development of an ‘edge-city’ urban morphological structure in a short time. In summary, Sandyford, as context in overall terms, has a low level of compositional complexity.

**Configuration**

Evidence of configurational complexity of the outer suburban ‘regional hub’ of Sandyford is provided in one of three possible criteria: intelligibility. While other evidence items could be described, for global and local integration and choice for this area, it is sufficient to review briefly the intelligibility of the context of the case urban site to demonstrate that low intelligibility and therefore low configurational complexity exists in this outer suburban context. The image\textsuperscript{140} indicating the position of the Sandyford area in the lower half of the scattergram of Dublin overall, with low intelligibility indicated by points mainly below the regression line in city terms, shows low configurational complexity of Sandyford.

\textsuperscript{138} See Volume Two, Appendix A, Morphology of Cases, Section 4.0, ‘Carmanhall’, Pg 53.


\textsuperscript{140} See Volume Two, Appendix E, Syntactic Analysis of Dublin, Section 8, Figure EE-10 Dublin Axial Map, Sandyford highlighted, Pg 167.
System

According to the conceptual framework of this study, exploring the spatial complexity of Sandyford by analyzing system criteria could involve analyzing street network complexity, path network complexity or pedestrian movement system complexity, and each is evaluated for the case site in the next Chapter. However, as it is the regional level infrastructure of the site which spatially defines this context, a morphological analysis image at this scale is prepared and employed. Graphical analysis of the context using Scheer’s tissue analysis categories (Scherr, 2001, 2003) reveals useful spatial system characteristics of the overall area (See Appendix A, Fig. AA-27, Morphology of Cases). High spatial system complexity is apparent at Sandyford, although this characteristic may not be represented again in evaluation at the scalar level of the urban site, in the next Chapter. See Appendix A, (Morphology of cases description, Section 3).

Spatial complexity of Sandyford context

From the three descriptions above, and applying the equal weighting principle to the three criteria of spatial complexity employed, and according the conceptual framework of this study, this exploration of the Sandyford context suggests low compositional complexity, low configurational complexity, but high system complexity at this scale of resolution. Although these criteria are not all evenly representing a low value, because of the predominance of low values, it is concluded that this outer suburban context is of low spatial complexity in overall Dublin terms.

141 The primary theoretical concept in this respect is that of ‘complex spatial systems’. Wilson’s (2000) definition describes four characteristics of these types of system: ‘contain many variables, high levels of interdependence between variables, are governed by non-linear processes, and have significant spatial structure’ (Wilson, 2000: 379). Wilson’s core interest is urban modelling, and his analysis ‘toolkit’ includes non-linear mathematics, computer simulation and visual representation. The primarily quantitative approach of many complexity scientists is responded to here for the discipline and scale of urban design by adding a more qualitative and mixed methodology, in order to be useful in practice, related to the analysis, evaluation and design of urban sites. Complex systems are of two types, natural and artificial, and cities are in the second category (Holland, 2012). Weaver classified three types of systems: ‘simple’ (having few variables), and then two types of complex system, ‘disorganised’ and ‘organised’ (Weaver, 1958). Disorganised systems are seen as having elements which are not strongly interdependant, whereas organised systems have strong interdependancies.
Conclusions on spatial complexity of the case contexts

This section has defined the concept of spatial complexity for urban design theory and practice through demonstration of an exploratory investigation of three case contexts. Results from exploration of the three case contexts are described and compared in this section. While the outline definition of spatial complexity for urban design offered at the outset of this study (‘the spatial component of urban complexity’) (Chapter One, Section 1.3.5.1 ‘Definitions’) was expanded upon in Chapter Two, as part of the theoretical exploration of concepts from complexity which may have meaning for urban design (Chapter two, Section 2.2.5 ‘Definition of spatial complexity adopted for this study’) it is in the demonstration of the exploration of contexts and evaluations of cases that a definition can be explained and used in a way which allows repeatability and transferability into evaluation practice in urban design. As regards exploratory investigation of three case contexts, Liberties is shown to have high explored levels of spatial complexity, Ballymun medium levels, and Sandyford low, (though having mixed indicators for this level of resolution). Synthesis in this section involves visual representations, in the form of complexity maps, for contexts of urban sites evaluated in the next Chapter.

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Liberties</th>
<th>Ballymun</th>
<th>Sandyford</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Composition</strong></td>
<td>high</td>
<td>medium/low</td>
<td>low</td>
</tr>
<tr>
<td><strong>Configuration</strong></td>
<td>high</td>
<td>medium</td>
<td>low</td>
</tr>
<tr>
<td><strong>System</strong></td>
<td>high</td>
<td>medium</td>
<td>high</td>
</tr>
<tr>
<td><strong>Explored spatial complexity</strong></td>
<td>high</td>
<td>medium</td>
<td>low</td>
</tr>
</tbody>
</table>

Table 5-5. Three explored spatial complexity results (case contexts)
(See also Addendum Section in Vol 2 for more visualised results of case evaluations)
5.5 Three case descriptions

In this Section, the more specific descriptions of the cases themselves are set out, as well as the distinct and contrasting nature of each urban site. Firstly, within the historic urban context of the Liberties quarter, one character area is selected as the case study site. The second selected urban site is located in Ballymun, referred to throughout here as the ‘Urban Ballymun’. The third case study site is the Carmanhall neighbourhood, another distinct and contrasting condition, located within the context of Sandyford, a former light industrial estate on the edge of the city. The geographical locations and key factual indicators of the three selected urban sites are illustrated in Figure 5-14 and Table 5-4. Following this general description of the three case sites, the next Chapter will describe evaluations of spatial complexity for the Liberties character area, urban Ballymun and Carmanhall neighbourhood respectively.
Figure 5-21. Liberties character area boundary

Source: Ordnance Survey Ireland, 2009, Dublin City 1:1000, Sheet 3263, Licence Number APL0000115.
Liberties Character Area

Within the context of the Liberties quarter, one character area identified in the LAP is selected as the case study site, referred to throughout here as the ‘Liberties character area’. The land area of the Liberties character area is 0.34 km sq (84 acres) and it has a total residential population of 3,822 persons (15,925 pers/ sq km). The case site is bounded to the east and south by modernist (C20) road widening schemes (Patrick Street, east, and Coombe Bypass, south).

[142] The concept of ‘character area’ is sometimes employed in urban design practice, and generally refers to the geographical definition of an urban area where identity is based on a particular activity or mix (Llewelyn Davies Yeang, 2007:40) or unifying formal characteristics. Definition of a character area is argued to reinforce local identity and enhance the marketing profile of a place. However in one study, significant differences were found between the character areas recognized by planners, researchers and the general public (Birkhamshaw, Whitehand, 2012) suggesting that extents of character areas are not widely agreed.
Figure 5-22. Urban Ballymun area boundary

Source: Ordnance Survey Ireland, 2009, Dublin City 1:1000, Sheet 3131-2, Licence Number APL0000115.
**Urban Ballymun**

Within the context of the regenerated suburb of Ballymun, one area is selected as the second case study site, referred to throughout here as the ‘urban Ballymun’. The geographical extent of this urban site is identified in the Dublin City Development Plan as a ‘Key District Centre’\(^{143}\). The overall land area of 2.85 km sq area (704 acres) has a total residential population of 16,236 persons\(^{144}\), which corresponds in turn to an average population density of 5,697 persons per sq km. The number of dwellings in this area was 5,795 in 2011\(^{145}\) and construction of housing is ongoing. The number of houses (that is, ‘own-door’ off street dwellings) in Ballymun was 3,609 in 2011\(^{146}\) and consequently apartments numbered 2,186. Therefore the percentage of apartments is 38%. This is above the average for Dublin city generally, where 30% of the population are apartment dwellers (source: Kearns, 2014:213). Ballymun contains five neighbourhoods, and one town centre, which includes a major civic space, Ballymun Plaza. However, the regeneration of Ballymun is incomplete, and the urban environment contains a number of stalled or empty sites present around the main Plaza.

---

\(^{143}\) Urban Ballymun is defined here as the ‘urban site’ which has the geographical extent outlined in the Dublin City Council Development Plan 2011-2017, (Map K, Key Developing Area outline, coloured in orange).

\(^{144}\) (Source, CSO 2011. The Ballymun area described here comprises four electoral districts (ED’s), Ballymun, A, B, C and D)

\(^{145}\) (Source, AIRO Census Mapping 2011, Theme 5-1 (a), Number of households by type of household, Total’, http://airo.maynoothuniversity.ie/external-content/dublin-city, accessed 011115).

\(^{146}\) (Source, AIRO Census Mapping 2011, Theme 6-1 (a) Private households by type of accommodation, ‘House/bungalow’ http://airo.maynoothuniversity.ie/external-content/dublin-city, accessed 011115),
Figure 5-23. Carmanhall neighbourhood area boundary

(Outline in red) Source: Ordnance Survey Ireland, 2005, Urban Place Map, Dublin City 1:1000, Sheet 3192-19,20, 24, 25, Licence Number APL0000115
Carmanhall
Within the context of Sandyford, one neighbourhood identified in the Framework Plan is selected as the third case study site, referred to throughout here as the ‘Carmanhall Neighbourhood’\(^{147}\). The land area of Sandyford is 1 km sq area approximately (255 acres). There was a 44% increase in population in the electoral district of Dundrum-Balally (which includes Sandyford) between the Census of 2006 and that of 2011, by 2,141 to 7,035 persons. Sandyford itself has a population of 2,600 approximately, over one square kilometre. For comparison, the average population density in urban areas in Ireland is 1,736 persons per km\(^2\) (CSO, 2012:1). The area is characterised by a mix of 1970’s light industrial units and a small number of more recent high-density apartment buildings in partly completed perimeter urban blocks. Some relevant features of these apartment developments include low owner-occupation (only one in five is owner-occupied), small numbers of families and children, and a high proportion of young single people or couples, who are renting short term in the area, one-third of whom are non-Irish. In response to a perceived previous lack of overall planning strategy for the area, the Sandyford Urban Framework Plan (SUFP) was prepared by Dún Laoghaire Rathdown County Council, the local authority, and completed in 2011.

The definition of the spatial unit of ‘Carmanhall Neighbourhood’ as a ‘case unit’ follows fieldwork assessment and urban analysis, as well as desktop analysis of the official designation in SUFP 2011, which defines ‘Carmanhall Road Residential Neighbourhood’ (SUFP 2011, Section 3.5.4, ‘Sustainable Residential Neighbourhoods’,

\(^{147}\) The definition of the spatial unit of ‘Carmanhall Neighbourhood’ as a ‘case unit’ follows fieldwork assessment and urban analysis, as well as desktop analysis of the official designation in the SUFP. This document defines ‘Carmanhall Road Residential Neighbourhood’ (Sandyford Urban Framework Plan, 2011, Section 3.5.4, ‘Sustainable Residential Neighbourhoods’, Pg 31), as two distinct and poorly spatially related urban blocks (or part thereof) only. (See also Sandyford Urban Framework Plan, Drawing 14, titled ‘Reference Sites’, indicating sites 1, 5 and 11). It has been decided to allocate an additional 4 urban blocks to the neighbourhood definition (urban site) of the case unit, (thereby including more densely ‘urban’ urban blocks’) and to describe this as the ‘Carmanhall Neighbourhood’, for the purposes of the case unit analysis. (This also allows for the later designation within the case of Carmanhall Neighbourhood, the embedded case of Beacon Court Shopping Centre, currently the most commercially vibrant and successful location in the area.).
Pg 31), as two distinct and poorly spatially related urban blocks (or part thereof) only. (See also Drawing 14, titled ‘Reference Sites’, indicating sites 1, 5 and 11) It has been decided to allocate an additional 4 urban blocks to the neighbourhood definition (urban site) of the case unit, (thereby including more densely ‘urban’ urban blocks’) and to describe this as the ‘Carmanhall Neighbourhood’, for the purposes of the case unit analysis.
5.6 Chapter Conclusions

This Chapter started by developing an overall aim of this study, of exploring spatial complexity of contexts of urban sites. This is achieved by linking general aspects of spatial complexity to one whole city unit, Dublin, in advance of detail evaluation for urban design of multiple urban sites in the next Chapter. It starts by answering the first of the two questions: ‘is it useful to urban design to explore the concept of spatial complexity for large urban geographical units?’ and making four points. Firstly, to evaluate spatial complexity at scales larger than urban sites is useful for urban design because this discipline and practice operates at increasingly larger scales and therefore needs new analysis tools, capable of operating across new and existing scales. Secondly, clear connections between urban and non-urban site evaluation and management can be seen for larger scale sites. This is important because hierarchical alignment between sites is still a fundamental of urban planning and design practice, and especially in Ireland. Thirdly, it seems appropriate to align an already developing classification systems in landscape with a future national system of spatial complexity classification of urban sites. Lastly, the ability to evaluate spatial complexity on larger scales could also enhance an evidence base of a national spatial strategy. The first section of this Chapter therefore concludes that, for these four reasons, it is useful to urban design to explore the concept of spatial complexity for large urban geographical units.

The second section of this Chapter introduces the city of Dublin as the overall context of the three case urban sites, and demonstrates that Dublin is of sufficient complexity in urban terms to warrant attention in this study. Three primary characteristics of the city
are described: its planning/policy status, its urban structure and size, and relevant socio-spatial and economic factors, and these are shown to make Dublin a suitable context for case study research on spatial complexity and urban design.

The second question of this Chapter asks: how spatially complex are the contexts of the case sites? This query relates directly to the spatial complexity of Dublin in whole city terms, as discussed in the last section, but also to more specific issues of spatial complexity, derived from the literature. One reason to ask this question is in order to screen potential case sites: that is, those contexts and sites which appear to demonstrate distinct and contrasting spatial conditions, in advance of focused spatial complexity evaluation of particular urban sites in the next Chapter. In framing an answer to this question, the three constituent issues of evaluated spatial complexity introduced earlier are used to structure the categorization of data sources for exploration of case context, that is: composition, configuration and system issues.
Chapter Six Three urban site evaluations

‘…the biggest problem in city measurement is the lack of specificity about the ‘on the ground’ physical reality of cities.’ (Talen, 2003:196)

While exploratory questions about spatial complexity of one city are answered in Chapter Five, this Chapter presents evidence in relation to a more precise question: how to evaluate spatial complexity of particular selected urban sites within a city. One of the conclusions of the last Chapter, that the explored spatial complexity ‘level’ of Dublin, in overall terms, is of a comparatively low and uneven nature, suggests a need to investigate spatial complexity in more detail. In order to demonstrate that the exploratory finding of Chapter Five can be supplemented with evaluation evidence from specific sites at more exact scales for urban design, the evaluated spatial complexity levels of three urban sites are now presented. The questions asked in this Chapter are linked to the second part of the research question of this thesis, which asks, following an increased exploration and understanding of spatial complexity, how can practical urban design evaluation tools be developed in order to evaluate the spatial complexity of urban sites? This chapter advances the overall argument of the thesis through generation of evaluation data. The main driver of this chapter is generation and representation of primary data, demonstrating evaluated spatial complexity at the scale of the urban site. Chapter Six therefore develops the overall aim of evaluating spatial complexity by linking explored general aspects of spatial complexity (in Chapter Five) to specificities of particular urban sites evaluated, in advance of detailed discussion of the results and findings about the case urban sites in the next Chapter.
6.1 Introduction

In focusing on exploration as well as evaluation, a multi-scalar approach of this study is made clear, as exploration in this study means analysis at larger geographic scales, and evaluation means closer measurement at finer scales associated with urban design at neighbourhood or urban site scale. This Chapter focuses on evaluation.

It is claimed that ‘any measure of complexity is most useful for comparisons between things at least one of which has high complexity by that measure’ (Gell-Mann, 1995:2), and therefore this Chapter presents evaluations of high, medium and low spatial complexity for comparison in the next Chapter. Specific protocols relating to use of the nine tools of evaluation described in this Chapter are contained in the separate Appendix B, the Evaluation Protocols Appendix. Each of the three issues of spatial complexity (composition, configuration, and system) is tested using a minimum of three tools. The practice-based approach of this thesis defines exploration and evaluation of spatial complexity as research which will have urban design practice usefulness (see Ch 2.4.2), and considers the knowledge developed to be most useful for urban design when conducted at the scale of the urban site, as opposed to the ‘whole city unit’. This innovation in ways to consider spatial complexity contributes to new understandings of exploration and evaluation of spatial complexity for urban design. It is an integrative and relational approach, focusing more on the specific urban design scales which are unique to urban sites, on characteristics and change in urban form over time (temporality and composition), on topological relations between local and global phenomena (relationality and configuration), and considering also ‘the changing parts’ (Alexander, 1966:403) (multiscalarity and system), all linked in an integrative way.
The urban sites evaluated in this study are located in spatial contexts where significant recent change is known to have occurred (1988-2008), in comparative terms both nationally and internationally\textsuperscript{148}. That this spatial change occurred in the context of broader economic and spatial restructuring dynamics in the context of the city unit of Dublin is acknowledged (Brady, 2002). Although definitions of the ‘functional unit’ (Williams, 2013) of the city of Dublin vary, and the regional definition is currently the official nationally favoured unit for description in international terms (UN Habitat, 2015)(RPG, 2010), in this thesis the ‘context’ or exploratory background to the detail evaluations of urban sites is considered to be the urban scalar unit directly ‘above’ the urban site selected in each case. In the Liberties character area, this is the city ‘quarter’ of the wider Liberties. In Ballymun, what is termed here Urban Ballymun (the DCC KDC area) sits within the larger unit of Ballymun, and in Sandyford, the Carmanhall neighbourhood sits within the wider ‘Sandyford Industrial Estates’ spatial unit. The collection of these and the other screened urban sites in Dublin are seen as set within an ‘ecosystem paradigm of cities’ (Marshall, 2012a:200), taken here to mean an understanding that the city in overall terms, like an ecosystem, has no knowable optimal future state. In this respect, the spatial contexts of the selected urban sites are not seen solely in a local authority hierarchical relationship (inner city, suburban, outer suburban) but also in a complexity frame, as locations with recent dynamically changing spatial circumstances in common.

\textsuperscript{148} These spatial conditions are described in more detail in later Sections of this Chapter. The Liberties, for example, includes the Inner Tangent Ring Road, the largest historic urban core ring road in Ireland, still incomplete, while Ballymun (the largest social housing estate in Europe on construction, and at one time the largest regeneration site in Europe) is unique in Irish housing and urban culture. Sandyford’s sudden development was assisted by by a large land allocation for a motorway junction between the Eastern Bypass, a key proposed link from Dublin Port to the edge of city at the M50 motorway, an already complete ‘C’-ring, to the north, west and south. Development in this site included the tallest building proposals nationally in 2003, of 65 storeys, and change of land use from rural directly to urban during the economic boom which ended in 2008. (Source, Duffy, 2008:9).
All three urban sites presented here are evaluated by the sequential analysis of the three issues of spatial complexity: composition, configuration and system. Each also can be understood within a complexity frame, and one aim of this thesis is for enhanced understanding of spatial phenomena through a complex systems approach to urban analysis. According to Wilson (2000), this approach has a number of distinctive features. Firstly, the object of analysis (in this study, the urban site) is considered to have a number of distinct features: ‘described by many variables, have high levels of interdependence between variables, governed by non-linear processes, and have significant spatial structure’ (Wilson, 2002:379). All of these features apply to the case urban sites. Wilson’s core interest is urban modelling, and his analysis ‘toolkit’ includes non-linear mathematics, computer simulation and visual representation (Wilson, 2002:381). The primarily quantitative approach of many complexity scientists is responded to in this study for the discipline and scale of urban design by adding a more qualitative and mixed methodology, in order to be useful in practice, related to the analysis, evaluation and design of urban sites.

The compositional complexity aspects of urban sites are particularly examined in the first unit of study introduced here, a local character area, in a historic inner city neighbourhood, the Liberties. The configurational complexity aspects are particularly examined in the second unit of study, a key district centre in urban Ballymun, in a regenerated suburban ‘New Town’. The system complexity aspects of spatial complexity of urban sites are particularly examined in the third unit of study, the planned future neighbourhood of Carmanhall, located in Sandyford, a regional hub. In this way, questions particular to each issue of spatial complexity can be answered by reference to one particular site, as an example of the phenomena observed. In the first
site, the question of how important history can be to the ‘static’ evaluation of spatial complexity of a site is addressed. Complexity theory suggests that the history of a complex system is important and cannot be ignored (De Roo et al, 2012:180). In the second site, the question of links between urban centres and surrounding at local and global scales, and how this affects the evaluated spatial complexity is answered. In the third site, the question of how to evaluate spatial complexity of an urban site in a large-scale system hub is answered.

In relation to the question of how to evaluate compositional complexity at the scale of the case urban site, it is important for these steps in the overall evaluation of spatial complexity to represent phenomena not captured in other evaluations for each of the three issues. So, while compositional complexity is captured by urban form, land-use mix, and density measures, these mainly capture larger scale, three-dimensional, and formal attributes. Later in this Chapter, configurational complexity evaluation captures global and local configurational aspects of urban sites, which are evaluated using different methods, and these capture topological relations. When configurational evaluation is overlaid with compositional evaluation, a picture begins to emerge of evaluated spatial complexity for the case sites. Then system aspects of urban sites are evaluated using distinct methods, and these results contribute pattern, network, and dynamic temporal readings in order to complete a comprehensive description of spatial complexity of three urban sites. Completing the evaluation by adding system evaluation as a third layer to the configurational and compositional evaluations completes the process of revealing a rich understanding of the spatial complexity of an urban site. The linkages between the three urban site units evaluated and the wider context are then established as a coherent spatial complexity frame for discussion in the next chapter.
6.2 Case One: Liberties character area evaluation

This section describes the spatial complexity evaluation of one urban site by considering three component issues introduced earlier: compositional, configurational and system. Each issue of evaluation is further divided into three criteria. The description therefore begins with an outline of the compositional complexity of the urban site of the Liberties as demonstrated in the urban form, land use mix, and density. The section begins with a brief morphological description of the context of the Liberties. The geographical extent of the case site in 2012 is illustrated in the Liberties urban site figure ground plan (of buildings) (Fig. 6-1).
6.2.1 Liberties morphological description

This section is a brief morphological description of the Liberties as context for the later urban morphological complexity ‘metrics’ or evaluation in this Chapter. A more detailed description is contained in Appendix A. In brief introductory terms, the urban site described here as the Liberties\textsuperscript{149} is partly located within the original medieval town plan of Dublin, south of the Liffey, the river which divides the city into north and south sides. Previous study of urban form of Dublin using a morphological approach and town plan analysis has included Simm’s studies of medieval Dublin (1979, 1992), and her analysis of primary (or origin) plan units of Medieval Dublin in conjunction with Brady (2001). The Liberties is considered to form part of the second morphological plan unit of development of Viking-age Dublin city, \{Brady, 2001 \#153\} developed following the first (origin) plan unit, which includes a small area north and west of Dublin Castle. Originally a medieval suburb, located just outside of the original walled city, the Liberties area is west of, and close to, the crossing points of ancient routes leading from the rest of the country towards the walled city of Dublin. ‘Áth Cliath’ is the name given to the likely primary original secular settlement in Dublin, located in the north-east part of the present Liberties. This settlement was located directly south of, above, and close to the first ford (river crossing) of the Liffey. Hence, this location (around present day Cornmarket) has been an origin site of historic urbanity in Ireland.

\begin{footnote}
\textsuperscript{149} The urban site defined as the Liberties in this Thesis, as described in Chapter Four, is based on the Character Area spatial definition contained in the Liberties LAP, 2009, and so not an exact historical definition, although there are numerous variations on exact geographical definition (for example, see ‘Liberties and Environs’ Map in Casey’s book, (2006:598), as compared with McCullough’s more spatially specific description, (McCullough, 2007:100)).
\end{footnote}

A morphological approach to analyzing the layout and character in the first century of the Liberties area, described as ‘the western suburb of medieval Dublin’ (Duddy, 2014:157) emphasizes the emerging street pattern, the development of streetscape and
contiguous nature of burgage plots in the area (Duddy, 2014). Burke’s study of morphogenesis\(^{150}\) (Burke, 1972) includes detail original graphical mapping of the development of the historic urban form of Dublin, and focuses attention on the Liberties as a primary location of commercial, markets and religious institutions. The Dublin Environmental Inventory project (1993)(which assessed buildings of the city centre only) was the first systematic morphological analysis of Dublin, and was influenced by Conzen’s method of dividing the urban fabric into plots, streets and plan forms (Kealy, 2008:41). This focused on inner city Dublin (within the canals) compiling individual street inventories for the area in the mid 1990’s. However, the Inventory did not extend to a definition of morphological plan units or periods for the Liberties quarter, and especially not in relation to the Liberties character area, the case site. The analysis described in Appendix A achieves this aim. In relation to compositional complexity of the present urban site, and a ‘static’ evaluation, many authors refer to the loss of complexity of the urban fabric in this area over time, including the loss of distinct character between Meath Street and Francis Street (Hickey, 2008:10) disappearance of all medieval structures (Casey, 2005: 601) or the loss of ‘increment and scale’ of the area, which meant streets of gabled houses ‘just remained to be photographed’ (McCullough, 2004:100). However, the endurance of the complexity of the town plan itself, as evidenced through the categorization of morphological periods, plan units an sub-units, supports Conzen’s claim that this aspect of the townscape is its most enduring characteristic. In conclusion, although previous study of urban form of the Liberties has been limited, a decline in historic formal complexity is a recurrent theme.

\(^{150}\) The definition of morphogenesis – ‘the study of the origin of urban areas’ is contained in Conzen’s seminal study of the town of Alnwick (Conzen, 1960). Rates of change in urban form are also discussed by Conzen Conzen MRG. (1981) Geography and townscape conservation. In: Whitehand JWR (ed) The urban landscape: historical development and management. London: Academic Press. and, as a consequence, are argued in this study to impact on evaluated complexity of the contemporary urban environment.
6.2.2 Liberties composition

Having analysed the urban morphological context of the Liberties quarter and the case site, this section involves compositional evaluation of the Liberties character area, the case site (and one of eight character areas in the quarter), and looks at three criteria of compositional complexity; urban form metrics, land-use mix and density.

Urban form evaluation (morphological complexity)

Certain compositional aspects of urban sites are particularly concentrated on through a close reading of the first unit of study introduced here, a local character area, in a
historic inner city neighbourhood. Quantitative measures of urban form at the resolution or scale of the urban site can reveal useful particularities and patterns of information in comparison to other urban sites. In this sense, urban form ‘metrics’ can be distinguished as a more ‘scientific’ approach, whereas urban morphological analysis is more associated with a historico-geographical development analysis approach (Birkhamshaw et al, 2012:4). As described in Chapter Four, seven selected measures of urban form are: firstly, ‘power law distribution’ of streets (Salat, 2012), secondly, ‘passive volume ratio’ of urban blocks (Salat, 2012), thirdly ‘ABCD street type analysis’ (Marshall, 2005). The fourth, fifth, sixth and seventh measures are: plot type, plots per hectare, blocks per hectare, and junctions per km sq. These are commonly used measures in urban analysis and design, selected to help to define a comparable difference in these compositional characteristics of urban sites. In line with the overall aims of the study, distinct and comparable evaluated conditions of spatial complexity are sought. Appendix A, ‘Morphology of cases’, Volume Two, describes in detail the data analysis aspects of each of the seven measures of urban morphological complexity for the site at Liberties character area. In reviewing across the seven selected measures of urban form evaluation, and more specifically morphological complexity of the Liberties character area (See Table 6-1), a uniformly high result is clear.
<table>
<thead>
<tr>
<th>Compositional Criteria</th>
<th>Method</th>
<th>Source</th>
<th>Indicators</th>
<th>Liberties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban form</td>
<td>1. Power Law Distribution</td>
<td>(Salat, 2012:29)</td>
<td>low-medium-high</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td>2. Passive Volume Ratio</td>
<td>(Salat, 2012:34)</td>
<td>%</td>
<td>95% (v. high)</td>
</tr>
<tr>
<td></td>
<td>3. Street type</td>
<td>(Marshall, 2005:84)</td>
<td>ABCD</td>
<td>A (high)</td>
</tr>
<tr>
<td>(urban morphological complexity)</td>
<td>4. Plot Type</td>
<td><em>(Song, Knaap, 2008:9)</em></td>
<td>Geometric aspects</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td>5. Plots per hectare</td>
<td>(Jacobs, Appleyard, 1987:117)(Norton, 2016)</td>
<td>/ha</td>
<td>31 plots/ha (high)</td>
</tr>
<tr>
<td></td>
<td>6. Blocks per hectare</td>
<td>(Dempsey, 2008:255)</td>
<td>/ha</td>
<td>1.34 blocks/ha (high)</td>
</tr>
<tr>
<td></td>
<td>7. Junctions per km sq</td>
<td><strong>(Song, Knaap, 2008:9) (Montgomery, 1998:107)</strong></td>
<td>/km sq</td>
<td>172 junctions per km sq (high)</td>
</tr>
</tbody>
</table>

Table 6-1 Liberties Urban Morphological Complexity Evaluation Form

* In (Song, Knaap, 2008:9), Song, Knaap evaluate ‘Plot Design and Density Measures’ including ‘number of single-family plots in the buffer area’

** In (Song, Knaap, 2008:8), Song, Knaap measure quantitative characteristics of neighbourhoods, including ‘street design measures’ such as ‘number of intersections’.

See full descriptions and graphics of each measure in Volume Two, Appendix A
Fig. 6-3 Compositional evaluation of Liberties character area

Examples of urban morphological complexity images contained in Appendix A. (Source: Author)
**Land-use mix**

The land-use mix measure of compositional complexity, (evaluated according to Protocol No 2), shows that the urban site of the Liberties character area has a predominance of housing function, and a lack of amenities is evident. In terms of spatial complexity, optimal conditions would seem to be more associated with the factors which would also encourage vitality, urbanity and density, all aspects of urban sites which could be negatively affected by low or medium levels of land-use mix. The medium function mix represented here for the urban site is not in line with expected mix of a historic city centre, but the morphological history described in the earlier section and Appendix A demonstrates the predominance of early modern housing developments in the area, and so reductions in the types of land-use mix normally associated with the inner city. The analysis indicates that in terms of the land-use aspect of compositional complexity, the Liberties character area is just within a medium (bi-functional) range, with two of the three measured uses (residential and commercial) predominating, and therefore this measure suggests a medium compositional complexity.

![Fig. 6-11 Land-use mix of Liberties](image-url)
Density

According to the density measure of compositional complexity, evaluated according to Protocol No 3, and as described in Chapter Four (Section 4.4.1), the two adopted density measures here include plot ratio and site coverage. In this analysis, urban blocks are mapped showing publicly available data on the two indicators\textsuperscript{151}. The relatively high site coverage and low plot ratio indicated is an unexpected characteristic of this historic urban site, as this type of location normally tends towards both high plot ratio and high site coverage. Although exact comparison with the Spacemate diagram of Berghauser Pont, Haupt, (2004:56), and in particular the eight groups or clusters of urban morphology types, cannot be made (because of different derivations of GSI and ‘site coverage’, see Protocol note) a visual reading would place the Liberties evaluated urban site generally close to the ‘F’ type cluster identified (mid-rise compact building blocks). Therefore in compositional complexity terms, the analysis indicates that the Liberties urban site has a medium evaluated density.

\textbf{Fig. 6-12} Density of Liberties

\textsuperscript{151} In the case site of the Liberties, graphical information available in the adopted Liberties Local Area Plan, (2009), Section 4.7 ‘Existing Heights’ (Pg.48), and Section 4.8 ‘Density’ (Pg.49), including indicated plot ratios, has been extrapolated, supplemented with site fieldwork, and triangulated with other available data, to ascertain approximate urban block densities in 2016.
Discussion (Compositional complexity of Liberties)

Three separate compositional evaluations are demonstrated here for the first urban site, urban structure/form analysis (including morphological complexity analysis), land-use mix and density analysis. It can be concluded from the analysis above that the Liberties character area is a compositionally complex urban site. While indicators of urban morphological complexity generally point to a high level of complexity, the land-use mix and density measures indicate a medium readings, so while the formal characteristics of this character area have a high complexity, the land-use mix and density of the area are in the medium range. The question of how important history can be to the ‘static’ evaluation of spatial complexity of a site is apparent, as a more comprehensive analysis of historical change in urban form would be likely to reveal higher urban morphological complexity, higher land-use mix and densities in the area. This aspect is discussed in more detail in Appendix A.
6.2.3 Liberties configuration

While compositional complexity is captured by analysis of urban form, land-use mix, and density, these capture larger scale formal attributes of urban sites. Configurational complexity is now described by analysis of more multiscalar characteristics, of global and local integration aspects of urban sites, as well as the ‘choice’ measure, and intelligibility. Depth\textsuperscript{152} measures the number of intervening lines that must be crossed to get from one space to another, and if the number is small, the area is considered to be more integrated (shallow depth), or if more lines have to be crossed, the area is considered to be more segregated. In relation to the first syntactical measure of configurational complexity, integration (local and global), this measure describes the average depth of a space to all other spaces in the system. The spaces of a system can be ranked from the most integrated to the most segregated (Klarqvist, 1993: 12). The second of the three selected configurational measures is choice, and local choice measure basically reflects the potential for each piece (segment) of a street to be selected as the shortest path on a route between two points (Al-Sayed, 2014:77). Choice is descriptive of ‘movement rather than occupation’ (Al-Sayed, 2014:15). In Chapter Five, two measures of choice were described for the whole city scale. As a second order configurational measure, intelligibility (defined in Chapter 4, Section 4.4) is the correlation between connectivity (a static local measure) and integration (a static global measure) \{El-Khouly, 2012 #287\}. The literature on urban analysis using space syntax methods repeatedly focuses on these aspects of urban complexity of a city system (Hillier, 2007) (Marcus, 2015) (Read, 1999).

\textsuperscript{152} Space syntax research (See Chapter Four) has a primary interest in interpreting the relationships between spaces, represented by lines drawn by the researcher on two-dimensional maps. This involves measuring distances between spaces topologically (as opposed to metric measurement), and this topological distance is called depth.
Global Integration

The overall Dublin Axial Map has a global average integration value of 0.557 (a reading which could be seen as low in international terms). However, the context of this urban site, called here ‘Liberties quarter’ (entire LAP Area), has 393 axial lines and a higher global average integration value than Dublin overall, of 0.699. Patrick Street, the most integrated street in the area, is one of the most globally integrated streets in the city (of 14,819 axial lines), with a global integration value of 0.7583, and therefore much higher than average. The case site, called here ‘Liberties Character Area’, has 67 axial lines and a higher global average integration value than both ‘Liberties quarter’ (entire LAP) Area and Dublin overall, of 0.8085. As discussed in Chapter Three, ‘The configuration of the urban grid itself is the main generator of patterns of movement’ {Hillier, 1993 #282} and areas of high global integration could suggest patterns of high movement, whether vehicular or pedestrian. However, high global integration is more associated with vehicle ‘to-movement’ (Van Nes, 2012:10), and tends to highlight the main city road or route network. This indicates that some of the most globally integrated roads in the city pass through the Liberties. Figure 6-13 indicates the high global integration status of this site within the overall Dublin axial map.

![Global integration of Liberties](image)

**Fig. 6-13** Global integration of Liberties

(1) Overall global integration of Dublin axial map with high integration of urban site (2) (mainly red lines) at Liberties indicated.

High low
Local Integration

As regards local integration, the overall Dublin Axial Map has a local average integration value of 1.438 (a reading which could be seen as low in international terms). The local integration value of ‘Liberties quarter’ (entire LAP Area) is 0.4706, much lower than the city average. In selecting 393 axial lines as the ‘Liberties quarter’ (entire LAP Area) context to evaluate local integration, the planning policy boundary line has been adopted. The smaller case site of Liberties character area has a higher local average integration value than the ‘Liberties quarter’ Area, and the overall city (2.1715, when 86 lines are selected, local integration r3). This suggests that the urban site of the Liberties character area is more integrated at local level than the surrounding context, being well above the city average. Figure 6-14 indicates the high local integration status of this site within the overall Dublin axial map.

![Figure 6-14](image)

**Fig. 6-14** Local integration of Liberties

(1) Overall local integration of Dublin axial map with high integration of urban site (2) Liberties local integration highlighted.
Choice

A ‘global’ choice map was prepared, derived from the Axial map, and from this map it is evident that the Liberties does not appear as a distinct area, surrounded by ‘natural boundaries’ (Peponis et al, 1990) although one significant road does appear (Patrick St). Secondly, from the more local radius of 1km applied to the choice measure, a second map indicates the Liberties overall emerging graphically as the most concentrated ‘hotspot’ of local choice in the entire city, possible indicating presence of public life in the area (Vaughan et al, 2009:476). The segment angular analysis mode is chosen from three possible modes of measurement: topological, angular and metric, to further focus configurational analysis on the case site. Segment analysis\textsuperscript{153} is argued to capture different ways of representing urban complexity (Hillier, Stutz, 2005:33). The metric radius segment analysis mode is chosen for this case\textsuperscript{154}. The analysis indicates that the Liberties character area affords multiple ‘through-movement’ route choices within the short metric distances normally associated with well internally connected pedestrian areas. The choice measures for the area suggest a configurationally complex urban site.

\textbf{Fig. 6-15}  \hspace{1cm} \textbf{Choice measure of Liberties}

Liberties urban site, choice measure, metric radius 400m.

\textsuperscript{153} See definition of segment analysis on Appendix B, Glossary of Terms.
\textsuperscript{154} Of 14,818 axial lines, the maximum choice reading in this analysis is 3315, and the average choice value is 106.8, according to the Attribute Summary of the DepthmapX Dublin Map 2012. The reading for the highest choice value (ie. most red line) in the case site is 2997, (on Meath Street) very close to the highest value for the city, of 3315, which is located just outside the case site in Temple Bar, at Essex St East, close to the corner of Sycamore Street. The r400m metric choice measure helps to derive a medium scale reading of the urban site being examined, in this case the ‘character area’ part of Liberties within the overall city centre. This medium or area scale has been described as the ‘catchment of the catchment’ (Hillier et al, 1993).
Intelligibility

In reviewing the context of the Liberties, the scattergram\(^{155}\) described in Chapter Five indicates a high intelligibility for many streets in this urban site, as they mostly appear above the regression line\(^{156}\). The intelligibility analysis indicates that the area is better connected and more integrated in city terms than most other locations in the city, as the cluster of selected axial lines appear in the top right part of the scattergram, which suggests a high intelligibility and therefore a configurationally complex urban site. The intelligibility analysis indicates that the area is relatively well connected and well integrated in city terms, which suggests an intelligible and therefore configurationally complex urban site.

---

\(^{155}\) A ‘scattergram’ defined by OED as a compound word of ‘scatter diagram’, is ‘a diagram having two variates plotted along its two axes, (used in statistics) and in which points are placed to show the values of these variates for each of a number of subjects, so that the form of the association between the variates can be seen’ (OED, accessed 041116). In space syntax, scattergrams are primarily used to visually judge the relationship between two continuous variables, and are useful to find out how recognized clusters might have spatial distribution. (Al Sayed, 2014:58).

\(^{156}\) A regression line is the best fitting straight line through a group of points on a scatter plot of x and y axes. In space syntax, the groups of elements plotted in a scatter plot (or ‘scattergram’) having the highest correspondence occur along, around and close to a regression line (al Sayed, 2014:59).
Fig. 6-16 Configurational evaluation of Liberties character area

Axial map (1), and Scatter plot with lines cluster highlighted indicating high intelligibility of urban site at Liberties Dublin, and axial lines highlighted (2). Sources: (1) Author, (2) S O’Gara, data visualised in Tableau.
Discussion (Configurational complexity of Liberties)

Three separate configurational evaluations are demonstrated here for the first urban site, integration analysis, choice analysis and intelligibility analysis. It can be concluded from the analysis above that the Liberties character area is a configurationally complex urban site. Firstly, a highly integrated status of this urban site is clear within the overall Dublin axial map, and the integration core described in Chapter Five shows this in graphic terms (Section 5.2.1.2). The analysis indicates that the Liberties character area has high global integration and high local integration indices, which are levels associated with well integrated inner urban sites, and therefore the integration measure suggests a configurationally complex urban site. The choice measures, at both overall city scale and local radii also suggest a configurationally complex urban site. Finally, the third configurational measure, intelligibility analysis, indicates a high intelligibility and therefore a configurationally complex urban site.
6.2.4 Liberties system

This Liberties character area system evaluation builds on the previous two evaluations, of composition and configuration, to provide a comprehensive three-sided analysis of the urban site. While compositional complexity is captured by analyzing urban structure/form, land use mix, and density, and configurational complexity is described by levels of measured integration, choice, and intelligibility, system complexity evaluation concentrates on some distinct system and ‘non-physical’ aspects of urban sites. Three measurement methods are selected: firstly, street network complexity (patterns), which applies a numerical index to complexity. Secondly, path network complexity (paths) is selected, which considers metric reach in the urban site, and thirdly pedestrian movement network complexity (people) is chosen, which records and evaluates a human movement system, considered as a complex system (Wei, 2015:87).
Figure 6-17. Liberties system complexity evaluation

Examples of urban system complexity images contained in Appendix D. (Source: Author)
Street network complexity (Patterns)

The evaluated street network complexity of the Liberties character area, using Marshall’s method, (2005)(See Chapter Four, Section 4.4) is illustrated in Figure 6-18. In an 84 acre urban site, 44 distinct routes are characterized, and 137 links and 23 route types are identified, leading to an evaluated street network complexity of 0.43. This figure could be compared with other examples calculated by Marshall and others in order to consider relative complexity of the Liberties, for example in international terms (See later system discussion section). However, the primary interest for this section is the relative level of system complexity that could be inferred from this measure, taking into account Marshall’s forty international examples 157. In conclusion, although not definitive, the street network complexity analysis indicates that the area is relatively complex, which suggests a spatially complex urban site in system terms.

![Hetgram Triangle for Street Network Complexity Analysis](image)

**Fig. 6-18 Street network complexity of Liberties character area**

157 ‘Copenhagen Central’ for example, an area which was also the subject of extensive research in relation to public space and pedestrian use by Gehl (See last evaluation, pedestrian network complexity) is given a complexity value of 0.37, and 18th in the list of 40 locations tested in ‘Streets and Patterns’ (Marshall, 2005:150), which is 0.06 points lower than Liberties.
**Path network complexity (Paths)**

In relation to this second measure of system complexity, evaluated path network complexity for the Liberties Character area, the method used is to calculate the metric reach\(^{158}\) of a point at the centre of the urban site (See Protocol 8). As described in Chapter Four, Ellis et al (2016) study footpath networks in preference to road networks to measure walkability because evaluating path networks overcomes the limitations of pedestrian network assessment based on road centre lines, for example, which can be too coarse to measure urban environments\(^{159}\). The mapped network for the Liberties shows a large, diverse network with a high density of paths across the urban site. The measured metric reach for Liberties is 8,260m, or 16 ‘times’ (the 500m ‘reach’) which indicates a high density and complexity of the network.

Fig. 6-19 Path network complexity of Liberties character area

---

\(^{158}\) Metric reach can be defined as ‘the network length that can be covered walking in all possible directions from a point of origin for a specified distance threshold, and is essentially a means of measuring the density of available footpaths’ (Ellis et al, 2016:141).

\(^{159}\) In this evaluation, paths could include, for example, in Liberties, very narrow historic lanes, internal passageways in markets and semi-private routes within urban blocks. All of these have in common a characteristic of acting as shortcuts or route choices located in the urban site, have particular familiarity to local users, and as such are included in the measure.
Pedestrian movement network complexity (People)

The third measure of system complexity, pedestrian movement network complexity, is evaluated according to Protocol No 9. The concept of pedestrian movement network complexity has established measurement methods, involving collection of observation data about people moving in urban sites. The fieldwork approach in this study involves timelapse observation, which records movement of pedestrians in one central location using stop-motion digital video, with a camera positioned to maximise viewing of expected busy centres of urban sites. However, for the case sites, the objects of this Chapter, and in the context of a lack of available data, additional gate tally counts of pedestrian movement are also carried out, to inform an overall picture of pedestrian movement in the case sites. Additionally, while gate counts are a purely quantitative dataset, timelapse data contains visual detail and richness of a qualitative method. The results of both fieldwork data collection exercises are set out in Appendix D (Pedestrian Movement Complexity Fieldwork). The pedestrian network complexity of Liberties as evaluated and illustrated suggests a high level of system complexity, which in turn suggests high spatial complexity in the local system.

![Pedestrian movement network complexity of Liberties character area](image_url)

**Fig. 6-20 Pedestrian movement network complexity of Liberties character area**
Discussion (System complexity of Liberties)

It can be concluded from the analysis above that the Liberties character area is a complex urban site in system terms. Evidence of system complexity is demonstrated in three parts: street network complexity, path network complexity and pedestrian movement network complexity. As regards evaluated street network complexity of the Liberties character area, Marshall indicates complexity values for forty different actual and prototype networks, and values vary from No 1., Bayswater (value 0.59) to No. 40, Hilbersheimer (prototype case)(value 0.00). According to this analysis, Liberties would rank in the highest quarter of values, with other examples including Bloomsbury and Cornhill, (London) (both value 0.43). However, while both of these locations can be associated with urban histories and morphological characteristics similar to Liberties\textsuperscript{160}, two other locations with the same complexity values cannot\textsuperscript{161}, so compositional characteristics alone are not sufficient indicators of this measure of street network complexity. As regards evaluated metric reach of the urban site, for comparison, Peponis et al measures mean network reach for 26 urban areas in the Atlanta region, and the downtown area, the highest value (53.24 for one mile (1.6km), extrapolating to 16 times approx. for 500m), approximates to the value for Liberties\textsuperscript{162} (Peponis et al, 2008:884). However, a separate study found 400m (0.25 of a mile) metric reach values for Atlanta of 3.5 times (Downtown), 3.2 times (Midtown), and 2.1 times (a primarily residential area) (Ozbil et al, 2011:133). These values are all well below the Liberties measure, and are better sized areas than the Peponis values to use for comparison.

\textsuperscript{160} Bloomsbury is characterized as an ‘inner urban grid’, while Cornhill is considered as the ‘historic core of City of London’ (See Appendix 5 Properties of Route Structure, (Marshall, 2005:280)
\textsuperscript{161} ‘Crawley Suburban’ is described as Wood Green, New Town Neighbourhood (Keeble, 1963), while Hamilton is described as ‘Central grid, Hamilton, Bermuda’. Hamilton has a population of 1,010 (2010), (‘the smallest of any capital city’, http://www.cityofhamilton.bm/, accessed 280316. (See Appendix 5 Properties of Route Structure, Marshall Pg. 280)
\textsuperscript{162} Peponis et al measures slightly different attributes to those measured here in two respects. Firstly, ‘mean’ metric reach refers to each street segment being measured, not just one point, as measured here. Secondly, a 2 mile x 2 mile area is measured, approximately 6 times the size of the metric limit here (500m), so the Peponis value has been divided according to reduced area of this study. See Table 2, Numeric Description of Areas in the Atlanta Regional Commission (Peponis et al, 2008:884).
Salingaros seeks a ‘multiplicity of irregular paths and connections’ in establishing the characteristic of complexity of the urban web (Salingaros, 1998:3). The path network of Liberties illustrated here suggests a high level of network complexity, which in turn suggests high spatial complexity in the local path system, and therefore a site of high system complexity. So while a high street network complexity is apparent in the analysis, this numerical index of complexity is complimented by the more mathematical method to measure path network complexity shows a large, diverse and complex network with a high density of paths across the urban site. When considered in conjunction with the third analysis method, high pedestrian movement network complexity is demonstrated through gate counts and timelapse observation data. The overall evaluation of high system complexity is confirmed. According to the definition of a system described in Chapter Two, (Section 2.2.5): ‘When the elements of a set belong together because they cooperate or work together somehow, we call the set of elements a system’ (Alexander, 1965:58). The further definition of system complexity of urban sites as ‘a measure of the numbers, size and relations between entities of the evaluated systems’ (Chapter Two, Section 2.2.5) has been tested for three systems in the case site of Liberties character area, and large numbers of elements, large size of systems and sufficient evidence of complex relations has been demonstrated.
6.2.5 Evaluated spatial complexity of Liberties character area

In the first site, the question of how important history can be to the ‘static’ evaluation of spatial complexity of a site is addressed. Complexity theory suggests that the history of a complex system is important and cannot be ignored (De Roo et al, 2012:180). The synthesised conclusion of this nine-step evaluation process is the preparation of the Spatial Complexity Evaluation Form for the first case site, the Liberties character area (see Table 6-2).

The morphological description and background analysis (Appendix A) suggest returning to analysis of the official planning/policy designation of this urban site (Chapter Five). The LAP boundary of the character area varies from historical definition and the plan-units identified in the morphological analysis of the Liberties area carried out as part of this study. This means that the compositional definition of the spatial unit is not historically or spatially accurate in official documents. One impact of this could be that historically acknowledged units of the city could be overlooked in planning and policy terms in considering new development in the urban site.

It was demonstrated in the urban morphological analysis of Liberties character area, in an inner city urban site, that while the contemporary ‘town plan’ retains elements of historic compositional complexity, in diverse geometries of streets and plots, the formal (or ‘above-ground’) complexity of the area is reduced by the lack of remaining historic structures in the area, due to change over time at the level of building development. In this analysis, complex built form is assumed to be historic built form, meaning that architectural, visual and urban complexity\textsuperscript{163} is more likely to have been retained where

\textsuperscript{163}Kaplan’s definition of complexity as ‘the number of different visual elements in a scene; how intricate the scene is; its richness’ is related to an environmental psychology approach to nature, and rural as opposed to urban environments (Kaplan & Kaplan,1989:53). Applying this definition to historic urban environments, it could be generally agreed that these retain variety of
historic structures and environments have endured. So while plot type and block type may have changed little, building type has changed a lot. It was demonstrated in the urban morphological complexity ‘metrics’ evaluation of the Liberties character area, that in an inner city urban site, distribution of distinct street widths within an area, passive volume ratios within urban buildings, formal characteristics of street pattern, plot type, as well as measures of numbers of plots, blocks and junctions, could together indicate levels of spatial complexity of urban form. While correlations to evaluated land-use mix and density levels are hard to quantify, broadly speaking, at least bifunctional land-use mix, together with typical Irish urban density levels\textsuperscript{164} can be associated with higher levels of evaluated spatial complexity of urban sites.

The evaluated urban morphological complexity metrics indicate that the compositional complexity of the historic city in the Liberties area is not at a very high level. This means that spatial complexity evaluation of a type that might otherwise be associated with historic urban fabric is missing in this part of Dublin. According to the major proposition of this study, the conclusion for the character area of the Liberties, of evaluated high compositional complexity, only encompasses a one-third part of the description needed to confirm an evaluated level of spatial complexity. High compositional complexity would be an expected evaluation result in an inner urban site.

\textsuperscript{164}Irish urban density levels are controlled for Dublin city centre, through Dublin City Council Development Plan recommended minimum and maximum site coverage (45-90\%) and plot ratios (0.5-3.0).
Configurational complexity\textsuperscript{165} is evaluated in this study as high, and this evaluation builds on the earlier compositional findings, to further suggest high spatial complexity of the urban site. However, specific aspects of low compositional complexity evaluated in the Liberties also suggest that spatial complexity may be decreasing in the area. As regards configuration, unexpectedly, the most integrated locations in the Liberties are not the most concentrated on for future conservation or enhancement, in official planning/policy terms. Choice for example, as an indicator of a legible neighbourhood, is most evident in Meath Street, away from the main thoroughfare of Thomas Street. Intelligibility at local level is also concentrated towards the spatial ‘centre’ of the case site, rather than on the ‘peripheral’ historic streets more formally associated with the area.

Next, in order to represent some system indices of spatial complexity, street network complexity is evaluated in Step 7, seeking to capture an additional aspect of the street pattern, and this has a high value for the Liberties. In Step 8 complexity of the scale of a network of pedestrian paths is also evaluated as high. The last step (9) then concentrates on the most detailed scale of urban design, pedestrian movement activity itself, also high. Therefore, systems evaluation results for the Liberties character area show that large numbers of elements, large size of systems and sufficient evidence of complex spatial relations has been demonstrated. In these terms, high evaluated system complexity of the urban site suggests high spatial complexity.

\textsuperscript{165} See Section 6.2.3. Configurational complexity is captured by Step Four (integration), Five, (choice), and Six (intelligibility).
Taken together with the earlier compositional complexity evaluation (between a high and medium level), and the overall high configurational complexity evaluated, a high spatial complexity level for the Liberties character area is confirmed by considering the third issue of spatial complexity evaluated, the system aspect of this urban site. In concluding on the findings for this urban site, the question of how important history can be to the ‘static’ evaluation of spatial complexity of a site is addressed. Multiple indicators, in compositional terms (distribution and quantities of streets, plots, urban blocks and junctions), in regard to configuration (local integration indices) and system indicators (footfall numbers) have connections to the physical and movement patterns which have been established over time, thus confirming the importance of history and temporality in determining evaluated spatial complexity levels of urban sites.
Spatial Complexity Evaluation Form

**Urban Site:** Liberties Character Area (case site)

**Date:** July 2016

<table>
<thead>
<tr>
<th>Issue</th>
<th>Criteria</th>
<th>Method</th>
<th>Indicators</th>
<th>Result</th>
<th>Spatial Complexity Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>Urban form</td>
<td>Conzenian Analysis</td>
<td>low-medium-high</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power Law Distribution</td>
<td>Curve type</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(relative to 2 others)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passive Volume Ratio</td>
<td>percentage</td>
<td>95%</td>
<td>(v high)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ABCD Street type</td>
<td>Correlational Graph</td>
<td>Street Type A</td>
<td>(high)</td>
</tr>
<tr>
<td></td>
<td>Land-use Mix</td>
<td>Van Den Hoek</td>
<td>Mix triangle</td>
<td>bifunctional</td>
<td>medium</td>
</tr>
<tr>
<td>Density</td>
<td></td>
<td>Plot Ratio/Site Coverage</td>
<td>Correlational Graph</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Configuration</td>
<td>Integration</td>
<td>Global</td>
<td>rN result</td>
<td>0.808 (67 axial lines)</td>
<td>high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local</td>
<td>r3 result</td>
<td>2.171 (86 axial lines)</td>
<td>high</td>
</tr>
<tr>
<td>Choice</td>
<td>Segment Angular Analysis</td>
<td>400m radius metric</td>
<td>2997 (Methe St)</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>Intelligibility</td>
<td>n/a</td>
<td>Scattergram</td>
<td>High cluster (79 axial lines)</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>System</td>
<td>Patterns</td>
<td>Street network complexity (SNC)</td>
<td>SNC Index</td>
<td>(0.43)</td>
<td>medium</td>
</tr>
<tr>
<td>Paths</td>
<td>Path network complexity</td>
<td>Metric Reach Measure</td>
<td>(16 times)</td>
<td>high</td>
<td></td>
</tr>
<tr>
<td>People</td>
<td>Pedestrian network complexity</td>
<td>Gate counts/timelapse</td>
<td>93/5 mins highest value</td>
<td>high</td>
<td></td>
</tr>
</tbody>
</table>

Table 6-2 Liberties Spatial Complexity Evaluation Form

(See also Addendum Section in Vol 2 for more colour visualised results of case evaluations)
6.3 Case Two: Urban Ballymun evaluation

This study refers to the second case site as ‘Urban Ballymun’ because the official planning designation of this urban site envisages substantial urban growth to an already designated key district centre, which implies existing and proposed urban densification. In this second case site, the question of links between urban centres and surroundings at local and global scales, and how this affects the evaluated spatial complexity, is answered. In complex system terms, the ‘many diverse components and interactions’ are of particular interest to evaluate. The configurational complexity aspects are particularly examined through a close reading of the second unit of study, a key district centre in Ballymun, in a regenerated suburban ‘New Town’. Urban Ballymun contains fifteen urban blocks (or parts thereof), fifteen streets, and one major civic space, Ballymun Plaza. The figure ground plan of urban Ballymun in 2016 is indicated (Fig. 6-21).

![Figure ground plan of Urban Ballymun](image)

**Fig. 6-21** Figure ground plan of Urban Ballymun

Source: Author
6.3.1 Ballymun morphological description

This section is a brief morphological description of Ballymun as context for the later urban morphological complexity ‘metrics’ or evaluation in this Chapter. A more detailed description is contained in Appendix A. The purpose of this section on the Ballymun area, as the morphological context of Urban Ballymun, the case site, is to make a descriptive evaluation of the compositional complexity of this specific urban site context, through a narrative account of this aspect. This is based on urban morphological analysis, and forms the background to more purely quantitative evaluations of the later sections of this analysis of the cases. In the second unit of study introduced here, an urban centre is contained within a collection of outer city neighbourhoods, collectively known as Ballymun. The analysis presented here does not question the official planning designation or geographical outline of the ‘key district centre’ area called Ballymun, described in this study as ‘urban’ Ballymun. This urban morphological analysis concentrates on two aspects which can reveal evidence of compositional complexity of the context and urban site: firstly, analysis of morphological periods166 (Conzen, 1960) of Ballymun and secondly, urban tissue categorisation and analysis (Scheer, 2001, 2003). The reasons to employ these techniques are, firstly, that analysis of morphological periods of Ballymun uncovers the multiple stages of development and spatial change in the area, which is centrally related to the compositional complexity of the urban site context. This description of morphological periods provides a synoptic explanation of the development of the urban form, which can then be evaluated for levels of spatial complexity, and therefore concentrates on formal or spatial aspects of urban morphology only. Secondly, the reason to employ urban tissue categorisation and analysis is in order to reveal the

166 A morphological period is defined as any cultural period that exerts a distinctive morphological influence upon the whole or any part of a town. Source, ISUF Glossary, http://www.urbanform.org/glossary.html accessed 090216.
compositional character and complexity of the area (Scheer, 2001, 2003), and in order to relate this aspect to international examples. A full description of these two approaches is contained in Appendix A. Briefly, five morphological periods are identified, starting from the ‘pre-urban’ history of the site, seen as running up to 1965, the year a ‘New-Town’ type social housing development began construction on the rural site. In particular, the sudden development of proto-urban development of high architectural (but low urban) complexity in the second morphological period, general decline in spatial complexity of the urban site in the intervening years to 1997, and general increase in spatial complexity of the area as a result of a regeneration policy from 2007 to 2015 is described.

As a second approach to descriptive urban morphological analysis, Scheer’s urban tissue categorisation and analysis suggests that more recently developed suburbs have less clear relationships of nested hierarchy than older parts of cities (where the larger parts like urban blocks, are composed of aggregations of the smaller parts, like plots). Streets and blocks are argued for example to not necessarily be related to building type, and the relationship between building, plot and street is argued to be much weaker than in the historic urban centre (Scheer, 2001:29). Scheer’s analysis is applied in this study to explicit evaluation of the spatial complexity of the urban site. Appendix A, Section 3, shows tissue analysis and Scheer’s categorization applied to the urban site, indicating how much of area is ‘static’ morphological tissue, (very little) how much is campus, (a central set of clusters), and elastic (a majority). The static clusters are isolated from each other, and from a more mixed urban form type. The campus clusters are dominant in the area, which indicates low numbers of landowners (and plots). From a review of the emergent morphologies in the area, it is apparent that static-type urban form seems to be
transforming into elastic-type to the north of the urban site. This is important because instability inherent in elastic type morphology would suggest areas of low complexity, with few paths or infill streets, and plots of highly varied sizes in poorly planned tissue. In conclusion, the particular spatial incidence of the three tissue types, (static, campus and elastic) in urban Ballymun suggests low compositional complexity of the site.
6.3.2 Urban Ballymun composition

Having analysed the urban morphological context of the suburban settlement of Ballymun, this section involves compositional evaluation of Urban Ballymun, the case site (an urban centre surrounded by five suburban neighbourhoods), and looks at three criteria of compositional complexity; urban form metrics, land-use mix and density.

Urban form evaluation

The analysis of the urban morphological complexity ‘metrics’ of Urban Ballymun, the case site, is concentrated on in the main body of this study, in order than comparable data can be set out for discussion as to how these affect evaluated levels of spatial complexity of an urban site. Three measures of compositional complexity evaluated for Urban Ballymun are urban form, land-use mix and density. Appendix A, ‘Morphology of cases’, Volume Two, describes in detail the data analysis aspects of each of the seven measures of urban morphological complexity for Urban Ballymun. In reviewing across the seven selected measures of urban form evaluation, and more specifically morphological complexity of Urban Ballymun (See Table 6-3), four low results and three medium results are derived.
<table>
<thead>
<tr>
<th>Compositional Criteria</th>
<th>Method</th>
<th>Source</th>
<th>Indicators</th>
<th>Urban Ballymun</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Passive Volume Ratio</td>
<td>(Salat, 2012:34)</td>
<td>%</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>3. Street type</td>
<td>(Marshall, 2005:84)</td>
<td>ABCD</td>
<td>D (low)</td>
</tr>
<tr>
<td></td>
<td>4. Plot Type</td>
<td>*(Song, Knaap, 2008:9)</td>
<td>Geometric aspects</td>
<td>medium</td>
</tr>
<tr>
<td></td>
<td>5. Plots per hectare</td>
<td>(Jacobs, Appleyard, 1987:117)(\times) (Norton, 2016)</td>
<td>/ha</td>
<td>1.25 plots/ha (medium)</td>
</tr>
<tr>
<td></td>
<td>6. Blocks per hectare</td>
<td>(Dempsey, 2008:255)</td>
<td>/ha</td>
<td>0.2 blocks/ha (low)</td>
</tr>
<tr>
<td></td>
<td>7. Junctions per km sq</td>
<td>**(Song, Knaap, 2008:9)(\times) (Montgomery, 1998:107)</td>
<td>/km sq</td>
<td>89 junctions per km sq (medium)</td>
</tr>
</tbody>
</table>

Table 6-3 Urban Ballymun Morphological Complexity Evaluation Form

See full descriptions and graphics of each measure in Volume Two, Appendix A
Land-use mix

In relation to land use mix, according to the evaluation in accordance with Protocol No 2, urban Ballymun has a good land use mix across all three functions: of housing, commercial and amenities. This would be expected in this regenerated urban centre, as most of the buildings were developed in conjunction with an urban design masterplan, which sought mix of uses for the regenerated urban centre of the ‘New Town’. In terms of spatial complexity, these optimal function mix conditions should also encourage vitality, urbanity and density, all aspects of urban sites which are associated with optimal levels of land use mix. However, in this multi-factor analysis, the recent history of the site is relevant, and the fact that much of the hoped-for redevelopment associated with regeneration and increased population has not taken place to date. This means that although the evaluation captures sites which are developed, the lack of any function of many empty or derelict sites adjoining these recently developed sites is not reflected in this analysis. This is a limitation of the evaluation method, which could be overcome in the analysis of an embedded case. In conclusion, although the land use mix of constructed development is high, the low percentage of completed sites (less than 60% land area of the urban site) means that the evaluated complexity level evaluated is medium/low for the overall urban site.

Fig. 6-29 Land-use mix of urban Ballymun
Density

The density measure of the urban Ballymun area, evaluated according to Protocol No 3, shows a relatively low site coverage and low plot ratio. These are unexpected characteristics of key district centre urban sites, which normally tend towards both high plot ratio and high site coverage. In this case, a significant national road divides the centre, and relatively low-density housing (pre-regeneration) as well as empty or derelict regeneration sites (which have brought down the averaged-out calculations) all contribute to a low overall density. In this sense, low density contributes to low evaluated complexity of the site.

Figure 6-30 urban Ballymun density
Discussion

In discussing the evaluated compositional complexity of Ballymun, firstly, according to the morphological analysis, very little of the area is comprised of ‘static’ morphological tissue, a majority of the urban form is ‘elastic’ in Scheer’s terms, and the static urban form seems to be emerging as ‘elastic’ to the north of the urban site. Given that the failure to complete regeneration of the urban site, while continuing the official ‘Key District Centre’ planning policy designation, it is unlikely that a more complex urban form can be retrofitted\textsuperscript{167}. Compositional complexity evaluation for the key district centre of Ballymun, (called in this study ‘urban Ballymun’), indicates that the geographical boundary of the urban site investigated, an official key district centre in the city development plan, does not correspond, in urban morphological terms, to recognisable neighbourhood unit boundaries, as evaluated in this study. So, while this officially constituted planning policy outline designates an area for development, there is a lack of clarity about how this boundary interfaces with the pre-existing spatial boundaries of the five neighbourhoods of Ballymun. The reason this is important for understanding spatial complexity in compositional terms for Ballymun is because spatial units (streets, plots and buildings) of the urban site should exhibit qualities of urban elements if the location is to be promoted as a district centre, but also the edges, entry points and connections to (primarily residential) surrounding neighbourhoods should to be spatially clear, in legibility terms.

In reviewing the three separate criteria of compositional evaluation of urban Ballymun, and seeking to derive an overall understanding of the compositional complexity of this urban site, it is evident that the first aspect evaluated, urban form, (an aspect of the case

\textsuperscript{167} Scheer (2003) cites two important impediments to densification of this ‘edge city, low density’ and low spatial complexity type of urban fabric: size (leftover sites of elastic tissue are likely to be low density) and infrastructure (‘without the street and utility network provided by a fine-grained network, it is impossible to support fine-grained density’) (Scheer et al, 2003:30).
context discussed in Chapter Five) that the rapid generation of a large suburban housing estate on the site had a significant spatial impact on this location. In this case, the sudden development of a complex urban morphological footprint in a rural site caused immediate spatial transformation. Subsequent additions of plan units of low complexity (single use, low density, no amenities) caused a perpetuation of problems commonly associated with rapid large-scale public housing development in peripheral areas. Three other criteria demonstrate compositional complexity of the urban form of urban Ballymun. The first is power law distribution of streets analysis, which shows a low complexity. Evaluated land-use mix in urban Ballymun\textsuperscript{168}, which is mainly multifunctional (housing, commercial, and amenities) has a high value of function mix, but only applies to developed regeneration sites, (less than 60% land area of the urban site) and so indicate a low compositional complexity for the overall site. It can be seen from the address point mapping (Appendix F) that urban Ballymun is distinctly different from the surroundings, which are mostly mono-functional residential areas\textsuperscript{169}. Evaluated density of urban Ballymun is categorized as low, indicating that compositional complexity related to this aspect is low. In conclusion, of the four indicators of compositional complexity evaluated, two (urban morphological analysis and power law distribution) indicate a low compositional complexity, and land-use mix and density are low overall. In spatial complexity evaluation terms, this indicates that all three of the ‘issues’ evaluated indicate low compositional complexity, which therefore suggests a low evaluated spatial complexity level for this urban site.

\textsuperscript{168} The larger context of Ballymun is primarily two storey terraced housing, as a requirement of the regeneration project was to re-house existing residents of demolished high-rise blocks ‘within the estate, so the gross density, in bedspaces per hectare, will remain unchanged (‘115 bedspaces per hectare, or 26 dwellings per hectare’). (Source: Ballymun Masterplan, 1998:31)

\textsuperscript{169} This compositional complexity indicator shows in urban Ballymun the distinct impact of strictly defining the boundary and resolution of the analysed urban site. Ballymun in overall terms would be evaluated as a much lower level of compositional complexity in this analysis.
6.3.3 Urban Ballymun configuration

The overall Dublin Axial Map has a global average integration value of 0.557. However, the context of this urban site, the ‘Ballymun Masterplan Area’, (selecting 210 axial lines) has a higher global average integration value than Dublin overall, of 0.753. Furthermore, Main Street Ballymun is the 176th most globally integrated street in the city (of 14,819 axial lines), high in citywide terms, with a global integration value of 0.672, and therefore has much higher values than average, and is well integrated at global level within the city. This places Main Street in the highest seventh (or 15%) globally integrated streets in the city. It is to be expected that this street is globally well connected to the rest of the city for vehicles, as it is located beside the M50 motorway, the major piece of road infrastructure circling the city. This global integration value is well above most other streets in the wider Ballymun Masterplan Area. The Dublin Axial Map has an overall local average integration value of 1.438. The local integration value of Ballymun Main Street is 2.908, higher than the city average. However, in selecting 210 axial lines as the Ballymun Masterplan Area context to evaluate local integration, the average value is 1.335, well below the value of Main Street, and of the average value for Dublin. Furthermore, some local integration values for individual streets in the Ballymun Masterplan Area context are amongst the lowest local integration values in the city. Considering the global and local integration values for the context of the case study site suggests that the Main Street is well connected to the wider city for overall movement (such as by car) but not to the local area (eg. for walking), or to the urban centre of Ballymun170.

170 Research suggests that urban areas with high levels of both global and local integration contain pleasant centres that support the overlap of various mobility flows (pedestrian, bicycle, car), and have urban spaces with qualities of mixed social and economic uses (Van Nes, Ye, 2013:7).
Integration

Configurational complexity is analysed for urban Ballymun here under three subheadings: integration (local, global and synergy), choice and intelligibility. From a correlation of the two observations on global and local integration above, a configurational characteristic of Urban Ballymun can be observed, a synergy measure\textsuperscript{171}. Isolating the axial lines relating to urban Ballymun, and observing these in both axial map and scatter plot, demonstrates that the selected streets, considered as an area, have medium synergy levels, seen in a city context\textsuperscript{172}. In reviewing this ‘regenerated’ centre as regards integration, Hillier’s claim that ‘both local and global properties are relevant to how centres form and evolve’ (Hillier, 2012:6) is relevant. Theory therefore suggests that high levels of both local and global integration would be necessary for the centre to grow, and that currently poor spatial configuration conditions inhibit this process. The integration data indicates that while, in this analysis, the Main Street seems well integrated in local terms, most other parts of the urban Ballymun area decrease in integration values rapidly, as would be expected for a suburban housing estate layout.

\textbf{Figure 6-31 urban Ballymun global integration}

Overall global integration of Dublin axial map (1), urban site at urban Ballymun highlighted (2).

\textsuperscript{171} Synergy as a measure, defined as ‘the relationship between smaller radii of integration (local) and larger radii (global)’ (Al-Sayed, 2014:15), is illustrative of the relation between the parts and the whole in the urban system of Dublin.

\textsuperscript{172} Hillier claims that the synergy correlation represents ‘how local movement potentials in the area relate to movement potentials through the area’ (Hillier, 2004:42) so an indicator of medium connectivity is added by this measurement of the area.
Choice

In Chapter Five, two measures of choice were described for the whole city scale. (Section 5.2.1.2, Configurational Overview of Dublin). Firstly, a ‘global’ choice map was prepared, and from this map it is evident that Ballymun does appear as a relatively distinct area, surrounded by ‘natural boundaries’ (Peponis et al, 1990) although, as confirmed by compositional analysis\textsuperscript{173}, it was evident that it is divided by one significant road. From the more local radius of 1km applied to the choice measure, a second map indicates Ballymun overall emerging graphically as a medium level cluster of local choice, possible indicating presence of public life in the area, as deduced for other areas using this measure (Vaughan et al, 2009:476). In the case of Ballymun, current Segment Angular Analysis (2012)\textsuperscript{174}, r400 Integration for the overall ‘area’, has been selected for analysis\textsuperscript{175}. The highest choice measure in Ballymun of 1168, and occurs away from the urban centre\textsuperscript{176}. However, the highest choice value in urban Ballymun is much lower, at 752, and also occurs away from the civic centre Plaza\textsuperscript{177}. This analysis of this area scale suggests that the environmental ‘regeneration benefit’ on the local choice measure of the urban Ballymun area does not seem to have been fully realised in the urban site or catchment.

\textsuperscript{173} The PLD analysis, in Section 6.3.1, ‘Ballymun Morphological Description’, (and Appendix A) shows Main Street is 34m wide.
\textsuperscript{174} In this section, the segment angular analysis mode has been chosen from three possible modes of measurement: topological, angular and metric, to further focus configurational analysis on the case site. Research has shown that ‘there is a stronger correlation between human movement and the spatial configuration of the street grid in the angular analyses (fewest angular deviations) than in the topological analyses (fewest turns)’ (Van Nes, 2012 #361; Hillier, 2007 #360).
\textsuperscript{175} The r400 choice measure helps to derive a medium scale reading of the urban site being examined, in this case the urban part of Ballymun within the overall development.
\textsuperscript{176} At the corner of Carrig Road, near Dane Road in Poppintree.
\textsuperscript{177} On Coultry Road, near the corner of Woodhazel Terrace, in Coulrty.
Intelligibility

In relation to the third syntactical measure of configurational complexity, intelligibility, and reviewing the context of Ballymun, the whole city scattergram described in Chapter Five indicates a below average intelligibility for some selected streets in this urban site (31 selected), as they sometimes appear below the regression line. The intelligibility analysis of urban Ballymun (28 axial lines highlighted) indicates that the area is not very well connected or integrated in city terms, as the cluster of selected axial lines appear around the middle part of the scattergram, which indicates a medium connectivity, medium global integration, and medium intelligibility. The scattergram also indicates a lower intelligibility for all streets other than the central Main Street, which is located high and separated on the upper right side of the scattergram.
Figure 6-32 urban Ballymun intelligibility

Scatter plot lines cluster highlighted (1), medium-low intelligibility of urban site at Ballymun Dublin, with 28 axial lines highlighted (2). Sources: (1) Author, (2) S O’Gara, data visualised in Tableau.
Discussion

It can be concluded from analysis of the evaluated configurational complexity of Ballymun above that urban Ballymun is an urban site of medium configurational complexity. Here below, a level of local configuration is shown, and the medium local choice reading is described above. Together, medium integration, medium choice and medium intelligibility signify medium configurational complexity of the site of urban Ballymun. In this second case site, the question of links between urban centres and surroundings at local and global scales, and how this affects the evaluated spatial complexity, is answered.

![Figure 6-33 urban Ballymun local integration](image1)

Overall local integration of Dublin axial map (1) with urban site at urban Ballymun highlighted.

![Figure 6-34 urban Ballymun local choice](image2)

Ballymun urban site on Dublin axial map (1) with choice measure, metric radius 400m.

High  ![High](image3)  low
6.3.4 Urban Ballymun system

The Urban Ballymun system evaluation described here extends and builds on the previous two evaluations, of composition and configuration, to provide a comprehensive three-sided analysis of the urban site. This in turn is useful for considering alongside both the overall and the system evaluations of the previous urban site considered, the Liberties, and the site to be evaluated next, Carmanhall.
Street network complexity (Patterns)

Two measures of street network complexity have been taken for Ballymun, the overall area, and just the district centre, or urban Ballymun, the case site. The results (complexity values 0.27 and 0.41 respectively, see Fig. 6-35) suggest a relatively high level of street network complexity of both spatial units, but a higher complexity of the Main Street area, as would be expected. In comparison with Marshall’s 40 areas considered in this regard, urban Ballymun would be comparable with Glasgow Southside (No 13 of 40 locations, complexity value 0.40), one of his sample sites. Marshall describes this type of layout as being ‘unplanned’ and having ‘no artificially low value of complexity (or artificially high degree of regularity)’ (Marshall, 2005:150). In the case of Ballymun, this is more likely an inadvertent result of accretion of street (or suburban road) pattern over time on a singular modernist road layout. In these terms of evaluating complexity of a system, the street network complexity of urban Ballymun illustrated here suggests a high level of system or network complexity.

Figure 6-35 urban Ballymun street network complexity
Path network complexity (Paths)

The results of evaluating path network complexity of urban Ballymun, in accordance with Protocol No. 8 (‘Measuring Metric Reach of Paths’) are illustrated here (See Figure 6-36). The measured metric reach for urban Ballymun is 4,600m or 9.2 times. The measure is normally expressed as a multiple of the threshold or perimeter distance of the radius measure (in this case 500m). The measure indicates a medium density and complexity of the path network of Urban Ballymun, relative to Liberties and Sandyford.

A study of metric reach of Atlanta found 400m (0.25 of a mile) metric reach values for Atlanta of 3.5 (Downtown), 3.2 (Midtown), and 2.1 (a primarily residential area) (Ozbil et al, 2011:133). These values are all well below the Ballymun measure, as would be expected when a European city is compared to a North American city of recent origin.

In these terms of evaluating complexity of a system, the path network of urban Ballymun illustrated here suggests a medium level of network complexity, which in turn suggests medium spatial complexity in the local path system, and therefore that this is a site of medium system complexity.

Figure 6-36 urban Ballymun metric reach
Pedestrian movement network complexity (People)

In assessing pedestrian movement network complexity (People), Protocol No. 9 has been followed. Two complimentary methods are used to collect pedestrian observation data: timelapse observation and gate counts. The desktop preparation, in advance of fieldwork, involves seeking background pedestrian data about the ‘case’ or urban site scale. Diverse sources of desktop digital data about pedestrian movement in Dublin are searched, and resulting information is collated graphically in order to formulate a mapped picture of the general pedestrian network complexity of the context of the three urban sites. In the case evaluations, the results contribute to a precise description of pedestrian activity at the centre of the urban sites examined. When overlaid on other evidence from the site, information on pedestrian activity can assist in arriving at an evaluation of spatial complexity of the urban site. In overall terms, the site of urban Ballymun compares poorly with pedestrian network complexity of the commercial heart of Dublin, having low relative numbers, few clusters of activity and low diversity of pedestrian type.

Figure 6-37 urban Ballymun pedestrian movement complexity

Timelapse: still from Thursday 24th July 2014, midday (l), plan of Civic Plaza (m) and sample of ‘in’ pedestrian counted 3pm, 220714 (r)

178 This protocol is titled ‘Measuring pedestrian movement network complexity’, and describes how to capture data as regards the network complexity apparent in pedestrian movement. The protocol involves a pair of separate approaches. (described in Appendix D, Pedestrian Movement Fieldwork)

179 Timelapse can capture observations on the nature of uses of spaces over time, and is based on the ‘Photographing’ tool described in Gehl’s book, ‘How to Study Public Life’ (Gehl, 2013:31).

180 Gate counts are defined as ‘recording observations of people or vehicles moving’ (Vaughan, 2001:3), and are recommended for urban areas. It is suggested the method should be applied with rigour and consistency at an abundance of locations.
Discussion (System complexity of urban Ballymun)

It can be concluded from analysis of the evaluated system complexity of urban Ballymun that while urban Ballymun has high street network complexity, it also has medium path network complexity and a low level of (pedestrian network) system complexity, and therefore can be regarded as a site of medium to low system complexity in overall terms. For example, as regards the overall city, diversity of pedestrian type cannot be compared, as the city centre data is aggregated without sub-categories, but the complete absence of tourists in Ballymun, as well as low numbers of children counted, confirms low diversity of pedestrian type. In response to the question ‘what is the system complexity of urban Ballymun?’ and considering pedestrian movement network complexity, the pedestrian movement network analysis data suggests a site of low complexity. Pedestrian movement flow categories are classified as ‘high’, ‘active’ and ‘low’\(^\text{181}\), and one gate (Balbutcher Lane, west) shows especially low levels on a certain day (weekday, midday), while the same gate has consistently ‘low’ counts on a weekend. In overall terms, the urban site of urban Ballymun compares very poorly with pedestrian network complexity of the commercial heart of Dublin, (described in Chapter Four) having very low relative numbers and no spatial clusters of activity. In conclusion, the pedestrian network complexity of urban Ballymun evaluated and illustrated here suggests a low level of system complexity, which is an additional indicator of low spatial complexity in the local system.

\(^{181}\) The ‘Pedestrian Comfort Guidance for London’ (2010:25) document defines these three flow categories of pedestrians. Up to 1,200 persons per hour (PPH) is classified as ‘high’, 600 – 1,200 PPH is classified as ‘active’, and less than 600 PPH is classified as ‘low’. This guide is recommended for use in Irish urban conditions by the ‘Design Manual for Urban Roads and Streets’, (2013:87).
6.3.5 Evaluated spatial complexity of urban Ballymun

The synthesised conclusion of this nine-step evaluation process is the preparation of the Spatial Complexity Evaluation Form for the second case site, urban Ballymun (see Table 6-4f). In this second urban site, the question of links between urban centres and surrounding at local and global scales, and how this affects the evaluated spatial complexity is answered. Compositional complexity of urban Ballymun is captured by measuring urban form, land-use mix, and density, but as these steps only capture larger form-related attributes of urban sites, and as the location is part of an unfinished urban regeneration project in a suburban location, these indicators are not sufficient to quantify spatial complexity. The conclusion for urban Ballymun, of evaluated medium compositional complexity, only encompasses a one-third part of the description needed to confirm an evaluated level of spatial complexity. Configurational complexity evaluation reveals high global integration, but generally low evaluated configurational complexity, building on the earlier compositional findings, to further suggest medium or low spatial complexity of the urban site. Next, street network complexity is evaluated, seeking to capture an additional system aspect of the street pattern. Then an additional set of system characteristics is evaluated, complexity of the scale of a network of pedestrian paths. The last step then concentrates on the most detailed scale of urban design, pedestrian movement activity itself. Taken together, these three indices suggest a medium system complexity, which is enhanced by regeneration of the civic centre. Considered alongside the earlier compositional complexity evaluation (a medium level), and the overall low configurational complexity evaluated, a medium spatial complexity level for the area is confirmed by considering the third issue of spatial complexity evaluated, the system aspect of this urban site.

182 From the configurational analysis of urban Ballymun in particular, it is clear that the surrounding neighbourhoods are poorly integrated to the urban site.
Spatial Complexity Evaluation Form
Urban Site: Urban Ballymun (case site)
Date: July 2016

<table>
<thead>
<tr>
<th>Issue</th>
<th>Criteria</th>
<th>Method</th>
<th>Indicators</th>
<th>Result</th>
<th>Spatial Complexity Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>Urban form</td>
<td>Conzenian Analysis</td>
<td>low-med-high</td>
<td>low</td>
<td>* Medium/low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Scheer’s Analysis</td>
<td></td>
<td>low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban morphological</td>
<td></td>
<td>medium/low</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>complexity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Power Law Distribution</td>
<td>Curve type</td>
<td>low (relative to 2 others)</td>
<td>* low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Passive Volume Ratio</td>
<td>percentage</td>
<td>low</td>
<td>* low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>ABCD Street type</td>
<td>Correlational graph</td>
<td>‘D’</td>
<td>* low</td>
</tr>
<tr>
<td>Land-use Mix</td>
<td>Van Den Hoek</td>
<td>Mix triangle</td>
<td>bifunctional</td>
<td>Medium/low</td>
<td></td>
</tr>
<tr>
<td>Density</td>
<td>Plot Ratio/Site</td>
<td>Correlational Graph</td>
<td>low</td>
<td>low</td>
<td></td>
</tr>
<tr>
<td>Configuration</td>
<td>Integration</td>
<td>Global</td>
<td></td>
<td>0.604</td>
<td>** high</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Rn result</td>
<td>(28 axial lines)</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local</td>
<td>R3 result</td>
<td>0.352</td>
<td>** low</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(28 axial lines)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Choice</td>
<td>Segment Angular Analysis</td>
<td>400m radius metric</td>
<td></td>
<td>752</td>
<td>***Medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(Coultry Rd)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Intelligibility</td>
<td>n/a</td>
<td>Scattergram</td>
<td>low cluster</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(31 axial lines)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>System</td>
<td>Patterns</td>
<td>Street network complexity (SNC)</td>
<td>SNC Index</td>
<td>(0.41)</td>
<td>high/medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Paths</td>
<td>Path network complexity</td>
<td>Metric Reach Measure</td>
<td>9.2 times</td>
<td>medium</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>People</td>
<td>Pedestrian network complexity</td>
<td>Gate counts/ timelapse</td>
<td>46/ 5 mins highest value</td>
<td>low</td>
</tr>
</tbody>
</table>

* Combining Conzenian, Scheer (low, low) and UMC (Medium/low) an overall result of Medium/low is decided.
** Averaging out a ‘high’ and ‘low’ integration value, a ‘Medium’ result is decided.
*** ‘Medium’ here is a low value in city terms, but medium between the two other cases.

Table 6-4 Urban Ballymun Spatial Complexity Evaluation Form
(See also Addendum Section in Vol 2 for more colour visualised results of case evaluations)
6.4 Case Three: Carmanhall evaluation

In the third site, the question of how to evaluate spatial complexity of a proposed future neighbourhood in a large-scale system hub is answered. In the third case, complex spatial system characteristics such as nested organisational levels, emergent properties, and feedback loops are examined. The system complexity aspects of spatial complexity of urban sites are particularly examined through a close reading of one case unit of study, the planned future neighbourhood of Carmanhall, located in Sandyford, a regional hub. This report on the evaluation of the spatial complexity of Carmanhall begins with an overall description of the morphological context of the case context, Sandyford, and subsequently the case site evaluation itself is presented under the three issue headings: composition, configuration and system.

Figure 6-38 Figure ground plan of Carmanhall in Sandyford context
6.4.1 Sandyford morphological description

This section is a brief morphological description of Sandyford as context for the later urban morphological complexity ‘metrics’ or evaluation in this Chapter. A more detailed description is contained in Appendix A. The purpose of this section on the Sandyford area, as the morphological context of Carmanhall, the case site, is to make a descriptive evaluation of the compositional complexity of this specific urban site context, through a narrative account of this aspect. This is based on historical analysis, and forms the background to more purely quantitative evaluations of the cases. In the third unit of study introduced here, a proposed future neighbourhood, Carmanhall, is contained within a strategic planning regional hub, Sandyford. The analysis presented here does question the official planning designation or geographical outline of the proposed future neighbourhood, and extends the outline of the urban site for reasons explained in Chapter Five, Section 5.4.3.3 (‘Current Planning/policy context’). The analysis concentrates on two aspects of urban morphology, which can reveal evidence of compositional complexity of the urban site: analysis of morphological periods and urban tissue categorization. Analysis of morphological periods of Sandyford uncovers the multiple stages of development and spatial change in the area, which is centrally related to the compositional complexity of the urban site context. Secondly, urban tissue categorisation (Scheer, 2002, 2003) reveals the character and complexity of the area and relates this aspect to international examples. As outlined in Section 4.3, the planning policy context of the case site is as a former industrial estate, which expanded into residential use due to public transport infrastructure provision without an overall master plan. Currently, the official definition of the settlement as ‘town’ has status under certain public mappings (eg. myplan.ie zoning classifications) though not in others. As in the case of Ballymun, morphological analysis based on Scheer’s theories and
methods of urban tissue analysis (2001, 2003) are considered most appropriate to analyse this proposed future neighbourhood. As regards the morphological periods of Sandyford, (as described in more detail in Appendix A) the seven morphological periods and six plan-units described do indicate a recent history of spatial change, and a dynamically changing urban site. However, the resulting compositional or morphological complexity is concentrated in individual sites rather than being evident at the resolution of the overall urban site of the Carmanhall neighbourhood. As regards urban tissue categorization\(^{183}\), while the surroundings of Sandyford are primarily static tissue, including the predominant urban form type, of low-density housing estate, some infrastructure elements such as motorway, reservoirs, and rail interrupt the morphological footprint, and emergent new development patterns associated with regional accessibility are appearing on the fringes of the urban site. However the primary tissue type is campus style development, a remainder from the original light industrial estate layout of the 1970’s. Morphological characteristics of this tissue type, in Scheer’s terms, include large tracts of land in single ownership, developed into multiple buildings, with internal paths organized as private streets and spaces. The morphological pattern of the urban site is extremely uneven, and the identification of morphological periods and plan-units helps to uncover a spatial history of the location at multiple scales.

\(^{183}\) See Scheer’s definitions of ‘static’, ‘campus’ and ‘elastic’ urban tissue types in Appendix A.
6.4.2 Carmanhall composition

The Carmanhall Neighbourhood is a future planned neighbourhood, to be situated within an urban framework plan area, surrounded by infrastructure, a business district, and light industrial estate uses. Carmanhall contains six urban blocks, eight streets (or roads), and one major civic space, Beacon South (which is privately owned). The first aspect evaluated, urban form, has a significant impact on the spatial reading of the urban site, due to the rapid development of the urban morphological structure of the urban site over a short time. This section involves compositional evaluation of the Carmanhall area, the case site (one of three proposed new neighbourhoods in the framework plan area), and looks at three criteria of compositional complexity; urban form metrics, land-use mix and density.

Urban form (morphological complexity)

Seven commonly used measures in urban analysis and design are undertaken. These are selected to help to define a comparable difference in the compositional characteristics of urban sites. In line with the overall aims of the study, distinct and comparable evaluated conditions of spatial complexity are sought. Appendix A, ‘Morphology of cases’, Volume Two, describes in detail the data analysis aspects of each of the seven measures of urban morphological complexity for the site at Carmanhall. In reviewing across the seven selected measures of urban form evaluation, and more specifically morphological complexity of Carmanhall (See Table 6-5), six of the seven measures show a low result, and one result is medium.
<table>
<thead>
<tr>
<th>Compositional Criteria</th>
<th>Method</th>
<th>Source</th>
<th>Indicators</th>
<th>Carmanhall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urban form (urban morphological complexity)</td>
<td>1. Power Law Distribution</td>
<td>(Salat, 2012:29)</td>
<td>low-medium-high</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>2. Passive Volume Ratio</td>
<td>(Salat, 2012:34)</td>
<td>%</td>
<td>medium</td>
</tr>
<tr>
<td></td>
<td>3. Street type</td>
<td>(Marshall, 2005:84)</td>
<td>ABCD</td>
<td>C (medium/low)</td>
</tr>
<tr>
<td></td>
<td>4. Plot Type</td>
<td>*(Song, Knaap, 2008:9)</td>
<td>Geometric aspects</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td>5. Plots per hectare</td>
<td>(Jacobs, Appleyard, 1987:117)(Norton, 2016)</td>
<td>/ha</td>
<td>0.7 plots/ha (low)</td>
</tr>
<tr>
<td></td>
<td>6. Blocks per hectare</td>
<td>(Dempsey, 2008:255)</td>
<td>/ha</td>
<td>0.19 blocks/ha (low)</td>
</tr>
<tr>
<td></td>
<td>7. Junctions per km sq</td>
<td>**(Song, Knaap, 2008:9)</td>
<td>/km sq</td>
<td>67 junctions per km sq. (low)</td>
</tr>
</tbody>
</table>

Table 6-5 Carmanhall Urban Morphological Complexity Evaluation Form

See full descriptions and graphics of each measure in Volume Two, Appendix A
Land-use mix

The land-use mix measure of compositional complexity for Carmanhall (according to Protocol No 2) has a predominance of commercial functions, very little amenities, and a lack of housing is evident. This is to be expected, as the origin of this urban site is as an industrial estate. However, the urban site is classified as bifunctional, (having more than 10% of at least two functions), so the evaluated function mix of constructed buildings is medium, but as all of the site is not built on this evaluation is considered as having low land-use mix. In terms of spatial complexity, low levels of existing land-use function mix suggest that the future neighbourhood planned here will face challenges in building towards optimal conditions. It is also evident from this analysis, when compared with the reality on the ground, that upper levels of housing, and high densities of mixed use conditions in some new urban blocks are not reflected in the address point data.

Figure 6-45 Land-use mix Triangle

(l), and sample address points around Carmanhall (r) (source, www.myplan.ie) (r)
Density

The density measure of compositional complexity, (according to Protocol No 3) indicates relatively high site coverage and low plot ratio, unexpected characteristics of this former industrial estate site. In this case, significant new high density urban perimeter blocks contribute ‘spot density’ to the centre, and relatively low density industrial units (pre-boom) as well as unbuilt/stalled development sites all contribute to a highly mixed local overall urban block density result. In evening out the evaluated density at the scalar resolution of the urban site, a medium density (and therefore compositional complexity) could be described, but on closer analysis of part-vacant sites, it is apparent that vacancy reduces the evaluated density of the urban site overall to a low value.

Figure 6-46 Density graph

(I), and plot ratio Carmanhall (r)
Discussion

Some preliminary comments on the evaluated compositional complexity of Sandyford can be made. This urban site is in a state of partial completion, so only some urban blocks are completed as originally planned, before work stalled in 2008. Therefore, an urban blocks per hectare indicator does not capture the intense urban quality of certain urban blocks in the area, nor the extremely non-urban character of certain (sometimes adjoining) shed type light industrial units, remaining from the original iteration of the urban site (See Appendix A, Morphology of Cases Description). In seeking a general conclusion as regards the urban morphological complexity of the urban site, and given that only two parts of the six urban blocks on the site are completed as designed, the neighbourhood of Carmanhall is still one of low morphological complexity, seen at this scalar resolution.
6.4.3 Carmanhall configuration

The overall Dublin Axial Map has an overall global average integration value of 0.557. The context of this urban site, called here ‘Sandyford’, (and selecting 46 lines) has a much lower global average integration value than Dublin overall, of 0.421. However, Carmanhall Road, the main road of the context area, has a global integration value of 0.523, not much below the city average (0.557), and so appears well integrated at global level within the city. However, for the case site of Carmanhall (29 axial lines) the global integration value is 0.528, a low reading in overall city terms. The overall Dublin Axial Map has an overall local average integration value of 1.438. The local integration value of the context of this urban site at Carmanhall, Sandyford Industrial Estates, is 1.509, higher than the city average. However, in selecting a slightly wider area than the 46 axial lines as the larger Sandyford context area (including the M50 motorway) to evaluate local integration, (243 axial lines) the local integration value of the wider context of this urban site drops to 1.381, below the city average. Furthermore, some local integration values for individual streets in this context are amongst the lowest local integration values in the city. For the case site of Carmanhall (29 axial lines) the local integration value is 0.443, a low reading in overall city terms.

![Overall global integration of Dublin axial map](image)

*Figure 6-47 Overall global integration of Dublin axial map* (1), with urban site at Carmanhall highlighted (2)
Integration

Considering the global and local integration values for the context of the case study site suggests that although the context is well connected to the wider city for overall movement (such as by car, to the M50) it is not well connected to the local area (eg. for walking), or to surrounding urban sites in the area. From these two observations on global and local integration, including the lack of overlap between global and local integration values for the context site, it can be deduced that the Sandyford context as well as Carmanhall have relatively low integration readings in overall terms.

Figure 6-48 Overall local integration of Dublin axial map

Overall local integration of Dublin axial map (1) with urban site at Carmanhall highlighted (2)
Choice

In Chapter Five, two measures of choice were described for the whole city scale. Firstly, a ‘global’ choice map was prepared, and from this map it is evident that Sandyford does not appear as a relatively distinct area, even though it is surrounded by ‘natural boundaries’ (Peponis et al, 1990) of roads on all four sides. From the more local radius of 1km applied to the choice measure, a second map indicates Sandyford not emerging graphically as a ‘hotspot’ of local choice, possible indicating a lack of public life in the area, as deduced for other areas using this measure (Vaughan et al, 2009:476). In the case of Sandyford, current Segment Angular Analysis (2012), r400 Integration for the overall ‘Sandyford Area’, has been selected for analysis\textsuperscript{184}. The analysis indicates that the area has very few ‘through-movement’ route choices within the short metric distances normally associated with well internally connected pedestrian areas, and therefore that the low choice measure at global, 1km, and 400m radius for the Sandyford and Carmanhall area suggests a configurationally non-complex urban site\textsuperscript{185}.

The highest choice measure in Carmanhall (29 axial lines) is in the east of the area\textsuperscript{186}. The attribute reading is 38, an almost negligible reading, in a city where the average attribute reading among 14,818 lines is 106. The lowest choice value in Carmanhall, of 2, is on the edge of the neighbourhood\textsuperscript{187}. The analysis indicates that the catchment of the area is not readable graphically in choice and configurational analysis terms, and therefore that through movement at a 400 m radius is not facilitated by the street structure.

\textsuperscript{184} The segment angular analysis mode has been chosen from three possible modes of measurement: topological, angular and metric, to further focus configurational analysis on the case site. Research has shown that ‘there is a stronger correlation between human movement and the spatial configuration of the street grid in the angular analyses (fewest angular deviations) than in the topological analyses (fewest turns)’ (Van Nes, 2012 #361; Hillier, 2007 #360).

\textsuperscript{185} This is manifested by mostly axial lines in the blue colour range, with two isolated light green lines to the west and east of the area only. The r400 choice measure also helps to derive a medium scale reading of the urban site being examined, in this case Carmanhall as the overall case site.

\textsuperscript{186} This is related to the axial line at Carmanhall Road, close to the corner of Arkle Road.

\textsuperscript{187} This is at Three Rock Road, between Corrig Road and Ravens Rock Road.
**Intelligibility**

In relation to the third syntactical measure of configurational complexity, intelligibility, this measure can be represented by a scattergram showing overall integration on the x-axis (HH) and connectivity on the y-axis. In Chapter Five, the scattergram for the whole city was described. In reviewing the context of Sandyford, the whole city scattergram described in Chapter Five indicates an above average intelligibility for many streets in this urban site, as they mostly appear above the regression line. The intelligibility analysis of the smaller site of Carmanhall indicates that the area is locally well connected and well integrated in city terms, as the cluster of selected axial lines appear towards the middle of the scattergram, which suggests a medium intelligibility and therefore configurationally a potentially complex urban site may emerge in the future.
Figure 6-49 Intelligibility of urban site at Carmanhall

Medium intelligibility of urban site at Carmanhall, axial lines highlighted (1) and scatter plot (2) of Dublin axial map. Sources: (1) Author, (2) S O’Gara, data visualised in Tableau.
Discussion

Carmanhall has relatively low configurational integration in overall terms, a low choice measure at global, 1km, and 400m radius, and a medium evaluated intelligibility, suggesting overall an urban site of low configurational complexity. Higher intelligibility is associated with grid-like urban structure (Read, 2005:350), which may explain the high intelligibility level measure for Carmanhall, as the site is the result of a single ‘planned layout’ of an industrial estate in the 1970’s (See Section 5.4.3.1 ‘Context Description’).

Figure 6-49 Carmanhall urban site, choice measure, metric radius 400m

Carmanhall urban site, choice measure, axial lines highlighted on Dublin axial map. (1) and local site (2).
6.4.4 Carmanhall system

The Carmanhall urban site system evaluation extends and builds on the previous two evaluations, of composition and configuration, to provide a comprehensive three-sided analysis of the urban site. This in turn is useful for considering alongside both the overall and the system evaluations of the previous two urban sites considered, Liberties and Ballymun.
Street network complexity (Patterns)

The evaluated street network complexity, as measured according to Protocol No 7, is now described for the Carmanhall area. The complexity value is 0.25, a low rating in relative terms. For comparison, Marshall’s 40 locations tested had 29 sites of higher value, so Carmanhall, when compared with international examples, would rank close to the lowest quarter of sites tested. In Dublin terms, this is also the lowest value of the three urban sites tested. This urban morphological tissue has been analysed in an earlier section, and classified as mainly campus style. This type of suburban form is associated with a single ownership, grid layout, and therefore linear, orthogonal street grid structure imposed in a short time. Marshall argues that ‘planned grid’ (Marshall, 2005:149) can lead to lower evaluated complexity levels, as in this case, even though this is a very recent case of the type he describes, and varies in being a low rise light industrial estate from inception till recently, whereas his examples are generally planned layouts in advance of urban design type intervention, in other words, to consciously design urban form.

Figure 6-50 Carmanhall street network complexity

Demonstrated street network complexity patterns: streets (1), depths (2).

188 Although only three street network complexity evaluations are contained in Volume One of this study, three others, (Overall Liberties, Overall Ballymun and Overall Sandyford) were also completed, and some of these are referred to and recorded in Volume Two Appendices.
Path network complexity (Paths)

The mapped path network for Carmanhall shows a sparse, grid-like network with a very low density of paths across the urban site. The measured metric reach for Carmanhall is 3,875m, or 7.75 ‘times’ (the 500m ‘reach’) which indicates a low density and low complexity of the network. Salingaros seeks a ‘multiplicity of irregular paths and connections’ in establishing the characteristic of complexity of the urban web (Salingaros, 1998:3). The path network of Carmanhall illustrated here suggests a low level of network complexity, which in turn suggests low spatial complexity in the local path system, and therefore a site of low system complexity. In Carmanhall, the path network includes privately owned public open spaces which are mainly publicly accessible pedestrian retail space. However, as these routes are subject to fluctuating access hours, and could become less accessible over time, these have not been included in the metric reach calculation.

Figure 6-51 Path street network complexity

Step 8, Paths. Carmanhall, urban blocks (1), and metric reach calculation (2)

---

189 For comparison, a study found 400m (0.25 of a mile) metric reach values for Atlanta of 3.5 (Downtown), 3.2 (Midtown), and 2.1 (a primarily residential area) (Ozbil et al, 2011:133). These values are all below the Carmanhall measure, but only by four times in the case of Downtown, so this urban site is beginning to be comparable to North American downtown urban sites, by this measure.
Pedestrian movement network complexity (People)

Carmahall is evaluated as a site of low pedestrian movement network complexity, as demonstrated in Appendix D, Section 3. However, emergent properties like large numbers of pedestrian congregating in an industrial estate around an unplanned event (an outdoor market) suggest a developing spine of public life.

Figure 6-51 Pedestrian movement network complexity

Carmanhall pedestrian gate count locations mapped (1) sample Timelapse: Carmanhall mixed use centre at Beacon South (2) and viewer location (3).

Discussion

Some preliminary comments on the evaluated system complexity of Carmanhall urban site system can be made here. In the third urban site, the question of how to evaluate spatial complexity of an urban site in a large-scale system hub is answered. In this case, complex system characteristics such as nested\textsuperscript{190} organisational levels, emergent

\textsuperscript{190} The concept of nested hierarchies is defined ‘a commonly accepted notion of scale’, and as ‘a set of areal extents in which it is assumed that the sum of all components at one level, such as counties or consumers, produces one component at a larger scale, such as states or households (Haggett, 1965)’ (Manson, 2001:408).
properties, and feedback loops\textsuperscript{191} arise, though scalar resolution issues can mask these. For example, the nested organisational level of existing part-complete ‘urban centre’, which officially describes this location in one official reading\textsuperscript{192}, is different to another official zoning, of ‘business district’, according to the local authority for the area, so organisational and governance complexity of the urban site is high. This has spatial implications, such as effecting city-wide decisions on location of tall buildings. A low level of system complexity, as suggested by the analysis of street network complexity (Patterns), path network complexity (Paths), and movement network complexity (People) is the overall finding of this evaluation. Other aspects of complexity at urban design scale, such as urban, architectural or landscape complexity would be expected to be evaluated as low for this type of urban site, according to prior theory and previous studies, as outline in Chapter Two. For example, at this scale of resolution, urban densities are hard to equalise, between vacant sites and highly dense urban perimeter blocks. Architectural complexity, though arguably present within specific plots, is also difficult to define and measure at this scalar resolution. And landscape ‘mosaics’, in a site so geographically close to open countryside, are also the wrong level of resolution to apply\textsuperscript{193}. Therefore, although only urban site level of resolution is evaluated, it is possible the evaluation would vary up or down significantly at varying levels of resolution.

\textsuperscript{191} Hillier’s (1996/2004:351) idea of positive feedback loops in urban sites, built on the foundation of the relation between grid structure and movement, leading to ‘urban buzz’ is also relevant to Carmanhall in particular, which is based on a grid-like plan, and has growing and emergent pedestrian movement patterns, as analysed in this study.

\textsuperscript{192} The website www.Myplan.ie, launched in 2012, is the first official national land use planning information system for Ireland. The service makes zoning and other planning related data sets available in an intuitive, user friendly geobrowser format. The zoning data comes in two forms, namely, the zones as adopted in statutory Development and Local Area Plans, and also in a Generalized Zone Type (GZT) format. Source: (McCormack, Cussen, 2012). While the GZT zoning equates closely to the local authority requirements related to zoning, some different general descriptions of areas apply, such as ‘M2-City/Town/village centre, central area’ the designation of almost a third of the lands at Carmanhall.

\textsuperscript{193} However, Andresson, (2006) in discussing urbanisation, suggests that this form of development may represent the most complex mosaic of vegetative land cover and multiple land uses of any landscape (Foresman et al. 1997) (Andersson, 2006:34).
6.4.5 Evaluated spatial complexity of Carmanhall

The synthesised conclusion of this nine-step evaluation process is the preparation of the Spatial Complexity Evaluation Form for the third case site, Carmanhall (see Table 6-6). In the third site, the question of how to evaluate spatial complexity of an urban site in a large-scale system hub is answered. Hughes describes Sandyford, the immediate spatial context of Carmanhall, as ‘a fast-growing and densifying suburban settlement’ (Hughes 2010:184). In another account, Sandyford is seen as the best exemplar of the development of edge city in Ireland (MacLaran, 2007:79).

The Carmanhall evaluation uncovers characteristics of complex spatial systems such as spatially nested organisational levels, in the form of grid like plots, nested within the overall original layout and design. Emergent spatial properties of the urban site, such as juxtapositions of high constructed density, and low levels of land-use mix are also evident. A spatial reading of feedback loops in the constructed urban form could investigate the original grants of isolated residential planning permissions (in the absence of a planning policy) on an industrial site, and argue that this policy change led to feedback loops of increasing tendency for residential development to occur. However, in making a static evaluation of spatial conditions on the ground, the primary evidence of feedback is the continuing (though stalled) development of high-density primarily residential construction in an otherwise low-density industrial estate.

---

194 Complex spatial systems have been described as ‘open systems which interact with their environment, comprising many diverse components and interactions, containing feedback loops, a ‘history’, they are nested, and encompass various organisational levels, emergent properties and multiple attractors’. (Rothmans, 2012).
Three criteria demonstrate low compositional complexity of the urban structure/form of Carmanhall at urban site scalar resolution. The first is power law distribution of streets, which shows a low evaluation, partly because all streets are equally wide, due to the original grid plan. Secondly, evaluated land-use mix, which is mainly bifunctional (commercial and amenities) has a medium value of function mix, and therefore, in this analysis, a medium compositional complexity. However, it can be seen from the address point mapping that Carmanhall is distinctly different from the surroundings, which are mostly monofunctional residential areas. This compositional complexity indicator shows in Carmanhall (as before in urban Ballymun) the distinct impact of strictly defining the boundary and resolution of the analysed urban site. Evaluated density of Carmanhall is categorized as medium, indicating that compositional complexity related to this aspect is medium, although many central sites here remain vacant, so the density analysis covers only 45% (site coverage) of the land area. Given this situation, the density in overall terms of Carmanhall is low. In conclusion, of the four indicators of compositional complexity evaluated, three (urban morphological analysis, power law distribution and density) indicate a low compositional complexity, and land-use mix is medium. In spatial complexity evaluation terms, this therefore suggests a low evaluated spatial complexity level for this urban site.

In Carmanhall, while all compositional indicators reveal a site of low morphological complexity at the scalar level of the urban site, some isolated plots within the urban site have starkly different readings to the evaluated spatial state. Compositional complexity is captured in this study by measuring urban form, land-use mix and density, but these only capture larger form-related attributes of urban sites. According to the major proposition of this study, the conclusion for the neighbourhood of Carmanhall, of
evaluated low compositional complexity, only encompasses a one-third part of the description needed to confirm an evaluated level of spatial complexity for urban design.

The three selected indicators of configurational evaluation (integration, choice, intelligibility) signify that Carmanhall has relatively low configurational integration in overall terms, a low choice measure at global and 1km radius, and a medium evaluated intelligibility, suggesting an urban site of overall low configurational complexity. The conclusion, of low evaluated configurational complexity, builds on the earlier compositional findings, to further suggest low spatial complexity of the urban site.

Next, in order to represent some system indices of spatial complexity, street network complexity is evaluated, seeking to capture an additional aspect of the street pattern, and then the network of pedestrian paths. The last step then concentrates on the most detailed scale of urban design, pedestrian movement activity itself. In Carmanhall, all three of the indicators have low evaluations. Taken together with the earlier compositional complexity evaluation (low level), and the overall low configurational complexity evaluated, a low spatial complexity level for the neighbourhood of Carmanhall is confirmed by considering the third issue of spatial complexity evaluated, the low system evaluation of this urban site. This section reports particularly on system complexity aspects of spatial complexity of urban sites, examined through a focus on one spatial system in the third case unit of study, the planned future neighbourhood of Carmanhall, located in Sandyford, a regional hub. A third distinct and contrasting condition to the two previous cases, of low evaluated spatial complexity, is therefore described.
## Spatial Complexity Evaluation Form

**Urban Site:** Carmanhall (case site)  
**Date:** July 2016

<table>
<thead>
<tr>
<th>Issue</th>
<th>Criteria</th>
<th>Method</th>
<th>Indicators</th>
<th>Result</th>
<th>Spatial Complexity Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>Urban form</td>
<td>Conzentian Analysis</td>
<td>low-med-high</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Schier’s Analysis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Power Law Distribution</td>
<td>Curve type</td>
<td>low</td>
<td>low</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(relative to 2 others)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Passive Volume Ratio</td>
<td>percentage</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td></td>
<td>ABCD Street type</td>
<td>Correlational graph</td>
<td>'C'</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>Land-use Mix</td>
<td>Van Den Hock</td>
<td>Mix triangle</td>
<td>bifunctional</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>Density</td>
<td>Plot Ratio/Site Coverage</td>
<td>Correlational Graph</td>
<td>incomplete</td>
<td>medium</td>
<td></td>
</tr>
<tr>
<td>Configuration</td>
<td>Integration</td>
<td>Global</td>
<td>Rn result</td>
<td>0.528 (29 axial lines)</td>
<td>low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Local</td>
<td>R3 result</td>
<td>0.443 (29 axial lines)</td>
<td>low</td>
</tr>
<tr>
<td>Choice</td>
<td>Segment Angular Analysis</td>
<td>400m radius metric</td>
<td>38 (Arkle Rd)</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>Intelligibility</td>
<td>Integration/Connectivity relation</td>
<td>Scattergram</td>
<td>low cluster (46 axial lines)</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>Patterns</td>
<td>Street network complexity (SNC)</td>
<td>SNC Index</td>
<td>(0.25)</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>Paths</td>
<td>Path network complexity</td>
<td>Metric Reach Measure</td>
<td>(7.75 times)</td>
<td></td>
<td>low</td>
</tr>
<tr>
<td>People</td>
<td>Pedestrian network complexity</td>
<td>Gate counts/timelapse</td>
<td>23/3 mins highest value</td>
<td></td>
<td>low</td>
</tr>
</tbody>
</table>

### Table 6-6  Carmanhall Spatial Complexity Evaluation Form

(See also Addendum Section in Vol 2 for more colour visualised results of case evaluations)
6.5 Observations within, between and across cases

Figure 6-52 Spider plots of spatial complexity

(1) Liberties, (2) urban Ballymun, (3) Carmanhall
The pattern predicted in Chapter Four, of ‘high’ (Liberties character area), ‘medium’ (urban Ballymun) and ‘low’ (Carmanhall neighbourhood) evaluated spatial complexity levels of three sites has been confirmed by the analysis described in this Chapter. In comparing characteristics of urban sites between cases, the three case urban sites evaluated represent distinct and contrasting spatial conditions. As it would be expected that higher urban (Lim, 2016) and spatial complexity would be associated with historic centres, and lower levels with newer urban centres (Ye, 2013) and outer edges (Scheer, 2003), this overall result can be understood as reflecting officially represented status in planning terms, namely, as inner city (Liberties), suburban (Ballymun) and outer suburban (Sandyford) units of the city.

However, within overall results, certain unexpected findings are evident within, between and across cases. In analysing spatial complexity and making observations on within-case analysis, stating the scale of resolution at which the object is perceived is important. Furthermore, in considering visual feedback provided by the tools in this study, formal measurement and visual interpretation are considered to go hand in hand, as described in Chapter Four (Section 4.5). In this part of the study, urban sites are mapped at an urban site (or neighbourhood) scale of resolution, which might approximate to 1:1000 scale mapping, a common scale of urban design analysis and figure-ground mapping in urban design (Carmona, 2003:273), as well as being an official Ordnance Survey city map scale. So for example, clusters of second order plan-units identified in the Liberties could be clearer if more detailed analysis of mapping at a different scale were examined. However, comparability across cases is important in this study, so scale of resolution of all graphical outputs is consistently even across the three urban sites.
Within the first case, a relatively even distribution of the evaluated aspects of composition, configuration, and system is apparent in the Liberties. However, this partly results from the ‘evenness’ provided by the case boundary, which delimits the character area in official and morphological terms as a coherent unit. If, for example, the case site included the large dual carriageway to the east (Clanbrassil St.) the evaluation would have have revealed many within-case contrasts; in street width, in numbers of plan-units, etc. Thus, the within-case contrasts in the Liberties are minor. However, Ballymun is defined by within-case contrasts, from compositional contrasts of modernist road widths alongside regenerated ‘postmodern urbanism streets’ (Hebbert, 2008), to configurational inconsistencies of choice and integration, to large differences between tally counts of pedestrian movement, indicating an uneven system. The third case, at Carmanhall, has even starker within-case contrasts, from compositional inconsistencies of 16 storey buildings alongside one storey sheds, to highly globally integrated routes alongside very poorly integrated zones, and again, even larger differences between tally counts of pedestrian movement.

In making further observations comparing evaluated compositional criteria of urban sites between cases, analysis of the evaluated sites reveals unexpected formal and compositional features of each case. In terms of urban form for example, while many of the historic town plan characteristics of the inner city persist in the Liberties, few historic buildings remain, so the compositional complexity is arguably reduced when compared to other historic inner cities. However, despite this, as a result of mapping four selected elements of town plan analysis in this study, as well as further plan-unit
categorisation and mapping, it is concluded in overall terms that the urban site of the Liberties manifests a high level of spatial complexity in relation to urban form.

Analysis of seven other characteristics of urban form in the Liberties confirms the high urban morphological complexity aspect of the evaluation. Ballymun, on the other hand, is compositionally mixed when considered at this general level of resolution, while Sandyford is arguably compositionally and spatially chaotic\(^{195}\), having highly complex structures adjoining empty sites. Another characteristic related to composition across the cases, that of population density, shows that, while all sites can be officially classified as urban, having a resident population of a minimum of 1,500 persons / km sq (Hughes, 2015) distribution of resident populations at urban block scale is radically different from block to block, particularly in the second and third cases. Therefore, in comparing between cases, compositional morphological complexity seems more unevenly distributed in suburban and outer suburban locations than in historic urban sites.

In comparing evaluated configurational criteria between cases, the three case urban sites have different numbers of axial lines selected for analysis, as there are different quantities of streets or roads present in each location. So at the larger extreme, the Liberties character area, (land area 0.342 km\(^2\), 84 acres) with a dense urban network of streets, has 72 axial lines, while at the lower extreme, Carmanhall (land area 0.314km\(^2\), 77 acres) has a minimal road network, and just 11 axial lines. As a comparison, urban Ballymun, where 28 lines are selected to assess integration, combines original social housing estate layout with some regeneration streets. As described in Chapter Five,\(^{195}\)

\(^{195}\) An interest in the concept of ‘spatial chaos’, (discussed later in a footnote to Section 7.4), was an original impetus to this research. In essence, the presence of high spatial complexity alongside very low spatial complexity (for example) could indicate spatial chaos.
Carmanhall, a recently developed urban site, was originally designed as a light industrial estate road layout on existing farmland in the 1970’s, and there have been minimal adaptations of the road network as the site has urbanised, so the site is evaluated to be of low configurational complexity. As expected, higher integration, better syntactic choice levels, and higher intelligibility occurs in inner city sites than in suburban and outer suburban sites, but configurational complexity also captures global attributes, and in this regard Sandyford, with lowest local integration levels, does not appear as a distinct area, surrounded by ‘natural boundaries’ when a ‘global’ choice map is analysed. However, it is geographically close to the highest global integration ‘spot’ in the city (Red Cow, M50 intersection), suggesting that a scalar level above that of an urban site could reveal more useful information about spatial complexity of the site. This in turn indicates that some urban sites need to be evaluated for spatial complexity at higher scalar levels than that of a neighbourhood unit or urban site.

In comparing evaluated system criteria between cases, while the urban centre of a historic neighbourhood would be expected to perform well as a system (Liberties), it is unsurprising given the undesigned and unfinished nature of both that the regenerated case of urban Ballymun, as well as the future neighbourhood of Carmanhall, fail to work as efficient systems.

In concluding this section on making observations within, between and across evaluated cases, the key points are:

- Across the three cases, none of the three urban sites have very high evaluated levels of spatial complexity, and the highest level of the three sites, Liberties, has relatively low land-use mix and density, for an inner city location.
• While within-case contrasts in the Liberties are minor, Ballymun is defined by within-case contrasts, and Carmanhall, has even starker within-case contrasts. This could suggest as a conclusion that non-historic urban centres need to be evaluated at more than one scalar level, and connections between the levels examined as well as more attention to within-case analysis.

• Compositional morphological complexity seems more unevenly distributed in Dublin suburban and outer suburban locations than in historic urban sites.

• Some outer urban sites need to be evaluated for spatial complexity at higher scalar levels than that of a neighbourhood or urban site.

In relative terms, as regards the three case sites, some evaluated ‘metrics’ do not follow the pattern of ‘high’ (Liberties character area), ‘medium’ (urban Ballymun) and ‘low’ (Carmanhall neighbourhood) evaluated spatial complexity levels. It is notable for example, that amongst the evaluated compositional criteria, the ‘plots per hectare/ urban grain’ measure is higher for Carmanhall than for urban Ballymun. This anomaly is explained by the history of public site ownership of the entire site of Ballymun until recently, and consequent lack of subdivision of plots. Other examples of ‘outlier’ results are for example, amongst the evaluated configurational criteria between cases, the high local choice levels found at Carmanhall, possibly due to the grid layout, and some very high gate counts of pedestrian movement, explained by one-off events. In conclusion, while the within-case comparisons confirm distinct and contrasting conditions of evaluated spatial complexity within one city, the aim of this chapter, observations at different scalar levels reveals inconsistencies in the evaluated relation between the three sites in relative terms.
6.6 Three spatial complexity visualisations

The exploration of spatial complexity of Dublin at whole city and case context scalar levels in Chapter Five describes a city of generally low and uneven spatial complexity. In order to find out more about more local scales for urban design, three case sites are then evaluated. According to the indicative method of evaluation and visualisation of spatial complexity of urban sites as proposed in Chapter Four (Figure 4-12), following the use of the evaluation tools, the recording of the results in a Spatial Complexity Evaluation Form, and the preparation of Spider Plot diagrams, the next step in understanding spatial complexity is visualisation of results. A total of six data analysis techniques are employed in this study\textsuperscript{196}: data transformation, instrument development, examining multiple levels, matrix preparation, pattern matching, and cross-case synthesis. The first four techniques are the selected ‘evaluatory’ data analysis procedures identified in the research design, following from the research strategy. Two further ‘exploratory’ data analysis procedures, pattern matching and cross-case synthesis are employed at higher level analysis of results\textsuperscript{197}. In this study, visualisation enables that each of the four evaluatory data analysis techniques, as described in Chapter Three, (Section 3.3.7, ‘Data analysis techniques’) can demonstrate findings of the study. Each is described her in turn with a visual example of an enabling visualisation technique, and its resultant insights are set out.

\textsuperscript{196} (as described in Chapter Three, Section 3.3.7)
\textsuperscript{197} The reasons that visualisation is important to understandings of spatial complexity were discussed in Chapter Four (Section 4.5.3), and can be summarised as: to stimulate the urban design process, to bring visual clarity to quantitative assessment, to allow for qualitative interpretation by a wide community around evaluation, to allow formal measurement and informal interpretation of results to be combined, and to allow the involvement of a wider group of stakeholders around evaluation.
Data transformation

In terms of data transformation (Creswell, 2009:200): quantification of qualitative data is shown in the Spatial Complexity Evaluation Form, where urban morphological complexity analysis, though including ‘metrics’ also has a more qualitative, text driven aspect, leading to evaluation. In this study, qualification of quantitative data involves interpretation of mathematical measures of spatial complexity (for example ‘integration’), broadening descriptions into high, medium or ‘low’. In order to visualise that equal weightings applying to these criteria are interrelated, and in order to allow comparisons across cases, colour weightings are applied to the Form, as described in Chapter Four, (Section 4.5.4 ‘Proposed visualisation methods for spatial complexity’). Other than in Figs 6-56 to 6-61, the digital dimension of the ‘signature’ of spatial complexity is not extensively developed in this Thesis, partly because specialist input would be needed from an expert in data visualisation, especially in exploratory and explanatory infographics, as outlined in Sections 2.4.2 (Pg 100, ‘Representation and visualisation theory’) and 4.5.3 (Pg 212, ‘Urban evaluation visualisation methods’)(Vol 1). However, it is important to the future development of the concept of spatial complexity that the specific identity and nestedness of an evaluation can best be visually represented within a digital environment. This is demonstrated by considering the RGB colour model, which is proposed in this study as a way to uniquely identify the evaluation ‘score’ of an urban site (See Fig 6-53). The Toolbox and Databox of this study achieve this by conferring a single, unique ‘signature of spatial complexity’ of an urban site, for a certain spatial unit, at a fixed point in time. The RGB colour model describes a colour of this signature by using three variables: red (R), green (G), and blue (B), a model commonly used in computer graphics, which is related to the way colour receptors of the human eye work.
Sample derivation for Carmanhall, and (1) Liberties, (2) Urban Ballymun, (3) Carmanhall (below), and sketch (above) showing how the RGB colour model (which is proposed in this study as a way to uniquely identify the evaluation ‘score’ of an urban site), can be extrapolated from separate issues and criteria of spatial complexity. In a digital development of this sketch, further work could assign this ‘signature of spatial complexity’ to each urban site evaluated.
**Instrument development**

The data analysis technique of instrument development involves developing themes in the early stage analysis of urban sites which may form the evaluation instrument in a later stage of data collection. For example, as part of instrument development in this study, it was found that urban morphological complexity is an ill-defined concept for urban analysis, but could be extended for use in urban analysis and evaluation (See Appendix A., Section One). As a result, from the emerging urban morphological analysis (qualitative) of an urban site during the study, a new geometrical analysis method for urban blocks and plots emerges in this study as a relevant and useful evaluation tool, and therefore the ‘Plot Type’ geometrical analysis method is developed in this study\(^{198}\). Development of compositional analysis instruments can concurrently direct the questions for the configurational and systems related data gathering. In this case, plot and block type analysis is clearly connected to power law distribution of streets for example, as similar evaluations occur in particular sites, and these relations are visualised through cross case synthesis illustrations, like spider plots.

\(^{198}\) This method is described in more detail in Appendix B, ‘Urban Morphological Analysis Protocol’ (1AA), Taxonomy Protocol.
Sample graphic of development of taxonomic analysis of figure ground plan outlines of urban plots in the Liberties, in an embedded case site around Cornmarket. In this approach, five large plot types and four small plot types of individual plot within urban blocks are organised. Centroids of the plot area are devised through visual approximation, and these are placed on a ‘cross-hair’ x and y axis. Plot outlines are overlaid to visually indicate relative complexity of compositional and geometric pattern. (See also Appendix A, Case Morphology Description)
Examining multiple levels and scales

In examining multiple levels and scales\(^{199}\), within the concurrent mixed methods model, in this study a quantitative survey of an urban site is undertaken at one scale or level, while at the same time more qualitative data is being collected at another level, for example in one street. Spider plots of overall evaluated spatial complexity of an urban site can be compared with a ‘lower’ level of evaluation, of ‘metrics’ of compositional complexity, to be used in detecting possible relations across criteria and issues of spatial complexity. In the sketch examples illustrated for example, (Figure 6-55 ) it is shown that while sites of high evaluated morphological complexity will also manifest high spatial complexity (an expected result), sites of medium evaluated spatial complexity could also contain relatively high readings in street network complexity, while sites of low evaluated spatial complexity could also contain relatively high readings in density terms. These ‘outlier’ instances suggest exploring spatial complexity at higher and lower scalar levels in some urban sites of low evaluated spatial complexity.

![Figure 6-55 Sketch Spider Plots for three urban sites](image)

1. Compositional complexity ‘metrics’ plotted (1), and overall spatial complexity evaluations (2)

---

\(^{199}\) ‘Levels’ of evaluation here refers to the difference between higher levels (3 issues) and lower levels (9 criteria) of the conceptual framework introduced in Chapter Four. ‘Scales’ means the convention in urban analysis to examine less detail at ‘higher’ scales (eg. an urban site or neighbourhood) than at ‘lower’ scales (eg. one street).
Matrix preparation

A matrix is recommended in data analysis for comparison of quantitative and qualitative data. In this research, the primary matrix-type evaluation tool takes the form of the Spatial Complexity Evaluation Form, and (at a lower level) a separate matrix of compositional complexity metrics, represented as a Table of Compositional Criteria. The separate matrices allow that data can be compared within, between and across urban sites, but also with other data from previous studies of the constituent criteria of spatial complexity. In this way, individual characteristics of the sites (like for example, evaluated density) could be compared, or the spectrum of densities evaluated across three urban sites in Dublin could be compared directly with international examples.

Figure 6-56 Compositional criteria Evaluation Form for three urban sites

In this image, colour has been applied to the Matrix, in order to visually reveal the variations in evaluated spatial complexity across the three sites for urban morphological complexity, one sub-criterion of one issue, that of spatial composition. It is evident that while there are variations within the last two cases, the uniformly high evaluations of the Liberties, the first case, conveys high evaluated spatial complexity in an immediately communicable way.
Figure 6-56 Applying colour weightings to Spider Plots
(1) Liberties, (2) urban Ballymun, (3) Carmanhall

Figure 6-57 Applying pixels and colour weightings to Databox
In these two images, the connection between a two-dimensional grid or pixel based graphic (above), and a more geolocated and precisely spatially positioned point in the urban site on the ground (below) is made. The upper image shows the vague boundary of the case site of Liberties within the spatial map of the overall explored spatial complexity map of the city, while the lower image shows a ‘zoomed-in’ location which directly connects to Irish Grid coordinates, thus linking a mathematical and GIS database to a more abductive and exploratory overall picture of explored spatial complexity of the city. In a more developed digital version of this approach, and as part of a follow up to this study, all of this data could be located within one custom-developed software package in a digital dimension.
Figure 6-59 Connecting address points and 2D section to Irish Grid and Databox

These two images demonstrate how pre-existing data can be employed to facilitate exploration, evaluation and visualisation of spatial complexity. The upper image identifies the boundary of an embedded part of a case site (at Cornmarket), applies the Irish Grid geolocated position to this spatial unit, and then overlays myplan.ie address point information for the area. The second image above shows a pre-existing cross section through one of the streets in the area, with a high complexity rating (red) denoting where artefacts have been discovered.

Figure 6-60 3-D Address points, Liberties, and comparable urban sites

Here address points in two urban sites from (Norton, 2016) are compared with Liberties.
The ‘model’ of a Databox for Carmanhall above is the ‘infographic’ version of a synthesis evaluation visualisation which could be developed, in a digital version, to show results for all three issues and nine criteria in a single image. In the developed version, a dynamic interface would allow evaluation to be traced across space (larger and smaller spatial units) and time (earlier morphologies or possible future design scenarios), as well as reduction of evaluation to a single, unique spatial complexity evaluation colour.
Visualising pattern matching and cross-case synthesis.

As described in Chapter Three, 3.3.7 ‘Data analysis’, the distinction between the four ‘evaluatory’ techniques described above and these two two ‘exploratory’ techniques can be seen as the distinction between more quantitative (the former) and more qualitative (the later) analysis. In this section, a review across visualisations of data combined from the three cases, and employment of pattern matching and cross-case synthesis demonstrates how visualisation enables these data analysis techniques.

Figure 6-61 Sample joined evaluations of the three urban sites
Pattern matching

As defined in Chapter Three, the first of the two selected techniques for data analysis, pattern matching, firstly involves identifying patterns. A pattern in research design terms is defined as ‘any consistent and characteristic form that is by definition non-random and potentially describable’ (Cao, 2007:447) and pattern matching is defined as ‘to compare an empirically based pattern—the “pragmatic reality”, with theoretical patterns—the “theoretical ideals”, or “systemic patterns” (Cao, 2007:447). Pattern ‘theories’ (Lincoln & Guba, 1985) are defined as explanations that develop during naturalistic or qualitative research. The pattern matching techniques selected for this research design, a ‘non-equivalent dependent variable as a pattern’, is described in Chapter Three as follows: ‘the quasi-experiment may have multiple dependent variables- that is, a variety of outcomes. If, for each outcome, the initially predicted values have been found, and at the same time alternative ‘patterns’ of predicted values (including those deriving from methodological artifacts, or ‘threats’ to validity) have not been found, strong causal inferences can be made’ (Yin, 2003b:116).

In this study, it is demonstrated through pattern matching that the three primary dependent variables, composition, configuration and system, are non-substitutable. For example, aspects of compositional complexity which are captured in analysis such as plot divisions and density counts could not be substituted for configurational characteristics or qualities of the urban sites. Similarly, system aspects of urban sites like pedestrian flows, as captured through gate counts, are not substitutable by other data about the locations. As described above, the pattern predicted in Chapter Four, of ‘high’ (Liberties character area), ‘medium’ (urban Ballymun) and ‘low’ (Carmanhall neighbourhood) evaluated spatial complexity levels of three sites has been confirmed by
the analysis described in this chapter. In comparing compositional characteristics of urban sites between cases, the three case urban sites evaluated represent distinct and contrasting spatial conditions, and can be understood as officially represented in planning terms, namely, as inner city (Liberties), suburban (Ballymun) and outer suburban (Sandyford) units of the city. These patterns are visualised in the images which bring together data evaluated across the three sites, such as for the three examples illustrated in Figure 6-61 showing power law distributions of streets (PLD), land-use mix, and ABCD categorisations. Firstly, in examining PLD across cases, it is clear that there is no pattern, or ideal alignment as between streets widths varying as numbers of streets increase, suggesting that a wider study may be needed to reveal an overall power law distributions of streets for Dublin, and therefore compositional complexity, at larger scales of the city. Secondly, land-use mix, as represented in the Van den Hoek triangle\(^2\) shows that urban Ballymun has the best mix. However, the compositional analysis shows that this urban site is less than 50% constructed urban form. So while the impression that urban Ballymun resembles historic urban form in land-use mix terms, (more so than Liberties) this example shows the necessity to pattern match across the analysed data, to derive a fuller picture of spatial complexity. Thirdly, ABCD analysis, using Marshall’s developed grid and hetgram\(^1\), and plotting all three cases, shows that only in one case do patterns follow established categories. So while Sandyford clearly follows a ‘C’ type ‘anywhere’ pattern, the other two cases are less easy to classify. In reviewing the pattern across cases, this could suggest that Dublin street pattern types may be more easy to categorise at a different scalar level, or by thinking differently.

\(^2\) Van Den Hoek (2008, 2009), represents the incidence of each of the uses visually as a percentage of a triangle, where each corner represents 100% of a single use. If an urban site has 33% of each use, it would appear in the centre of the triangle. See Appendix B, Evaluation protocols, Protocol 1.2.

about urban site boundaries, a topic returned to in the conclusions of this study, where abductive spatial boundaries are suggested.

**Cross-case synthesis**

As described in Chapter Three, (3.3.7, ‘Data analysis’), in cross-case synthesis, each case must be treated as a separate study, and findings are aggregated across the cases. Yin’s suggestion of creating ‘word tables’ to display data from across the cases according to some uniform framework (Yin, 2003b:134) is employed and extended in the Databox and Toolbox approaches described in Chapter Four, (Section 4.5) and illustrated in this Chapter. An argumentative interpretation is part of this approach (Yin, 2003b:137), strong, plausible and fair arguments that are supported by the data are developed in the discussion and findings section of this study. In this Chapter, the descriptions and discussions of results within, between and across the cases have shown cross-case synthesis, and the findings and conclusions further develop this aspect of data analysis. In relation to visualisation through the RGB model leading to cross-case synthesis, although a more extensive study of efficiencies of colour choice related to evaluated levels for spatial complexity could suggest other alternatives, the selected colour for high spatial complexity is red, and the selected colour for low spatial complexity is blue, and quintiles represent the high/medium, medium, and medium/low evaluated colours between. This follows a convention used in space syntax methodology, and is used for convenience in representing one of the three issues (configuration) and adapting this well established colour palette for the other two issues of spatial complexity, composition and system.

---

202 One alternative development of this approach could be to attribute one of each of the three constituent colours of the RGB Model to each of the three constituent issues of spatial complexity. However, other issues are raised by this decision, including for example the fact that the colour grey would represent any case where the three issues scored equally numbered evaluations (i.e. R=G=B), thus negating the purpose of keeping a clear visual comparison map for the evaluated sites, as is the case in space syntax methodology.
6.7 Chapter Conclusions

This Chapter answers the question of how practical urban design evaluation tools can be developed in order to evaluate the spatial complexity at the scalar level of three urban sites, by demonstrating the tools in operation, and reporting on the results. The method of adapting existing urban analysis techniques in order to focus on evaluated spatial complexity proposes three issues of analysis: compositional, configurational and system. Within these, nine separate developed evaluation tools related to criteria are demonstrated, across three distinct and contrasting spatial conditions within the city of Dublin. In this way, a ‘Toolbox’ approach to evaluating spatial complexity is demonstrated.

In Section one, in order to demonstrate that differing weightings can apply to diverse aspects of urban sites, the compositional complexity aspects of urban sites are particularly examined through a close historical reading of the first unit of study introduced here, a local character area, in a historic inner city neighbourhood, the Liberties. In Section two, the configurational complexity aspects are particularly examined in the second unit of study, a key district centre in Ballymun, in a regenerated suburban ‘New Town’. Section three particularly reports on system complexity aspects of spatial complexity of urban sites, examined through a focus on one system in the third case unit of study, the planned future neighbourhood of Carmanhall, located in Sandyford, a regional hub. In this way, questions particular to each issue are answered by reference to one particular site, with examples of the phenomena observed.

In the first urban site evaluated, the question of how important history and temporality can be to the ‘static’ evaluation of spatial complexity of an urban site is addressed.
Complexity theory suggests that the history of a complex system is important and cannot be ignored. Emergence of urban structure over time is demonstrated, and diversity of the resulting urban site is measured in urban structure/form, function mix and density, which indicates spatial complexity in these conditions. In complex system terms, the ‘many diverse components and interactions’ (De Roo et al, 2012:180) are of particular interest. The first urban site of the Liberties is evaluated as having high levels of spatial complexity. In the second urban site evaluated, the question of relationality, and links between urban centres and surrounding at local and global scales, and how this affects the evaluated spatial complexity is answered. The second urban site of urban Ballymun is evaluated as having medium levels of spatial complexity. In the third site evaluated, the question of multiscalarity, and how to evaluate spatial complexity of one urban system, as part of a large-scale regional hub, is answered. The system characteristics especially of interest are those of a complex system, including processes of spatial change, and heterogeneity of systems indicating spatial complexity. The third urban site of Carmanhall is evaluated as having low levels of spatial complexity. The fourth section of this Chapter advanced the overall argument of this study by showing how exploration, evaluation and visualization of spatial complexity of urban sites can be reported. In particular, the data analysis techniques proposed in Chapter Three are used in Chapter Six to structure the reporting of the evaluations of this study. Two of these techniques, observation of theoretic patterns, and cross-case synthesis (following analysis of individual cases) as described, formed the main driver of this Section. The ‘Toolbox’ approach to evaluating spatial complexity is expanded upon when case findings are graphically represented in a ‘Databox’, in advance of a discussion of findings both from Chapter Five (exploring spatial contexts of urban sites) and from Chapter Six (evaluating spatial complexity of urban sites) in the next Chapter.
Chapter Seven  Findings and Discussion

Introduction

The major proposition of this study is that evaluated levels of spatial complexity in urban sites are related to and influenced by compositional, configurational and system properties. Following from this claim, the findings and discussion chapter is structured to present the outputs of the exploratory examinations of the case contexts of the study, of Chapter Five, and to combine these with results of the static evaluations of the case sites, of Chapter Six. This structure leads to an integrative synthesis of findings and discussion of results. This Chapter is divided into four sections. The first section describes the structure for reporting findings. The second section reports on the results of the three case context explorations. The third section reports the results of the three case evaluations. The fourth section returns to the major proposition of the study, and discusses how visualisation captures the evaluated levels of spatial complexity of urban sites from combining explorations of case contexts and evaluations of compositional, configurational and system properties of case urban sites. The main driver of this Chapter is reporting a case study-driven exploration and evaluation of spatial complexity. This is done in advance of setting out the conclusions of the overall study in the next Chapter. This chapter is linked to the detail evaluations of the case sites in the last Chapter by the way in which it builds and expands on the data analysis of that Chapter. The overall argument of this thesis is advanced by synthesizing the data and presenting an integrative visualization approach to evaluation. In this way, subsequent evaluations of spatial complexity of urban sites for urban design can benefit from descriptions of explored, evaluated and visualised spatial complexity in this research.
7.1 Structuring findings

This section discusses the structure for reporting findings in two parts, as described in the conceptual framework (Chapter Four). This involves firstly a return to the study propositions, and secondly, a return to the assessment criteria. Each is now described in more detail, as a foreground to the detail findings.

Return to study propositions

Chapter One of this study sets out the claim that evaluated levels of spatial complexity in urban sites depend on compositional, configurational and system properties\(^{203}\). In relating the findings of this study to the major proposition, the concept of dependance is relevant. While an earlier iteration of this proposition stated that evaluated levels of spatial complexity ‘are related to and influenced by’ certain properties, the final proposition goes further in implying that the evaluated condition depends, in a causal way, on the selected properties. However, dependence is understood in this study to relate to causality in a complexity frame, and considered to be an aspect of evaluation to be treated with caution. Other factors, such as visual complexity of urban pedestrian places for example (Isaacs, 2000) could influence perceptions of spatial complexity, so dependence is considered to be a questionable aspect of evaluation in this context, related to qualitative as well as quantitative aspects of spatial complexity, and therefore open to multiple interpretations. Hence, one outcome of the study is less to claim certainty about the hard scientific findings of the evaluations of spatial complexity of urban sites, especially where these contradict more qualitative, observation based data. Therefore presentation of findings in this Chapter minimises emphasis on dependence.

\(^{203}\) The three minor propositions of this study, following from the major proposition, as described in Chapter One, ‘1.3.3 : The Research Hypothesis’, are related to composition, configuration and system aspects of urban sites, and are further described in Chapter Three, Section 3.3.2 ‘This case study design’.
between variables. Three minor propositions are also key to this study. In structuring findings and seeking to organise the order of priority of findings, the minor propositions are discussed in this Chapter within the reporting on each context and case. In this way, the minor propositions can be directly linked to data gathered for reporting and later discussion.

The first minor proposition is that evaluated levels of compositional complexity of urban sites primarily depend on three factors: morphological complexity (Conzen, 1960)(Salat, 2011), land-use mix (Van Den Hoek) and density (Berghauser Pont & Haupt). The second minor proposition is that evaluated levels of configurational complexity of urban sites primarily depend on three factors: integration (Hillier, 1998, 1999)(Bafna, 2003:616), choice (Krafta, 1997)(Marcus, 2015) and intelligibility (Hillier, 2005). The third minor proposition of this study is that evaluated levels of system complexity of urban sites primarily depend on three factors: street (pattern) network complexity (Marshall, 2005), path network complexity (Wei, 2015) (Peponis et al, 2008), (Ellis et al, 2016), and pedestrian movement network complexity (Ewing et al, 2009). The following two sections of this Chapter demonstrate that the one major proposition and three minor propositions of the study are valid.

**Return to study assessment criteria**

As described in Chapter Three, (Section 3.3.2, this case study design) in exploratory cases, unlike other case types, a purpose of the study is recommended to be stated in advance (Yin, 2003b:22). In this study the stated purpose, as outlined in Chapter One, is to define and operationalise the concept of spatial complexity for urban design theory and practice. In this study, the two assessment criteria are: firstly, does the study define
the concept of spatial complexity for urban design theory and practice? And secondly, does the study operationalise the concept of spatial complexity for urban design theory and practice? This Chapter demonstrates that these two criteria have been met in the study. The concept of spatial complexity is now defined for urban design theory and practice through demonstration of an exploratory investigation of three case contexts. Demonstration of operationalisation of the concept of spatial complexity for urban design theory and practice is through further evaluation of spatial complexity of three case sites, as described below.

A total of six data analysis techniques are employed in this study (as described in Chapter Three, Section 3.3.7): data transformation, instrument development, examining multiple levels, matrix preparation, pattern matching, and cross-case synthesis. The first four techniques are the selected ‘evaluatory’ data analysis procedures identified in the research design, following from the research strategy. Two further ‘exploratory’ data analysis procedures, pattern matching and cross-case synthesis are employed at higher level analysis of results. This section presents findings which result from the analysis of the data, and uses these six techniques to structure the resulting discussion. In presenting the findings, it is the three core issues of spatial complexity which are concentrated on, unlike the last Chapter where the description of the cases led the presentation. In this way, foregrounding evaluation of the issues and criteria of spatial complexity can demonstrate in detail both the meaning of the concept of spatial complexity, and the operationalisation of the concept for urban design theory and practice.
7.2 Exploration findings

7.2.1 Defining whole city exploration of spatial complexity

The aim of the exploration part of the study was to present data derived from a number of primary and secondary sources, working from the theoretical proposition that this aspect of urban sites can be investigated at a scalar level above that of a case site, against the background of the whole city. A visibility cluster analysis approach was adopted, as one of the six data analysis techniques of this study, data transformation. (See also, Appendix B, Evaluation Protocols, Section 4.0, ‘Note on deriving exploratory complexity maps’). Diverse data sources were combined in a compositional complexity map to illustrate explored alignments between morphological, land-use and density aspects of the city in order to identify clusters and absences of compositional complexity. Whole city level measurement of syntactic aspects of Dublin city were examined to identify high and low instances of integration, syntactic choice and intelligibility, in order to identify clusters and absences of configurational complexity. Finally, multiple data sources were combined to prepare a system complexity map of Dublin, in order to identify clusters and absences of system complexity. Then the three exploratory complexity maps, (composition, configuration and system), were overlaid to derive a spatial complexity map of the city.

7.2.2 Spatial complexity of one city

In synthesising the results of the three issues of spatial complexity for the background of Dublin, and applying equal weighting to all three, it is found firstly that the city unit has a lack of overall discernable graphical pattern in relation to explored compositional, configurational and system complexity, and is therefore assessed as manifesting low and uneven explored spatial complexity.
7.2.3 Defining contexts of the case urban sites

As part of this exploratory investigation at whole city scalar level, certain urban site contexts are identified, through visibility clustering analysis (Gal, Doytscher, 2014:526), as having high or low compositional, configurational and system complexity at whole city scalar level, indicating possible distinct and contrasting conditions of explored spatial complexity of urban sites. Three particular urban contexts were identified as manifesting distinct and contrasting spatial conditions (Liberties, Ballymun, Sandyford), and from these three further urban (case) sites were selected: Liberties character area, urban Ballymun, and Carmanhall neighbourhood.

7.2.4 Spatial complexity of the case contexts

The explored spatial complexity of the case contexts, supported by evidence of distinct and contrasting conditions of compositional, configurational and system complexity, were found to be high (Liberties), medium (Ballymun), and low (Sandyford) respectively. These are exploratory findings based on secondary data, desktop analysis and graphical and visual interpretation of city-scale mapping and numerical data.

7.2.6 Summary of findings for explorations of spatial complexity

In summary, it is found firstly that the city unit has a lack of overall discernable graphical pattern in relation to explored spatial complexity, and is therefore assessed as manifesting low and uneven explored spatial complexity. Secondly, distinct and contrasting conditions of explored spatial complexity of urban site contexts are identified through a spatial complexity mapping exercise. Thirdly, the explored spatial complexity of the case contexts were found to be high (Liberties), medium (Ballymun), and low (Sandyford) respectively.
7.2.7 Discussion of findings for explorations of spatial complexity

The lack of overall discernable graphical pattern of spatial complexity of Dublin, and low assessment, is an exploratory finding based on a combination of primary and secondary data, and a combination of quantitative and qualitative methods. So whereas economic complexity evaluations of countries rely on large amounts of quantitative data, and therefore can situate countries within rankings, and establish benchmarks of evaluated economic complexity, urban design does not yet have clear parameters and available data at whole city level. However, the emergence of ‘dashboard’ type information collection and dissemination for cities is likely to lead to more accurate data sources citywide in the near future. As regards individual urban site contexts, enough data was generally available to make exploratory findings about contexts. However, although full secondary data was not available to ascertain the system complexity of the third case context (Sandyford) at the scalar level of case context, an explored high spatial system complexity at a higher scalar level was a result, which varies from the low explored compositional and configurational complexity levels. This implies that exploratory findings which equally weight issues of spatial complexity could be verified and tested in the evaluation stage related to higher and lower scalar levels of urban sites.

In summary, there are three exploration findings. Firstly, the city unit of Dublin has a lack of overall discernable graphical pattern in relation to explored compositional, configurational and system complexity, and is therefore assessed as manifesting low and uneven explored spatial complexity. Secondly, distinct and contrasting conditions of explored spatial complexity of urban site contexts are identified through a spatial complexity mapping exercise. Thirdly, the explored spatial complexity of the case
contexts were found to be high (Liberties), medium (Ballymun), and low (Sandyford) respectively. The two objectives in exploratory mappings of spatial complexity in this study were met. Firstly, clusters of spatial complexity at city scale were visually identified, and secondly, spatial complexity aspects of urban site contexts were explored.
7.3 Evaluation findings

7.3.1 Compositional complexity of the cases

In this Section evaluation findings about compositional complexity examined through employment of a Toolbox and a Databox (in Chapter Six), are used to build on the exploratory results related to the case contexts in Chapter Five. Analysis of the compositional data in this study was undertaken in accordance with the relevant protocols developed as part of this study (Steps, 1,2,3, Appendix B).

7.3.1.1 Defining the urban sites

The primary criterion for defining the urban sites involved seeking distinct and contrasting conditions of explored spatial complexity. All three sites were identified through the exploration stage of this study, including mapping of compositional, configurational and system complexity at whole city scalar level. Other criteria for selecting case sites included clear official urban land designations, distinct urban form and morphology type of each site, (inner city, suburban and outer suburban), broadly comparable land area (size) and contrasting urban population densities in each site.

Urban morphological complexity of the cases

While the evaluated urban morphological complexity within the cases is even, between the cases it is uneven at this level of resolution. While Liberties character area is shown to have high geometrical complexity of historic plots in general terms, this high measure is not repeated in either of the other two sites. While it is to be expected that non-historic suburban and outer suburban sites would have less geometrical complexity of plots, some other measures (urban grain, blocks per hectare, junctions per sq km) are also substantially below the measures of the inner-city urban site. Across the three
cases, urban morphological complexity does have distinct and contrasting evaluations, which is important to know in seeking benchmarks for other case urban sites.

**Land-use mix of the cases**

None of the three cases has a very high evaluated land-use mix, suggesting firstly and most significantly that at least the selected inner-city urban site, but also the other two sites, could be lacking this key ingredient of high urban quality, diversity and social usage (as described in Section 4.4.2). As urban complexity is associated with high land-use mix (Talen, 2006), vitality and viability of city centres (Dept of Environment, 2012) it can be deduced that the Dublin cases are all urban sites of low urban complexity.

**Density of the cases**

None of the three cases has a very high evaluated density, suggesting most significantly that the inner city in general could be lacking this key ingredient of urban complexity (as described in Section 4.4.2). Low urban densities are associated with poor levels of walkability, (Ewing et al, 2006) and also low compactness and intensity (Lim, 2016).

**7.3.1.2 Compositional complexity of the cases**

In combining the urban morphological, land-use mix and density evaluations, and summarising as a result the compositional complexity of the cases, none of the three cases has very high evaluated levels of compositional complexity. However, as the method was suitable for distinguishing distinct and contrasting evaluated levels, results can be compared with other cases. The method is also transferable to larger or smaller urban site sizes, as units are measured per hectare, or km sq for example. The evaluations are shown to be repeatable by the carrying out of three iterations of evaluation (according to the Protocols contained in Appendix B).
7.3.1.3 **Summary of findings for compositional complexity**

The principal findings for compositional complexity of the case sites are:

- The methods of data collection, analysis, and transformation leading to evaluating urban morphological complexity, land-use mix and density are suitable, transferable and repeatable for other urban sites, and are compatible with already established methods in evaluating the separate criteria, and therefore results are comparable across urban scales and sites.

- In each case, there is a theoretic pattern demonstrated, whereby evaluated levels of compositional complexity follow a prior stated theory of spatial complexity, (See Section 3.3.2 This case study design, Pg 124), and the relationships between morphological complexity, land-use mix and density, and between high, medium and low levels of compositional complexity are demonstrated.

- There are strong correlations between criteria evaluated and differences in evaluated levels of compositional complexity. For example, the case of Liberties has higher urban morphological complexity, better land-use mix and higher density than either of the other two cases, and the relationship between these criteria follows in the other two cases.

- The matrix preparation, pattern matching, and visualisation of results demonstrates interrelationships of issues and criteria of compositional complexity within, between and across three cases.
• The demonstrated relations between the three selected criteria of morphological complexity, land-use mix and density, (together comprising the issue of compositional complexity) shows the validity of one of the three minor propositions of the study, that evaluated levels of compositional complexity of urban sites primarily depend on three factors: morphological complexity, land-use mix and density. The explanatory value of these selected measures is therefore demonstrated.

7.3.1.4 Discussion of findings for compositional complexity

Five points summarise the compositional complexity evaluation findings of this study. Firstly, it is demonstrated that urban morphological analysis methods adopted in this study are useful for evaluating urban sites, and demonstrate practice-led use of historico-geographical methods from the literature. Combining these with ‘metrics’ of urban form evaluation improves on single method approaches by developing a richer measurement format which combines strengths of quantitative and qualitative methods of urban morphological analysis.

Secondly, in the three urban sites, it is shown that urban morphological analysis methods can be combined with more quantitative analysis methods like evaluations of land-use mix and density, in relation to evaluation of selected compositional criteria of urban sites. These three primary variables of establishing compositional complexity, as proposed in this study, are a form of instrument development, one of the six data analysis techniques employed in this study. They are shown to be workable criteria from which benchmarks could be established by means of further study of cases. Gil’s proposition (Section 4.3) that multi-criteria analysis (MCA) is regarded as the preferred
method for evaluation at the level of the urban sites, is supported by the findings of this study, and therefore the next step could be the derivation of benchmarks as ‘target values to achieve specific quality levels’ (Gil, 2013:313) of spatial complexity of urban sites.

Thirdly, compositional complexity evaluation findings of this study develop research which links compositional complexity to urban (Krafta, 1997)(Marshall, 2005)(Marcus, Legeby, 2012) and spatial (Hillier, 1997, 1998) (Batty, 2011:7) complexity, and specifically adds useful case studies at urban site scalar level to compare with prior measures in this regard.

As a fourth finding, this study extends current understandings for Dublin of land use dynamics at neighbourhood level related to complexity (Barredo, 2004). Land-use and density of Dublin has been examined at neighbourhood level by Nedovic-Budic (2016). In this study, findings from previous studies are confirmed, extended and visualized in finer scalar and three-dimensional detail than previous studies. For example, inner city compositional complexity is examined in a new way, by focusing attention on plots and urban blocks in geometric terms, a technique not previously employed to assess morphological complexity of Dublin.

A fifth finding is that this study confirms research which links compositional complexity to urban environmental benefits. Lim (2016) for example, associates emergent urban properties of resilience, including diversity, networks, and increased numbers of agents through density and proximity, to urban areas that have developed incrementally over time, such as European medieval cities (Lim, 2016:98). Complexity
and temporality are also linked by this result. The findings for the Liberties support this. In this way, compositional complexity is linked to the benefits of spatial complexity, in a wider theoretic frame.

### 7.3.2 Configurational complexity of the cases

#### 7.3.2.1 Analysis of the configurational data

Analysis of the configurational data in this study was undertaken in accordance with the relevant protocols developed as part of this study (Steps, 4,5,6, Appendix B), based on a dataset referred to throughout this study as the ‘Dublin Axial Map 2012’\(^{205}\), supplied to the researcher in May 2014 by Space Syntax Ltd. London. In general terms, overall comparison shows a city of very low configurational complexity, as Dublin has the lowest rating of all 48 cities in six indicators: number of axial lines, connectivity, integration (global, local, integration core), syntactic choice (overall and local) and intelligibility. These are examined in more detail in Appendix E, ‘Syntactic Analysis of Dublin’, (Section 1.0).

**Integration of the cases**

All three urban case sites evaluated were found to have distinct and contrasting levels of syntactic integration. However, as described in the relevant Appendix, (Appendix E, ‘Syntactic Analysis of Dublin’) According the r3 Local Integration Map [HH], Dublin appears to have only a small number of local or neighbourhood level integrated cores, meaning places of particular importance for local users of the city, (or ‘centres’) and which connect to other places well in configurational terms. This result confirms against the link between (low) relationality and (low) complexity.

**‘Choice’ measure of the cases**

\(^{205}\) The supplied dataset is known to Space Syntax Ltd. as the Dublin Spatial Network Model.
In Chapter Five, two measures of choice were described for the whole city scale. Firstly, a ‘global’ choice map was prepared, and from this map it is evident that only one of the three urban case sites, Sandyford, appears as a distinct area, surrounded by ‘natural boundaries’ (Peponis et al, 1990). However, at more local radii, other spatial analysis is more specific. From applying a local radius of 1km to the syntactic choice measure, a map indicates the Liberties overall emerging graphically as the most concentrated ‘hotspot’ of local choice in the entire city, possible indicating presence of public life in the area, as deduced for other areas using this measure (Vaughan et al, 2009:476). This finding suggests a configurationally complex urban site. In Ballymun, the suburb is seen in overall terms emerging graphically as a medium level cluster of local choice, possible indicating presence of public life in the area. However, the analysis of the medium or area scale suggests that the environmental ‘regeneration benefit’ on the local choice measure of urban Ballymun area does not seem to have occurred in the urban site or catchment, according to this analysis. In Carmanhall, the analysis indicates that the area has very few ‘through-movement’ route choices within the short metric distances normally associated with well internally connected pedestrian areas, and therefore that the low choice measure at global and 1km radius for the Sandyford and Carmanhall area suggests a configurationally non-complex urban site. In summary, the evaluated choice of the three cases were found to be high (Liberties), medium (Ballymun), and low (Sandyford) respectively.

**Intelligibility of the cases**

In the Liberties character area, the intelligibility analysis indicates that the area is better connected and more integrated in city terms than most other locations in the city, as the cluster of selected axial lines appear in the top right part of the scattergram, which suggests a high intelligibility and therefore a configurationally complex urban site. In
urban Ballymun when 28 axial lines are highlighted, their axial mapping indicates that the area is not well connected or integrated in city terms, as the cluster of selected axial lines appear in the lower middle part of the scattergram, which indicates a low connectivity, medium global integration, and therefore medium intelligibility. Together, these three indicators signify medium configurational complexity of the urban site. The intelligibility analysis of the site of Carmanhall indicates that the area is locally well connected and well integrated in city terms, as the cluster of selected axial lines appear towards the middle of the scattergram, which suggests a medium intelligibility and therefore configurationally a potentially complex urban site. Hillier claimed that high intelligibility can predict high public space occupancy, and has tested this in studies in London (Hillier et al, 1987). In overall terms, given prior claims that intelligible places are also well connected (locally), and that good wayfinding environments are also intelligible, it is concluded that two of the three urban sites evaluated (Ballymun and Carmanhall) may have low public space occupancy, be medium or poor wayfinding environments, and have poor local connections.

7.3.2.2 Configurational complexity of the cases

Taking together the three indicators of configurational complexity for the three urban sites, it is shown that distinct and contrasting levels of configurational complexity are evident across multiple scalar levels, including the primary one evaluated, of the urban sites themselves.

---

206 However, Read (2005) suggests that in conditions where mean connectivity becomes low, occupancy cannot be predicted by intelligibility, according to his results for the Dutch city.

207 See Chapter Four, Section 4.4.2, ‘Configurational criteria of spatial complexity’: ‘an intelligible system is one in which well-connected spaces also tend to be well integrated spaces’ (Hillier, 1999: 194), and ‘key elements of a good wayfinding environment are structurally (that is, configurationally) inherent to it’ (Bafna, 2003:28).
7.3.2.3 Summary of findings for configurational complexity

The principal findings for configurational complexity of the case sites are:

- The methods of data analysis and transformation leading to integration, choice and intelligibility measures are suitable, transferable and repeatable for evaluating configurational complexity of the urban sites, and are compatible with already established methods in evaluating the separate criteria, and therefore results are comparable across urban scales and sites.

- In each of the three cases, a theoretic pattern is demonstrated, whereby evaluated levels of configurational complexity follow a prior stated theory of spatial complexity, and the relationships between integration, choice and intelligibility, and between high, medium and low levels of configurational complexity are demonstrated.

- The examining of multiple levels, matrix preparation, pattern matching, and visualisation of results demonstrates interrelationships of issues and criteria of configurational complexity within, between and across three cases. For example, relations between global integration and connectivity of urban sites are expressed through intelligibility measures, and can be compared within, between and across the three sites.

- The demonstrated relations between the three selected criteria of configurational complexity, (together comprising the issue of configurational complexity) shows the validity of one of the three minor propositions of the study, that evaluated levels of configurational complexity of urban sites primarily depend on three factors: integration, choice and intelligibility. The explanatory value of these selected measures is therefore demonstrated.
• Functional benefits of optimal configurational complexity already demonstrated in the literature (Krafta, 1996), (Krafta, 1997), (Law, 2013) are supported by results of this study, which finds higher land-use mix and density in configurationally complex urban sites.

7.3.2.4 Discussion of findings for configurational complexity

The findings resulting from evaluations of configurational complexity of three urban sites firstly demonstrate the effectiveness of space syntax analysis methods in relation to evaluation of selected configurational and relational criteria of urban sites, like integration, choice and intelligibility. However, limitations in the data (See Appendix E, ‘Limitations in the data’), and the particular scope of syntactical analysis, which has been critiqued (See Section 4.3.1.2, ‘Configurational (space syntax) theory and methods’) means that a two-dimensional, topological, mathematics and graph-theory based analysis method is only partly suitable to evaluate spatial complexity of urban sites of distinct and contrasting conditions. However, although suitability is reduced by limitations in the dataset as described, this has not had a major impact, as local levels of syntactic configuration are concentrated on in evaluating urban sites, and the limitations primarily affect the global scales. Transferability of the method is evidenced by the fact that many researchers already use these methods to study urban sites (Ye, 2013)(Marcus, 2016), so these findings can be compared directly. The evaluations are shown to be repeatable by the carrying out of three iterations of evaluation on the separate sites (according to the Protocols contained in Appendix B). In particular the claim that integration is best understood for walkable urban areas at low radii (Al-Sayed, 2014, 25) is shown in the case of Liberties. The claim that syntactic choice calibrated at a metric radius of 400 m metric can indicate presence or absence of distinct
urban sites, surrounded by ‘natural boundaries’ (Peponis et al, 1990) is supported in the case of Carmanhall. Findings of distinct and contrasting intelligibility levels of different urban site types, of inner city (Read, 2005), suburban (Vaughan et al, 2010), and outer suburban (Serra et al, 2012) are confirmed in this study and new cases are presented for comparison. In particular, Serra’s findings of (Serra et al, 2012) clear ‘intelligibility inequalities’ between study areas of Oporto are repeated for Dublin in this study. Other space syntax papers which use mixed methods approaches to understanding urban form, syntactic relations and urbanity (Van Nes, 2012)(Ye, 2013) are supported by findings of this study on urban sites. In particular, the finding that different configurational and spatial analysis tools are suitable for different neighbourhood patterns (Berghauser Pont, Marcus, 2015) is reinforced in this study. The link between relationality and spatial complexity is also demonstrated in the way highly spatially complex urban sites are found to be also highly spatially relational.

7.3.3 System complexity of the cases

7.3.3.1 Representing the system
This issue of system complexity of urban sites, in relation to evaluating spatial complexity for urban analysis and design, has been represented in this study by three criteria which capture aspects of the locations unaccounted for by use of the other selected analysis tools. The findings in this section therefore uncover new characteristics of the sites, to be weighed equally alongside the other aspects. However, the fact that the urban system is in fact ‘unknowable’ because of large number of agents, is also acknowledged in this study.

208 In particular, Serra et al found sharp decreases in intelligibility of Oporto during periods of most intense growth of the city over time, which has parallels in fast changing edges of Dublin like Sandyford (Serra et al, 2012:14).
Street network complexity of the cases

The street network complexity analysis of Liberties character area indicates that the area is relatively complex, which suggests a spatially complex urban site in system terms. This finding would support Gudmundsson et al’s (2013) finding that streets in older denser parts of cities are more tightly ordered and form denser networks, than in outer and more recent parts (Gudmundsson et al, 2013:1). Findings for this criterion in urban Ballymun suggest a relatively high level of street network complexity of the Main Street area, as would be expected in a regenerated civic centre. The evaluated street network complexity of the Carmanhall area is a low rating in relative terms when compared with international examples, and would rank close to the lowest quarter of international sites tested by Marshall (2005).

Path network complexity of the cases

The mapped path network for the Liberties shows a large, diverse network with a high density of paths across the urban site, through a measure of metric reach, indicating a high density and complexity of the network. This measure indicates a medium density and complexity of the path network of Urban Ballymun, relative to Liberties and Sandyford. The mapped path network for Carmanhall shows a sparse, grid-like network with a very low density of paths across the urban site, which indicates a low density and low complexity of the network.

Pedestrian movement network complexity of the cases

The pedestrian network complexity of Liberties as evaluated using both gate counts and timelapse video suggests a high level of system complexity, which in turn suggests high spatial complexity in the local system. The site of urban Ballymun compares poorly with pedestrian network complexity of the commercial heart of Dublin, having low relative numbers, few clusters of activity and low diversity of pedestrian type (see
Appendix D). Carmanhall also compares poorly with pedestrian network complexity of the commercial heart of Dublin. In this urban site, relative complexity of the pedestrian movement network is revealed through gate counts by evidence of small size (low total number of pedestrians observed), clusters (low spatial concentrations of activity), and type diversity (mostly adults, few kids and no tourists).

7.3.3.2 System complexity of the cases

Systems evaluation results for the Liberties character area show that large numbers of elements, large size of systems and sufficient evidence of complex spatial relations has been demonstrated. In these terms, high evaluated system complexity of the urban site suggests high spatial complexity. The main finding from the analysis of urban Ballymun was that while it has high street network complexity, it also has medium path network complexity and a low level of (pedestrian network) system complexity, and therefore can be regarded as a site of medium to low system complexity in overall terms. In Carmanhall, a low level of system complexity, as suggested by the analysis of street network complexity (Patterns), path network complexity (Paths), and movement network complexity (People) is the overall finding of this evaluation. In particular, considering and comparing pedestrian movement network complexity, the data suggests a site of low complexity.
7.3.3.3 Summary of findings for system complexity

The principal findings for system complexity of the case sites are:

- In each of the three cases, a theoretic pattern is demonstrated, whereby evaluated levels of system complexity follow a prior stated theory of spatial complexity, and the relationships between street network complexity, path network complexity and (pedestrian network) system complexity, and between high, medium and low levels of evaluated system complexity are demonstrated.

- There are relatively strong correlations between criteria evaluated and differences in evaluated levels of system complexity in the three sites. For example, the case of Liberties has medium to high street network complexity, high metric reach and high pedestrian movement when compared to the other two cases, and the strong cor relational relationship between these criteria follows in the other two cases.

- This study shows that system complexity measures of urban sites can be observed across temporal ranges. For example, the examining and visualising of multiple levels of footfall data, including 5 minute, hourly, weekly, and annual counts, graphically illustrates how system complexity of urban sites is a temporal as well as a spatial measure. The finding builds on studies related both to questions of ‘sensory complexity’ (Mehta, 2014) or a ‘moving’ version of a proposed coefficient of (environmental) complexity (Owens, 1995), by showing that measurement over time of system complexity could enhance understandings of neighbourhood form and pedestrian life (the former) or evaluating public space (the latter).
• Linkages of data for specific urban sites allows reinforcement of findings of other studies, which associate urban and environmental complexity for example with pedestrian areas (Rapoport, 1987)(Owens, 1993), but do not provide a spatial evidence base, which this study does.

• The demonstrated relations between the three selected criteria of street network complexity, path network complexity and (pedestrian network) system complexity, (together comprising the issue of system complexity) shows the validity of one of the three minor propositions of the study, that evaluated levels of system complexity of urban sites primarily depend on three factors: street network complexity, path network complexity and (pedestrian network) system complexity. The explanatory value of these selected measures is therefore demonstrated.

7.3.3.4 Discussion of findings for system complexity

The findings resulting from evaluations of system complexity of three urban sites support prior studies of system aspects of neighbourhood level analysis. For example, the finding that high street pattern, path and pedestrian movement complexity occurs in the inner city, (the finding for Liberties) supports and extends D’Arcy’s (2013a) (2013b) studies on walkability which find that inner city areas of Dublin have, in general, higher walkability than suburban areas, by visualising findings across temporal range for specific urban sites at neighbourhood scale. Development of the methods used in this study to evaluate system complexity of three urban sites involved a form of instrument development, one of the six data analysis techniques employed in this study. This study has confirmed, with new multiscalar example cases, that street network complexity analysis methods can demonstrate distinct and contrasting characteristics of
urban sites (Marshall, 2005). Instrument development in this situation involved undertaking the analysis at two scalar levels simultaneously. Path network complexity analysis in this study has shown through different metric reach measures of urban sites that these are helpful to strengthen the claim that the spatial structure of urban areas plays a significant role in the distribution of pedestrian movement on a street-by-street basis (Peponis et al, 2011:137). In this study higher metric reaches are associated with higher pedestrian footfall counts. As discussed in Section 5.2.3.1, while Dublin in overall terms has been considered a walkable city, (D'Arcy, 2013) the physical characteristics of the pedestrian system, or walking path infrastructure of Dublin has not been previously studied at urban site scalar level. The finding that evaluated system complexity of the case sites is medium and low in suburban and outer suburban sites respectively extend understandings of this aspect of urban sites in Dublin.

If Marcus & Legeby’s claim that ‘co-presence’\textsuperscript{209} in public space is a prerequisite for the presence of a complex (spatial and urban) system (Marcus & Legeby, 2012:6), it is likely that lack of pedestrian network complexity in particular could indicate a similar lack of spatial and urban complexity for the case urban sites in Dublin. This applies in particular to the suburban and outer suburban cases. Given that Ballymun is the most significant publicly financed urban regeneration project in Ireland, low evaluated system complexity, suggesting low levels of urban and public life, seems to indicate a failure of this aspect of the project up to this point. Carmanhall, as a future neighbourhood in a regional hub, could be expected to have a lower value, but the results indicate a practically non-existent public and urban life, which in turn could indicate the low priority of this aspect in formal planning for the urban site. It is

\textsuperscript{209} Legeby separately defines ‘co-presence’ as ‘sharing space with others, which does not necessarily imply focused interaction’ (Legeby, 2012:i), and the separate paper quoted above describes the condition of co-presence as ‘-a necessary but not sufficient condition- for complex systems to develop and be sustained’(Marcus & Legeby, 2012:6).
especially in the multiscalar evaluations that these aspects become clear, and the link between spatial complexity and multiscalarity is demonstrated in this study.

7.3.4 Spatial complexity of the cases

This section summarises findings across three urban sites related to evaluated spatial complexity of the cases. While some spatial indicators of the complexity level at the ‘whole city scale’ have been explored in earlier findings, it is in detail cases that levels of spatial complexity can be demonstrated for urban design practice, from results of the evaluations of the case sites.

7.3.4.1 Representing and visualising spatial complexity

In this study it is found that the devices of Toolbox and Databox, as introduced in Chapter Four, and demonstrated in Chapter Six, enhance representations of evaluations of urban sites. Batty (Batty et al, 2000) discusses communicating urban design to planners and decision-makers, showing that visualization is key to the process of ‘survey-analysis-plan’\(^{210}\), including evaluation of alternative proposals against criteria emanating from an initial set of goals. However, the positive impacts of digital technologies on visualization of evaluation, expected by Batty et al in 2000, have arguably failed to materialise a decade and a half later. For example in plan-making, especially at the level of development control and implementation, urban design is still led by two dimensional, static zoning plans. This study tests visualisation approaches for practice, including toolbox and databox, spider plots, and other visualisations which

\(^{210}\) Batty describes the ‘survey-analysis-plan’ techniques as the traditional sequence in town planning, originally accredited to one of the fathers of town planning, Patrick Geddes (Batty et al, 2000:1). Although regarded as still ‘a powerful doctrine’ in contemporary schools of planning, (and urban design), it is seen to have been replaced in turn by a system approach, synoptic methods and even, most recently, a complexity/matrix approach to design process Çalışkan O. (2012) Design thinking in urbanism: Learning from the designers. Urban Design International 17: 272-296.
could in future form ‘dashboard’ type indicators of changing spatial complexity of urban sites.

**7.3.4.2 Spatial complexity of the cases**

Taken together with the earlier compositional complexity evaluation (between a high and medium level), and the overall high configurational complexity evaluated, a high spatial complexity level for the Liberties character area is confirmed by considering the third issue of spatial complexity evaluated, the system aspect of this urban site, which is also high. In urban Ballymun, considered alongside the compositional complexity evaluation (a medium level), and the overall medium configurational complexity evaluated, a medium spatial complexity level for the area is confirmed by considering the third issue of spatial complexity evaluated, the system aspect of this urban site, which is evaluated as low. In Carmanhall, all three of the indicators have low evaluations. Taken together with the earlier compositional complexity evaluation (low level), and the overall low configurational complexity evaluated, a low spatial complexity level for the neighbourhood of Carmanhall is confirmed by considering the third issue of spatial complexity evaluated, the system aspect of this urban site, which is also low at urban site scalar level of resolution.

**Spatial complexity within the cases**

The findings for the individual cases in relation to evaluated spatial complexity, although derived from nine equally weighted criteria, do not reflect inconsistencies within the cases themselves. So for example, while the overall evaluation of Liberties is high, the compositional complexity is evaluated between a high and medium level. In Ballymun, while both composition and configuration are evaluated as medium, system complexity is low. And in Carmanhall, although all three of the system indicators have
low evaluations, a high system complexity is suggested for a scalar level above that of
the urban site. Meanwhile, at a scalar level below that of the urban site, some isolated
plots within the urban site have starkly different readings to the evaluated spatial state.
In this study, it is found that within the cases, inconsistencies across evaluation can be
better understood through analysis at other scalar levels around the urban site, both
above and below.

**Linkages between the cases**

The concept of linkages between cases, in complexity terms, has been described in
Chapter Four, (Section 4.5.2, ‘Urban evaluation visualization methods’). In summary, it
is held that: ‘the interaction among constituents of the system, and the interaction
between the system and its environment, are of such a nature that the system as a whole
cannot be fully understood simply by analysing (only) its components’ (Cilliers, 1998,
page viii). It is found in this study that visualisation of evaluation is key to making
linkages between urban sites (See for example, Fig 6-61, and Appendix F, Vol. 2).
These represent overlaps between criteria and issues, and connections between the three
aspects of spatial complexity evaluated: compositional, configurational and system. So
for example, links can be made between extreme juxtapositions of density in single
plots in Carmanhall and extreme global integration and high configurational complexity
at city level, as manifested in Sandyford on the overall axial map.

**Spatial complexity across the cases**

This study of multiple urban sites considers that in complexity terms, a strictly
hierarchical structure for analysis has only a partial usefulness, as units of observation
are considered to constitute a ‘constellation’, as opposed to lower and higher layers or
levels of importance or focus, and need to be continuously regarded within spatial
nestings (Dekay, 2012) and systems (Wilson, 2002). So while the distinct and
contrasting evaluated levels of spatial complexity can be seen as hierarchical levels (inner city high, etc) it is within and between, as well as across the cases, and in the detail of three issues and nine criteria of spatial complexity, explored at whole-city and case context scales, and evaluated at case level, that the full picture emerges. In particular, it is through visualisation that the smallest indivisible unit (the pedestrian) and the largest scalar unit considered here (the whole-city) can be regarded and understood in a temporal, relational and multiscalar context.

7.3.4.3 Summary of findings for evaluations of spatial complexity

The principal findings for spatial complexity of the case sites are:

- In each of the three cases, a theoretic pattern is demonstrated, whereby evaluated levels of spatial complexity follow a prior stated theory of spatial complexity, and the relationships between composition, configuration and system complexity, and between high, medium and low evaluated levels of spatial complexity are demonstrated.

- Findings of previous studies linking compositional complexity to historic inner cities, (Conzen, 1961) and a lack of compositional complexity to suburban and outer suburban sites (Scheer, 2001, 2003), are supported and extended in the findings for spatial complexity of the case sites. Specifically, for example, urban morphological complexity metrics, such as quantities of urban blocks, plots, and junctions show distinct and contrasting results for inner city, suburban and outer suburban sites. Particular land-use mix measures and density analysis in this study confirms associations made by other studies between land-use mix measures (Hoek, Berghauser Pont), density (Tussa, 2014)(Porqueddu, 2015) and
complexity. In this study, those previous findings are supplemented and become part of a broader platform of evaluation.

- As previous mixed methods studies have shown (Van Nes, 2012, Ye, 2013, Berghauser Pont & Marcus, 2016), and this study’s findings for spatial complexity of the cases confirm, in overall terms syntactic analysis methods need to be combined with more qualitative and spatial understandings of cities.

- System complexity findings for spatial complexity of the case sites describe examples of complex and less complex street pattern complexity for example, showing that quantitative measures can distinguish between higher spatial complexity (for example, Liberties) and lower (for example Carmanhall).

- Matrix preparation, pattern matching, and visualisation of results demonstrates interrelationships of compositional and configurational issues and criteria of system complexity within, between and across three cases.

7.3.4.4 Discussion of findings for evaluations of spatial complexity of the cases

As discussed in Chapter Two, (2.2.5 ‘Definition of spatial complexity adopted for this study’), although Krafta has discussed configurational complexity and developed one definition of spatial complexity, (‘the spatial component of urban complexity’) (Krafta, 1997:2) he does not develop the concept211. The findings of this study for spatial complexity of the cases develop Krafta’s theoretical understandings of this concept for urban design, and in particular for the scalar level of urban sites or neighbourhoods. So

211 Although Krafta does not define urban complexity, and he does confine his disciplinary scope to urban configurational studies (Krafta, 1997:1), he does agree that urban designers and urban morphologists regard complexity as an urban property: ‘related to at least one of the concepts of variety, scale (size), growth, intensity, continuity, density. Hence complexity could be understood as a particular state of urban form/life, in which one or more of those aspects are present in a great extent, or beyond a given threshold’ (Krafta, 1997:1)
while Krafka supplied a very specific definition of the concept, (as described in Chapters One and Two) he does not develop this for urban sites or for urban design. Others discuss quite hard-scientific and global scalar understandings in relation to the city (Hillier, 1997, 1998),(Batty, 2011, 2013)(Medda et al., 2009) and also without specifically defining the concept. Therefore, a theoretic pattern, demonstrated in this study for the cases, deepens the concept of spatial complexity for urban design.

Findings for spatial complexity of the cases related to compositional complexity confirm in overall terms some results of other studies. For example, Tussa (2014) found juxtapositions and abrupt variations of density outside of city centres and resulting poor urban conditions, also recorded in this study. Porqueddu’s (2015) study of ‘intensity without density’, and its concentration on the lack of complexity of low density places is also supported by this study, which finds medium and low spatial complexity conditions in two of the three case sites, Ballymun and Carmanhall.

Findings for spatial complexity of the cases confirm in overall terms that syntactic analysis methods need to be combined with more qualitative and spatial understandings of cities, as well as fieldwork on the ground. For example, at ‘whole-city’ scalar level, the mappings available for Dublin fail to record important features of the integration structure of the city, like bridges and tunnels (See Appendix E, ‘Limitations of the dataset’).

Findings for spatial complexity of the cases in system terms extend, with new case studies, understandings of system complexity of urban sites. One example of this is

street network complexity measurement. So while Marshall’s cases (2005) are primarily UK based examples of complex and less complex street pattern complexity, in this study Irish examples are added. In this sense, it is found that primarily medium or low complexity street pattern complexity is evident across the three cases, although the scalar resolution is important to describe clearly, and the street pattern complexity measure could change with more or less specificity of case size.

In considering the three issues of spatial complexity (composition, configuration and system) together, the findings for urban sites in Dublin can be related to a number of prior similar studies. The claim of Van Nes et al that there are correlations between degrees of mix of function (land-use mix), density and integration at the scalar level of neighbourhoods \(^{213}\) (Van Nes, Berghauser Pont, 2012) is supported by the findings in this study. The findings for urban sites in Dublin also confirm previous justification in the literature for different spatial analysis tools for different neighbourhood patterns (Berghauser Pont, Marcus, 2015). The Berghauser Pont study compares ABCD measures of street networks with syntactic measures and then overlays pedestrian footfall readings for three neighbourhoods in Stockholm. The previous finding that with measures of density and syntactic choice (at 1km metric radius) pedestrian density and pedestrian distribution respectively (Berghauser Pont, Marcus, 2015) can be predicted is repeated in this study, and visualised in three dimensions in a cross scalar way.

The findings on compositional complexity of this study show that mixed methods enhance this type of analysis. The findings can be particularly compared with Oliveira’s study of Oporto, (Oliveira, 2013) also (Van Nes, Berghauser Pont, 2012) (Ye, 2013)

\(^{213}\) Even though the neighbourhood concept is not easy to apply in this study (as stated in Chapter Three, Section 3.3.2, ‘This case study design’) for comparison with international examples this scalar unit applies.
and (Berghauser Pont, Marcus, 2015) each of which engaged with some or all of the same tools as this study to examine composition and urban form. Oliveira’s study of Oporto for example, showed that presence (quantity) of morphological plan sub-units could be combined with other criteria such as land-use (Oliveira, 2015:77) to evaluate urban morphological complexity, as also found in this study.

The evidence provided by (Ye, 2013) related to spatial flaws of new towns combines Spacematrix, space syntax and mixed use index, and finds high levels of street network integration, land-use mix and building density in old centres, while new towns lack these qualities of vibrant centres. This study of urban sites in Dublin confirms previous (Ye, 2013) findings related to spatial flaws of new towns, and provide more case examples in a very different cultural context. In summary, the findings for spatial complexity of the cases also respond to Karimi’s and others call for connecting evidence-based methods related to urban design by developing methods which are easily applicable by following short Protocols (in Appendix B).
7.4 Visualisation findings

7.4.1 Defining visualisation of spatial complexity

The reasons to employ visualisation in this study involve benefits to urban designers in practice including: to stimulate the urban design process, to bring visual clarity to quantitative assessment, to allow for qualitative interpretation by a wide community around evaluation, to allow formal measurement and informal interpretation of results to be combined, and to allow the involvement of a wider group of stakeholders around evaluation (See Section 4.5.2, ‘Urban evaluation visualization methods’). In Chapter Four, Figure 4-14 describes the method of employing both the Toolbox and Databox in the evaluation of an urban site. Synthesis, in Chapter Six, involves visual representations of spatial complexity levels for both contexts and urban sites evaluated in Chapters Five and Six. Nedovic-Budic suggests that a three-dimensional measure of aspects of urban form, like land-use mix, would be difficult to achieve (Nedovic-Budic et al, 2016:161) and therefore does not present this aspect in the study of urban form of Dublin, but Norton has shown that land-use mix in two urban sites in Dublin can be captured over multiple levels (Norton, 2016) and this study goes further, and shows that this aspect can also be represented and visualised in three dimensions, as well as compared with other urban sites. Other ways in which this study extends methods of visualising evaluation of urban sites are described in Appendix F (Visualising Spatial Complexity, Introduction).

Visualisation findings for one city

Patches of spatial complexity can be clearly outlined for certain areas of the city, and some urban sites, (like inner city) but in other less mophologically clear urban sites,
where data is less available, contexts, urban sites and embedded cases are harder to evaluate. For example, in the Sandyford context, and the Carmanhall urban site, visualisations of scalar resolution vary from pockets of extreme spatial complexity in single buildings for example, to a possible spatial chaos\textsuperscript{214} at the regional scale, manifested in the extreme juxtapositions of composition, configuration and system, evident at urban site scale, but also at higher and lower scales.

**Visualisation findings for the case contexts**

Case context findings, in relation to visualisation, suggest that boundaries of urban sites need to be treated as abductive outlines rather than fixed limits in relation to evaluations of spatial complexity. In visualising, for example, the many competing boundary outlines for the Liberties, it is clear that official edges can be politically or locally ‘driven’ to satisfy immediate goals, rather than broadly agreed and dynamic, which could allow for richer understandings of the boundary conditions of urban sites. In this respect, Bostonography.com, an online mapping exercise which allows city neighbourhood dwellers in Boston to draw their own neighbourhood outlines, is interesting as a way to counter overly-fixed official case boundaries for evaluation. (See also Appendix F, Visualising Spatial Complexity, ‘Visualising Case Contexts’).

**Visualisation findings for the case urban sites**

It is found in this study that ‘evening out’ of quantitative and qualitative data related to spatial complexity of urban sites enhances information communication, while still

\textsuperscript{214} Henri Lefebvre’s description of ‘spatial chaos’ is part of his wider argument about the production of space, including this key section: “The combined result of a very strong political hegemony, a surge in the forces of production, and an inadequate control of markets, is a spatial chaos experienced at a parochial scale just as on a worldwide scale… Might not the spatial chaos engendered by capitalism, despite the power and rationality of the state, turn out to be the systems Achilles’ heel?” Lefebvre H. (1991) The Production of Space, Oxford: Blackwell Publishing.
retaining units of data separate to overall visualised results. This responds to Gil’s call for contemporary tools to evaluate urban design to include indicators that ‘make the consequences of design actions directly observable and understood by the stakeholders to facilitate the interaction and iteration processes’ (Gil, 2013:314).

7.4.2 Summary of findings for visualisation of spatial complexity

In summary, the principal findings for visualisation of spatial complexity of the case sites are:

- Patches of spatial complexity can be clearly outlined for only certain areas of the city in visualisation terms
- Case contexts and boundaries of urban sites need to be treated as abductive outlines in visualisation rather than as fixed limits in relation to evaluations of spatial complexity
- ‘Evening out’ of quantitative and qualitative data related to spatial complexity of urban sites enhances information communication, while still retaining units of data separate to overall visualised results.

7.4.3 Discussion of findings for visualisation of spatial complexity

In relation to visualisation of spatial complexity of multiple cases, the most significant aspect of each case is concentrated on in visualising this research. As regards evaluated levels of spatial complexity of urban sites, the most significant aspect of the Liberties character area case is the rich historical compositional complexity, which emerged over time, the temporal connection to complexity. The most significant aspect of the Urban Ballymun case is the medium configurational complexity of this regenerated suburb, which it is suggested is a result of a part-realised regeneration project in a suburban
‘New Town’, and shows the connections between relations and complexity. The most significant aspect of the Carmanhall neighbourhood case is the low system complexity at the urban site scalar level in this otherwise highly pivotal regional hub location, which is highly spatially complex at lower and larger scales, showing the importance of holding in mind an overall multiscalar frame of analysis.

As described above, certain relevant other studies (Oliveira, 2013)(Van Nes, Berghauser Pont, 2012) (Ye, 2013) and (Berghauser Pont, Marcus, 2015) combine a mixed methods approach to analysing compositional complexity, and most use a raster grid cell approach to visualisation, but no standardised approach or agreed level of resolution for presenting results is evident. This study improves on previously diverse methods to study compositional and other aspects of urban form, sites and spatial complexity, by showing a standardised approach to visualisation (for example, pixel size per resolution, 3d databox views, allowance for temporal reading) based on a review of these and other prior studies.

This study on explored and evaluated levels of spatial complexity of urban sites seeks to build on previous studies which concentrated on single scales, (such as Nedovic-Budic, 2016) by mapping and visualising their results in an integrated, multi-scalar way. Thus, context as well as the urban sites themselves are visualised and mapped. It is found that the adopted visualisation method can allow previous studies (at multiple scales) to be collected into a spatial complexity frame, as well as incorporate future results of varying scales of spatial research about Dublin. The concept of spatial complexity in this meaning implies exploration and evaluation at more than one scale, as a necessary requirement, in line with complexity theories which seek multi-scalar understandings of
phenomena. As described in Chapter Two, at the scale of the case, a three-dimensional aspect is included in visualisation in this study, as this is an important aspect of urban design readings of urban sites. This helps to distinguish the urban design focus of this study from a planning research approach, which would concentrate more on policy, zoning and other normative and positivist readings of urban sites (Davoudi, 2012).

In each case in this study, it is found that comparable visualisation is possible between sites, and that this can be related to an overall colour ‘index’ of spatial complexity, which could be related to any scalar level, and could be visualised in many dimensions. Hillier claims that space syntax expresses spatial complexity in ways which access it to design intuition, ‘for example by the simple procedure of using colours to represent patterns of numbers’ (Hillier, 2005:105), and this study extends this benefit across other urban analysis methods in an integrative approach. (See also Volume Two, Appendix, F, ‘Colour and visualisation’).

In visualising findings of this study, there is also an awareness that ‘static’ evaluation can form a part of an ongoing evaluation process over time. Hence, results of other research in the fields of landscape, spatial planning, and urban design could be geolocated by reference to a CSO 1km x 1km GIS basemap used in this study, and this could in turn be rendered in three dimensions as the scales of resolution become more and more detailed, and mapped across time. This method of visualising spatial complexity of urban sites, the Toolbox and Databox (described in Chapter Four) is set out in detail in Appendix F, as well as graphical outputs of visualising the results of the explorations and evaluations. In conclusion, it is found that visualisation methods

215 For example, one dimension (the Spatial Complexity Evaluation Form), two dimensions (Spider Plots), three dimensions (Databox) and four dimensions (dynamic adjustments to Databox covering scalar level and temporal change).
developed in this study respond to Gil’s call for diagrams resulting from evaluation to be ‘operational’: i.e. ‘immediately usable in the design process without expert intervention for further technical manipulation or statistical analysis’ (Gil, 2008:262).

Four summary visualisation-related findings can now be summarised, related respectively to standardisation, integration, comparability and operationality. Firstly, it is found that this study improves on previously diverse methods to study compositional and other aspects of spatial complexity, by showing a standardised approach to visualisation (for example, pixel size per resolution, 3d databox views, allowance for temporal reading) based on a review of these and other prior studies. Secondly, it is found that the adopted visualisation method can allow previous studies (at multiple scales) to be integrated into a spatial complexity frame, as well as incorporate future results of varying scales of spatial research about Dublin. Thirdly, it is found that comparable visualisation is possible between sites, and that this can be related to an overall colour ‘index’ of spatial complexity, which could be related to any scalar level, and could be visualised in many dimensions. Lastly, visualisation methods developed in this study respond to a call for diagrams resulting from evaluation to be operational.
7.5 Integrative exploration, evaluation and visualisation

The literature review for this study ranged across CTC, landscape, urban design, architecture, complexity sciences, environmental behaviour, ecology, artistic research and representation and visualisation theory. It became clear that exploration, evaluation and visualisation are all of equal importance to the primary aim of this study, that is to introduce a spatial complexity frame to the discourse on urban design. In this sense, the interconnectedness of an iterative exploration, evaluation and visualisation of spatial complexity of cities and urban sites is an overall conclusion theme. One of the high level conclusions of this study concerns the relative prominence of exploration, evaluation and visualisation of spatial complexity of urban sites. These three aspects of understanding the ‘condition’ of an urban site through its evaluated spatial complexity, could be weighted in multiple ways. So, while the qualitative judgements involved in exploration at whole city scale have importance to the later single case urban site evaluations, the visualisation of the results of both, overlaid and contextualised across the city become important to understand together, in a non-hierarchical format. In complexity theory terms, the presence of a hierarchy does not determine that all relations are hierarchical, but that ‘determination runs in all directions, not just top down’ (Byrne, 2005:105).

As described in Chapter Four (Section 4.3.1.5, ‘Integrative urban design theory’) an integrative approach is considered in this study as any ‘interdisciplinary’ (Dalton et al., 2012: 10), or ‘transcending’ (Carmona, 2014b) urban design research practice in relation to the spatial disciplines, related to urban sites. This includes mixed methods
research and approaches in urban design (Xerez, 2011). A mixed methods approach is associated with enrichment of theoretical and empirical urban research (Batty, 2009; de Roo, 2012c). This study demonstrates that by combining quantitative and qualitative methods, mathematical and interpretative interpretation, vector and raster analysis, compositional, configurational and system investigation methods for exploratory analysis of Dublin including case contexts, as well as the evaluations of three urban sites, that an integrative exploration, evaluation and visualisation approach reveals distinct and contrasting levels of spatial complexity in one city.
Chapter conclusions

Chapter Seven brings together the findings of the previous two chapters, on explorations, (Chapter Five) evaluations, and visualisations (Chapter Six) of spatial complexity. After a description of the structure for reviewing the results of the data analysis, in Section One, the Chapter firstly summarises and discusses the findings related to exploration of spatial complexity at whole city and case context scalar levels. In the next three Sections, findings related to the component issues of spatial complexity of urban sites are concentrated on, before the findings of resultant integrative evaluation of the cases is presented. Thus the Chapter includes a synthesis of explorations of case contexts, substantive findings for each case site, and then concludes on the overall evaluated levels of spatial complexity at the scale of the city. The central argument of this chapter is that multi-scalar understandings of urban sites, in a complexity frame, are enhanced by the use of a Toolbox and a Databox to evaluate and visualize spatial complexity of urban sites. This chapter advances the overall argument of this thesis firstly through discussion of findings for exploration, evaluation and visualisation separately, and then for consequent overall findings for spatial complexity. This setting out of findings of three evaluations and discussion of outputs is linked to the final concluding chapter by setting the context for the return to the core propositions of the research.
Chapter Eight  Conclusions

Introduction

Having established the theoretical and disciplinary context, described a research problem and a research question, proposed a research design and developed a conceptual framework, this study has collected and analysed data about spatial complexity of urban sites, through exploration, evaluation and visualisation. The research focus is at the intersection of complexity, urban design and evaluation. The three dimensions of the research problem are: a failure within urban design to investigate complexity, a lack of integrative evaluation at the scale of the urban site, and a failure to understand the benefits of spatial complexity. Complexity science of cities has been shown in this study to not especially focus on urban sites, neighbourhoods or urban centres at the scales of urban design. The discipline has not succeeded to date in providing a substantial evidence base for urban design propositions (designs). This is despite the fact that urban design does, by definition, have a focus on synthesising knowledge: in single theories, projects or images, or selected spatial planning instruments or design interventions, such as local area plans, masterplans or other design projects. Evaluation has been shown in this study to be a recent development in relation to urban design, and is generally of the static ‘snapshot’ type, often in the dynamically complexifying urban realm.

---

216 At the scalar level this means a number of urban blocks, the spatial, geometric or three dimensional aspects of a single street, or a public space, like a square or public park.

217 As described in Chapter Two (Section 2.2.5 ‘Definition of spatial complexity adopted for this study ’), Cuthbert (2007:196) describes numerous synthesizing theories of urban design (Hillier & Hanson 1984, Alexander 1987, Salingaros, 2005, Shane, 2005) but also suggests these have been unsuccessful, and suggests that urban design should connect with social science through the mechanism of spatial political economy, ‘a synthesis discipline which already has a history of two and a half centuries’ (Cuthbert, 2007:211).
In this context, the absence of prior attention to spatial complexity matters because optimally complex urban sites are shown to have environmental, functional and social advantages, including enriched urban life, increased resilience and diversity. For that reason, the purpose of this study was to explore and evaluate spatial complexity of urban sites for urban design, by demonstrating how understanding, measuring and communicating evaluated spatial conditions at the scalar level of the urban site enhances iterative urban description, prescription and design. As described in Chapter One, urban design is argued to improve human health and condition, and other aspects, such as economic, social and environmental value of urban sites can be benefits of good urban design. Evaluation prior to spatial change is especially important in urban sites which are changing rapidly, as in the three selected cases\(^{218}\). The need for spatial complexity understandings of urban sites in the selected range can be described as including the lack of previous focus by spatial research on these types of location, the dynamically changing character of these site types, as well as the claim that these types of sites demonstrate conditions of cultural definition and international relevance. In this investigation\(^{219}\), an integrative urban design approach is adopted (See Section 4.3.1.5, and Figs. 6-60-1), as iterative evaluation of spatial complexity during this process is argued to enhance urban design outcomes, and as a result could improve urban sites. Theories of evaluation of the designed environment for urban design suggest this aspect is currently subjective, multi-dimensional, and provisional\(^{220}\). If evaluation can be seen as a broader understanding of environments, for example of urban networks, or public space quality indices, urban design evidence is more specifically understood in the

\(^{218}\) The three cases in this study are contained within spatial planning and urban design designations of urban sites: Liberties character area is spatially defined as one of nine character areas in a Local Area Plan, urban Ballymun is spatially defined in the city Development Plan as a ‘key district centre’, and Carmanhall, is defined in the Sandyford Urban Framework Plan, prepared by the local authority, as a future neighbourhood.

\(^{219}\) (see Chapter One, 1.2.2, ‘Introducing urban design’)

\(^{220}\) (See Chapter Two, Section 2.3.3, ‘Exploration and evaluation studies for urban design’)

452
literature as associated with decision making for design. This study keeps open the potential for subjectivity, through exploratory and visualisation techniques of analysis, with abductive approaches to results, makes a multi-dimensional focus central to evaluation, and suggests abductive rather than just deductive or inductive understandings of urban sites for design.

In demonstrating the contribution of this study to addressing issues described above, this concluding Chapter firstly returns to the steps undertaken in this study, and a summary of how this study achieves the research aim, answers the research question, and meets objectives set out in Chapter One. The second section of this Chapter sets out the conclusions which result from the findings and discussion of the last Chapter, and these in turn follow the description of the data analysed in Chapters Five and Six. The third section of this Chapter demonstrates possible applications of methods used in this study, for urban description, prescription and design. The final section of this Chapter discusses possible implications for theory and practice, limitations, and recommendations of the study.
8.1 Return to research aim, question and objectives

This chapter is linked to the findings and discussion of the previous chapter by synthesizing the conclusions of the study in a wider context. This chapter particularly addresses the integrative aspect of exploring, evaluating and visualising the concept of spatial complexity, how this synthesis addresses the aims and questions of the study, and implications and recommendations for further research.

8.1.1 Steps taken

The following three steps have been taken in this research (see also Fig. 1-1, Pg 50):

Theory

- The theoretical conceptualisation of spatial complexity, already understood in the science of cities realm, has been broadened for urban design, and the main focus has been on urban sites. While the concept of urban complexity has been well investigated by others, as well its impacts on the city, the more specifically spatial aspects, and the relationship of these to design had been less explored. The question of how the theoretical concept of spatial complexity can be constituted and operationalised for urban design is answered. The separate question of what spatial complexity is in relation to urban sites is investigated, and has been answered through the proposition that primary components include composition, configuration and system aspects.
Exploration

- However, the established theories are also weak on where spatial complexity occurs in the city, and therefore the second step involves a focus on urban exploration and evaluation, through development of a conceptual framework and evaluation tool. In this respect, urban morphology theories help in identifying compositional and formal complexity, space syntax theories enable the study of configuration from the viewpoint of spatial manifestation, and system and network theory contributes to city system analysis at local level.

Evaluation

- In a third step, evaluation involves three specific aspects. Evidence is provided for correlations between evaluated urban form, analysed configuration, and measured system aspects of urban sites, and when combined, these three issues indicate where varying evaluated levels of spatial complexity occur. It is demonstrated through visualisation that the varying levels of evaluated spatial complexity in three urban sites constitute distinct and contrasting conditions. This enriches the urban design discourse on compositional, configurational and system issues of spatial complexity, and furthers the argument for evaluation of this characteristic of urban sites in urban description, prescription and design.

The three stages of work; firstly, exploration of theory and components of spatial complexity: secondly, development of a conceptual framework and evaluation tool, and finally, the evaluation and visualisation of the results of urban sites themselves, within, between, and across cases represent the three primary steps taken in this study.
8.1.2 Achievement of aims

Two aims of this study relate to exploration of the theory of spatial complexity and the practice of evaluation for the discipline of urban design. While concepts from complexity were explored in Chapters One and Two, including the reason to engage with complexity, this study has described a research interest in connecting design, and in particular urban design to the ‘complexity turn’ (Urry, 2005).

The two stated aims of this study were: firstly, to introduce a spatial complexity frame to the theoretical discourse on urban design and, secondly, to deepen the meaning and significance of the concept of spatial complexity for the discipline of urban design. A spatial complexity frame is introduced to the theoretical discourse on urban design through a text-based review of the definition, meanings and relevance of complexity theory and complexity theories of cities (CTC) for urban design (Chapter Two). Developing the meaning and significance of the concept of spatial complexity for the discipline of urban design is partly demonstrated by linking evaluation theory to complexity and urban design in a new way (Chapter Two). Previously, although urban complexity and visual complexity have been investigated for this discipline, no study has linked spatial complexity to urban design.

Secondly, in order to deepen the meaning and significance of the concept of spatial complexity for the discipline of urban design, evaluation (practice and evidence) aspects 221 Thrift’s proposition that ‘the geographical world is a messy one, it does not cohere’ (Thrift,1999:32) and his subsequent claims for complexity theory to be applied to geographical and spatial sciences, suggests that a complexity frame could also be useful to urban design theory and practice. Thrift’s definition of the complexity sciences is relevant to urban design process: ‘the idea of a science of holistic emergent order; a science of qualities as much as of quantities, a science of ‘the potential for emergent order in complex unpredictable phenomena’ (Goodwin, 1997: 112), a more open science which asserts ‘the primacy of processes over events, of relationships over entities and of development over structure’ (Ingold, 1990: 209) (Thrift,1999: 33). In the urban design process, iterative evaluation and assessment of potential development options is a requirement of good practice, and leads to better final outcomes. In this respect emergence, unpredictability, processes and relationships can be key drivers of urban designs.
of the research have included two aspects. For practice, an aim was to operationalise the relationship between spatial complexity, urban sites and evaluation by proposing a new evaluation Toolbox and Databox, which are useful for urban design practice (Chapter Four). For urban design evidence, a second aim has been to apply an evaluation Toolbox and Databox, which presents an empirically rich account of spatial complexity levels of multiple urban sites in one city, illustrating instances of evaluation of single urban sites, and differences within, between and across three urban sites (Chapter Six). In proposals for descriptive, prescriptive and design applications of the evaluation method (this Chapter) the viability of this approach is demonstrated. In summary, the two stated aims of the study have been achieved.

8.1.3 Answering the research question

The research question of this study is: how can a combination of complexity theory and urban design theory contribute to an increased exploration and understanding of the theoretical concept of spatial complexity (composition, configuration and system properties) for urban analysis and design, as well as to development of practical urban design evaluation tools for urban sites? Spatial complexity, for the purposes of this study, and in order to contain the scope of the research related specifically to urban design as a discipline, was defined in the introductory Chapter to this study (Chapter 1, Section 1.3.5.1) as the spatial component of urban complexity.

In concluding on the results of the development of the theoretical concept of spatial complexity for urban design theory and practice, it has been shown that this theoretical concept is useful for urban design theory because it can synthesise quantitative and qualitative aspects of evaluation. It was shown that, prior to this investigation,
complexity theories of cities (CTC) concentrated on hard-sciences and mathematical concepts of urban complexity and that environmental and urban complexity evaluation, for example, has had an over-emphasis on qualitative aspects of complexity (see Chapter Two). Further, it was demonstrated that, following precise definition and evaluation of three proposed primary components of spatial complexity of urban sites (composition, configuration and system properties), these can be evaluated, and are shown to assist in the visualising distinct and contrasting evaluated levels of spatial complexity in three urban sites. It was also demonstrated that this type of evaluation can improve on existing urban description, prescription and design of urban sites, as described in the Report on each application of the evaluation tools (See Appendix G).

The first part of the question relates to exploration of spatial complexity for urban design, and is more related to qualitative research methods (eg. theory development, historical interpretative understandings), in order to usefully increase knowledge and understandings for urban design discourse, seen as a more theoretical emphasis. The second part of the research question concerns evaluation, and is more related to quantitative research methods (eg. metric measurement), and specifically seeks to develop evaluation tools for urban design practice. (Section 1.3.2)

The findings of this study related to practice operationalise the concept of spatial complexity for urban design theory and practice through demonstration of evaluation of spatial complexity of three case sites. As an example, as mentioned above, this study builds on a study by Van Nes et al (2012)\(^{222}\), and combines analysis methods to study spatial properties of the built environment. The Van Nes (et al) study argued that its

\(^{222}\) The Van Nes et al (2012) study combined analysis methods to study spatial properties of the built environment, finding correlations between degrees of mix of function (land-use mix), density and integration at the scalar level of the neighbourhoods of South Rotterdam.
tools provided much more fine-grained analysis than contemporary Dutch planning practice (Van Nes et al, 2012, 8003:1). In the Irish context, this study also improves on current planning and urban design analysis tools. This is demonstrated by a review of the three planning and urban design policy documents associated with the selected urban sites in this study, all of which are currently officially planned for and/or undergoing rapid spatial change. None present any primary research on compositional, configurational or system aspects of the respective urban sites223. In summary, this section has demonstrated how the research question of this study has been addressed, through exploration, evaluation and visualisation of spatial complexity of urban sites.

8.1.4 Achievement of research objectives

To achieve the research objectives of this study, a total of six data analysis techniques are employed (as described in Chapter Three, Section 3.3.7): data transformation, instrument development, examining multiple levels, matrix preparation, pattern matching, and cross-case synthesis. The first four techniques are the selected ‘evaluatory’ data analysis procedures identified in the research design, following from the research strategy. Two further ‘exploratory’ data analysis procedures, pattern matching and cross-case synthesis are employed at higher level analysis of results. The application of the four ‘evaluatory’ techniques is described in Chapter Six, where results are presented. Two ‘exploratory’ data analysis procedures are also central to the study, pattern matching and cross-case synthesis. The selected pattern matching technique of analysis of data for this research design, as described in Chapter Three (Section 3.3.7, Data Analysis) is defined as ‘non-equivalent dependent variable as a pattern’. This technique is described as one which can be used in quasi-experimental research designs.

223 The three relevant planning policy and urban design documents are the Liberties Local Area Plan (LAP) (2009), the Ballymun Masterplan (1998) and the Sandyford Urban Framework Plan, (2011). A possible exception is a Conservation Report prepared for the Liberties LAP by Dublin Civic Trust, on the recommended geographical extent of an Architectural Conservation Area for the Liberties.
whereby: ‘the quasi-experiment may have multiple dependent variables- that is, a variety of outcomes. If, for each outcome, the initially predicted values have been found, and at the same time alternative ‘patterns’ of predicted values (including those deriving from methodological artifacts, or ‘threats’ to validity) have not been found, strong causal inferences can be made’ (Yin, 2003b:116). Results (Section 6.6) demonstrate that predicted patterns are found. Cross-case synthesis is also employed, and descriptions and discussions of results and observations (Section 6.5) show cross-case synthesis of findings. Each data analysis technique demonstrates how the research objectives of this study are achieved.

8.1.5.3 Demonstrating high quality analysis

Yin (Yin, 2003b:137) proposes that there are four principles underlying all good social sciences research, and which can demonstrate a high quality analysis. These are, firstly, attending to all the evidence, secondly, addressing all major rival explanations, thirdly, addressing the most significant aspect of the case study, and lastly, use of the researchers prior, expert knowledge in the case studies. In this section, these four principles are returned to, and it is demonstrated that each of these principles has been applied. Firstly, in relation to attending to all the evidence, Appendices in Volume Two of this study open out the evidence gathered for this study, including related to morphology of cases (Appendix A), pedestrian movement fieldwork (Appendix D), syntactic analysis (Appendix E), and visualisation (Appendix F). Extensive description is contained in these parts of the study to show that all evidence was carefully examined. Secondly, as regards addressing all major rival explanations, this would involve seeking rival theories which might account for evaluated levels of spatial complexity of urban sites, for example. However, after a review of Yin’s ‘nine types of
rival explanation’ Table (Yin, 2003b:113), it was considered that these potential rival explanations mainly covered experimental type cases, where ‘intervention’ of the researcher can influence results. However, the limitations section of this study (later in this Chapter) discusses some possible limitations of the study.

Thirdly, as regards addressing the most significant aspect of the case study, each case has a most significant aspect. In relation to of multiple cases, the most significant aspect of each case is concentrated on in visualising this research. As regards evaluated levels of spatial complexity of urban sites, the most significant aspect of the Liberties character area case is the rich historical compositional complexity, which emerged over time, foregrounding the temporal aspect. The most significant aspect of the Urban Ballymun case is the medium configurational complexity of this regenerated suburb, linking to the relational aspect of complexity. The most significant feature of the Carmanhall neighbourhood case is the low system complexity in this otherwise highly pivotal regional hub location, emphasising the need for multiscalarity in analysing this type of site. Lastly, as regards use of the researchers prior, expert knowledge in the case studies, the three applications of the proposed methods of evaluation and visualisation of spatial complexity for urban design utilise urban sites known to the researcher. This is due to prior involvement by the researcher in each case as an urban design practitioner, undertaking research, design commissions and masterplan projects. (See Appendix G)
8.1.5.4 Theoretic patterns

Yin comments on the role of theory in case study research have been stated earlier (Section 3.3.4): ‘the role of theory was to specify the differences between the two types of states that would be considered substantively critical.’ (Yin, 2003b: 24). Three rival theoretic patterns were described in Chapter Three, portrayed as alternative scenarios, and these are returned to following data collection and analysis (See Table 8-1). They are:

High levels of evaluated spatial complexity are associated with high levels of compositional, configurational and system complexity.

Medium levels of evaluated spatial complexity are associated with medium levels of compositional, configurational and system complexity.

Low levels of evaluated spatial complexity are associated with low levels of compositional, configurational and system complexity.

The statements above served earlier in this study as the detailed and prior development of the rival theoretic patterns, portrayed as alternative scenarios, in advance of data collection and analysis. The review of these scenarios (or descriptive theories) is the theory-generated background against which the actual data is compared in the findings and discussion Chapter of this study (7). Based on (Yin, 2003b:113) and within overall case study analysis strategy of ‘relying on theoretical propositions’ (Yin, 2003b:111) or returning to theoretical propositions after evidence gathering, this has been demonstrated in Chapter Seven. The techniques are useful in developing internal validity and external validity associated with case studies (Yin, 2003b:115) and therefore these are both addressed next in this section.
<table>
<thead>
<tr>
<th>Main Proposition</th>
<th>Three detail propositions</th>
<th>Fourth (overarching) proposition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaluated levels of spatial complexity in urban sites are related to and influenced by compositional, configurational and system properties.</td>
<td>Evaluated levels of <strong>compositional</strong> complexity of urban sites primarily depend on three factors: morphological development over time (Conezio, 2011), sufficient land-use mix (Van Den Hoek) and optimal urban density (Rechhauer, Post &amp; Haug). Evaluated levels of <strong>configurational</strong> complexity of urban sites primarily depend on three factors: integration (Hillier, 1998, 1999b), Bahra, 2003:615), choice (Krafta, 1997b, Marcus, 2015) and intelligibility (Hillier, 2005). Evaluated levels of <strong>system</strong> complexity of urban sites primarily depend on three factors: street (pattern) network (Marshall), path network (Wei, 2015) (Psponis et al., 2008), (Ellis et al., 2016), and pedestrian network (Ewing et al, 2009) complexity.</td>
<td>Evaluated levels of spatial complexity of urban sites can be derived from combining evaluations of compositional, configurational and system properties.</td>
</tr>
</tbody>
</table>

**Table 8-1. Main and minor propositions**
**Internal validity**

Although Cresswell associates internal threats to validity primarily with experiments, this case study could have two particular threats mentioned in his Table 8.5 ‘Threats to internal validity’, related firstly to selection, and secondly to instrumentation. In relation to selection, while Cresswell guides as regards self-selection of participants in an experiment, selection of cases in this study was related to predicted theoretic patterns, so his recommendation to ‘select randomly’ does not apply. His second relevant threat, instrumentation, relates to changes in instrumentation midway through an experiment. This could have impacted on some fieldwork of this study, (eg. Gate counts) but all measurement instrumentation was the same for all fieldwork, so this threat to internal validity does not apply.

**External validity**

As regards Cresswell’s suggested external threats to validity (Cresswell 2009:155), the first of these ‘Interaction of selection and treatment’ describes the threat as ‘because of the narrow characteristics of the participants in the experiment, the researcher cannot generalize to individuals who do not have the characteristics of the participants’. In relation to this study, although experiment is not a chosen method, this could relate to the question of whether the urban sites chosen as case studies are ‘representative’ of other urban sites in Dublin, or further afield. In response, Cresswell suggests researchers can ‘restrict claims about groups to which the claims cannot be generalised’, suggesting also that the researcher should conduct experiments with other groups if necessary to extend external validity. The threat to external validity in this study is avoided by restricting claims about study cases to the cases themselves.
8.1.5.6 Return to issues and criteria of study

This section returns to a review of the three issues and nine criteria selected to evaluate spatial complexity in this study, in order to discuss whether they have revealed usefully distinct and contrasting results for the case sites. In this study composition, configuration and system aspects are proposed as the ‘issues’, which are most important for evaluation of spatial complexity of urban sites (the objects of this study), as demonstrated from the literature review (Chapter 2 Section 3). Different issues of spatial complexity are found to be more or less appropriate to measure in urban sites, depending on hierarchical levels of urbanity (eg. visual complexity is more important in a historic urban core). However, it is also apparent from this study that composition, configuration and system, as issues, broadly suit typical Irish urban site types. While this conclusion could be seen to limit transferability to ‘global’ cities, the deepened concepts and arguments advanced do form a baseline for comparable urban site types, and others could be added for less or more urban locations. Criteria of spatial complexity were found in this study to suit exploratory and explanatory goals, but this is on the assumption that the evaluator has sufficient prior understanding of appropriateness of criteria to particular site types, something expected of most experienced urban design practitioners.
8.2 Overall Conclusions

While the evaluation Toolbox in this study is designed to produce measures in each of three categories (issues) and nine sub-categories (criteria), and a Databox visualises measures, one general result (of high, medium or low evaluated spatial complexity of urban sites) also serves as an overall evaluation. Therefore, in interpreting evaluations, for example, it is possible to establish how lively an urban site is (pedestrian network complexity, system issue, step nine), but also relate this to the morphological complexity (composition issue, step one), which could be useful for those engaged in the urban design of vibrant urban centres. In broader terms, overall explored spatial complexity of the city (Chapter 5) can then be compared with other research, related especially to the issues and criteria identified in this study as most relevant to spatial complexity. Exploratory findings also allow comparison with other cities to see, at a higher scalar level, which criteria may be affecting the current evaluated levels of spatial complexity of urban sites in Dublin. The usefulness of a multiscalar reading in a complexity frame\textsuperscript{224}, from a single pedestrian to the whole city, is the reason that exploratory, evaluation and visualisation conclusions are integrated in the final part of this study.

\textsuperscript{224} Byrne (1998:101) argues that the lowest spatial unit of aggregation to consider in a complexity frame related to the social sciences is the individual household, but in this study the individual pedestrian represents the smallest indivisible unit related to evaluated spatial complexity of the urban site for urban analysis and design.
8.2.1 Exploration conclusions

Two exploration conclusions are described here, related to conceptual underpinnings, and uneveness of explored sites across scalar levels.

**Assemblage and abductive approaches define exploration**

Two conceptual underpinnings are suggested in concluding on exploration of urban sites for urban design. Exploring and evaluating spatial complexity of urban sites is multi-scalar, and has potential to improve urban design practice, but exploration of spatial complexity in particular at large urban scales should be treated firstly as the product of an assemblage\(^{225}\) approach to analysis. DeLanda’s philosophical concept of ‘social complexity’ combines complexity theory with an assemblage theory approach, drawing philosophical support from non-linear mathematics and physics, seeing social life as a complex set of components, virtualities and potentials, whereby the social is both non-material and real (DeLanda, 2006). A useful theory of spatial complexity for urban design would seek similarly encompassing and exploratory approaches.

Secondly, an abductive\(^{226}\) reasoning approach is seen in this study as helpful in interpreting an assemblage approach to spatial complexity. This study entails a hybrid combination of abductive, inductive and deductive approaches, which together are argued to advance the understanding of a phenomenon (Kitchin 2014:5) in an exploratory science approach. At the ‘highest’ relevant scalar level for urban design

---

\(^{225}\) ‘Assemblage’ as a concept ‘is increasingly used in social science research, generally to connote indeterminacy, emergence, becoming, processuality, turbulence and the sociomateriality of phenomena.’ (McFarlane, 2011:205). (See also, Appendix C, Glossary of PhD Terms).

\(^{226}\) Abduction, in philosophical terms, is defined as: ‘the formation or adoption of a plausible but unproven explanation for an observed phenomenon; a working hypothesis derived from limited evidence and informed conjecture’(OED). A hybrid combination of abductive, inductive and deductive approaches are argued to advance understandings of phenomena, and are recommended in research involving big data (Kitchin 2014:5) particularly related to geography (Kitchin, 2014), also in design (Cross, 2011), urbanism and urban design (Çalık, 2012). (See also, Appendix C, Glossary of PhD Terms).
practice, exploration results at whole-city level are recommended in this study as part of the complexity frame within which results at two lower scalar levels (urban site context, urban site) could be considered. Also, in complexity theory terms, useful information about exploring spatial complexity of urban sites can be uncovered in the linkages and associations between the scalar levels. However, abductive method does not seek definitive answers, but open understandings in the light of available facts, which aligns with exploratory research aims. In summary, both assemblage and abductive thinking help to define the meaning of exploration of spatial complexity of urban sites for urban design.

**Explored spatial complexity of urban sites is uneven**

The second conclusion related to the exploration aspect of this study is that explored spatial complexity is not evenly distributed within, between, and across urban sites. Therefore an evaluation measure of spatial complexity of urban sites (though static) can clarify relations between spatially complex locations and other types, whether more or less spatially complex. Urban design seeks to ‘steer’ possible futures for places and urban sites, but often lacks evidence of present evaluated spatial conditions (Karimi, 2012). Explorations and evaluations of spatial complexity of urban sites in this study enhance the evidence base for spatial planning and urban design decisions. Additionally, although complexity is considered to be increasing\(^\text{227}\), and urban and spatial complexity are especially manifest, the increasing spatial complexity has not previously been studied with an integrative urban design focus on urban sites. In summary, a key theoretical proposition\(^\text{228}\) of this study is confirmed, that optimal spatial

\(^{227}\) The theory of ‘complexification’ is outlined in Chapter One, Section 1.3.1, ‘Problem statement’.

\(^{228}\) See Chapter Three, 3.3.4, ‘Theory and the cases’.
complexity is a relative value, both in terms of high and low evaluated levels, but also spatially related to the centrality or spatial hierarchical structure within which the urban site is contained.
8.2.2 Evaluation conclusions

Three overall conclusions of this study, directly related to findings of evaluation, are described here related to theory, the cases, and methods.

Spatial complexity theory can apply to urban design

The findings of this study for spatial complexity of the cases develop Krafta’s theoretical understandings of this concept as the spatial component of urban complexity for urban design, and in particular for the scalar level of urban sites or neighbourhoods. Furthermore, a theoretic pattern demonstrated in this study for the cases deepens the theoretical concept of spatial complexity for urban design. Complexity theories of cities can usefully be extended to evaluation of spatial complexity of urban sites for urban design.

Urban site case studies extend understandings of spatial complexity

As regards the cases themselves, findings for spatial complexity of the cases related to compositional complexity confirm in overall terms some results of other studies, such as for abrupt variations of density outside of city centres, and the lack of complexity of low density places. The claim that there are correlations between degrees of mix of function (land-use mix), density and integration at the scalar level of neighbourhoods is also supported by the findings of the cases in this study. The results on suburban and outer suburban sites in Dublin confirms previous findings related to configurational and spatial flaws of new towns, and provide more case examples in a specific Irish cultural context. Findings for spatial complexity of the cases in system terms extend with new case studies current understandings of system complexity of urban sites. Findings for spatial complexity of the cases in the evaluation phase of this study extend, with new
case studies, previous separate understandings of compositional, configurational and system complexity of urban sites. By integrating these three separate concepts into one synthesis, of spatial complexity, urban design understandings of urban sites are deepened and extended.

**Mixed methods and tools enhance evidence of spatial complexity**

As regards methods and tools for urban design research, the findings for spatial complexity of the cases respond to Karimi’s and others call for connecting evidence-based methods related to urban design by developing methods which are easily applicable by following short Protocols (in Appendix B). Evaluated readings of spatial complexity of distinct and contrasting cases confirm in overall terms that syntactic analysis methods need to be combined with more qualitative and spatial understandings of cities, including analysis of compositional and system analysis techniques for urban sites, as well as the need to combine desktop analysis with fieldwork on the ground. The findings for urban sites in Dublin also confirm previous justification in the literature for different spatial analysis tools for different neighbourhood patterns. Previous findings by others using mixed methods that, with measures of density and syntactic choice (at 1km metric radius), *pedestrian density* and *pedestrian distribution* respectively can be predicted, is repeated in this study, and visualised in three dimensions in a cross scalar way. The findings on compositional complexity from this study support the claim that mixed methods enhance this type of analysis. The findings for spatial complexity of the cases respond to calls for connecting evidence-based methods related to urban design by developing tools which are easily applicable. The mixed methods and tools of evaluating spatial complexity introduced in this study show that this type of analysis develops enhanced evidence, which is visualised in three dimensions in a cross-scalar
way. When considered in an appropriately hierarchical policy and planning context, and
bearing in mind complexity theory on limits to hierarchical structures of complex
spatial systems, multiple sources of evidence can enrich detail of evaluation. For
example, it is found in this study that urban sites of low spatial complexity are also low
quality urban environments. However, it is in understanding the compositional,
configurational and system detail of these spatial conditions that each aspect can be
targeted in an intergative way, to seek more optimal levels of spatial complexity, which
according to this study, are associated with higher quality urban environments.
8.2.3 Visualisation conclusions

Three overarching visualisation-related conclusions are now described, connected respectively to urban design evaluation, data visualisation and interpretative analysis.

Visualisation of spatial complexity enhances urban design evaluation

This study has shown that visualising spatial complexity enhances urban design evaluation for description, prescription and design. As regards description, urban design relies on visual communication of alternative possible plans or solutions to design problems (Batty, 2000), and better communication of urban design assists communities, stakeholders and decision making in and around urban sites (Talen, 2003)(Gil, 2013). Visualising spatial complexity enhances urban design evaluation for prescription, an aspect of urban design which currently lacks policy definition (Carmona, 2016). Visualising spatial complexity has the potential to enhance urban design evaluation for design, through an iterative process of testing design options for change, or through evaluation of existing conditions for description purposes alone, or, for example in pre-construction, or post-occupancy evaluation in new urban areas.

Data visualisation for urban design includes visualising spatial complexity

In relation to representation and visualization of spatial complexity, earlier in this study it was concluded that the majority of the representations (ie. non-text) in this study can be defined as ‘infographics’ (See Ch 4, Section 4.5.2). Exploratory infographics are especially employed in the exploratory ‘whole-city’ data analysis stage of understanding spatial complexity. However, exploratory data visualizations229 are also

229 Exploratory data visualizations, as described in Chapter Four, (Section 4.5.3, ‘Urban evaluation visualization methods’). Visualization, in categorization terms, is considered to have two types, exploration and explanation (Iliinsky et al, 2011:7), and each suggests different approaches and tools. So while exploratory data visualizations are associated with high levels of granularity, where large amounts of data are in play, at the data analysis phase of a project, the narrative emerging from the data is still to be set.
derived and employed. These are especially used in the case study evaluations, to further informative and persuasive aims of the overall study. Extensive data visualization is not a feature of this study, partly due to limitations on the skills base of the researcher, but also because the concept of spatial complexity is not relying on prior theory, and so agreed data visualization methods are not established in the literature. One finding (and therefore conclusion) of this study (See Chapter 7) is that a ‘hybrid exploratory/explanation data visualization vehicle’ (such as a interactive website, app, etc) could be useful to the development of theory and practice around spatial complexity for urban analysis, description, prescription, design and visualization. This is not achieved within the scope of this study, but could inform a future study.

**Interpretative analysis contributes to urban design practice**

As regards the relevance of the art of urban design, (or of ‘art’ to the practice of urban design) as introduced in Chapter Two, an further explored in Chapter Four, (Section 4.5.2) it has been demonstrated, especially in the exploratory stages of this study, that the interpretative, artistic interpretation of the infographics employed has enabled ‘abductive’ knowledge to emerge, and that this knowledge contributes to later, more hard-scientific, evaluation results. Hence, it can be concluded that the interpretative, creative, and ‘designerly’ aspects of urban analysis do have a place in urban evaluation, and therefore do contribute to urban design practice. (See also Appendix F, Visualising Spatial Complexity, ‘Art practice and urban design visualisation’).

Explanatory data visualizations, in contrast, are seen as connected more to facts which are already known to the designer/researcher, and to reporting more concrete results, and as part of the presentation phase of a project.
Discussion on final conclusions

In exploratory terms, Dublin city as context is found to have low and uneven explored spatial complexity, but dynamic and fast changing spatial conditions of urban sites exist, in situations of specific cultural definition and international relevance. For example, proposals for dramatically altering building heights, scale and massing in and around parts of the case urban sites were made in the years close to the end of Ireland’s most recent economic boom (1988-2008). As described elsewhere, (See Chapter Five, Section 5.4.1.3, ‘Current Planning/policy context’) in the Liberties, a development proposal was made for a building of 53 storeys, which would have been three times as high as the tallest existing building in the city. In Ballymun, the largest mixed-use town centre permission ever granted in Ireland permitted streets, urban blocks and structures of major scale, bulk and mass, which would have dramatically changed the urban site (See Section 5.4.2.3, ‘Current Planning/policy context’ on Ballymun planning context).

In Sandyford, proposed development included the tallest building proposals ever in Ireland (in 2003), (Duffy, 2008:9) of 65 storeys, and change of land uses from almost rural status directly to urban, during the economic boom which ended in 2008. Such juxtapositions of spatial condition, scale, mass, and urban density were unprecedented in urban Ireland, and although the proposed single developments remain uncompleted, the plans raised important new questions about Irish urban spatial quality, design and evaluation of urban sites, still unanswered in 2016. In this sense, contemporary spatial conditions in urban Dublin have international relevance for other rapidly urbanising locations.

230 These spatial conditions are described in more detail in Chapter Six. The Liberties, for example, includes the Inner Tangent Ring Road, the largest historic urban core ring road in Ireland, still incomplete, while Ballymun (the largest social housing estate in Europe on construction, and at one time the largest regeneration site in Europe) is unique in Irish housing and urban culture. Sandyford’s sudden development was assisted by a large land allocation for a junction between the Eastern Bypass, a key proposed edge of city motorway to the M50, and already complete ‘C’-ring, to the north, west and south. Development in this site included the tallest building proposals nationally in 2003, of 65 storeys, and change of land use from rural directly to urban during the economic boom which ended in 2008. (Source, Duffy, 2008:9).
The evaluation methods developed are shown to combine the qualitative depth of a morphological approach with the synoptic quantitative advantages of morphological, syntactical and systems viewpoints, as well as adding the observer perspective of fieldwork data. In disciplinary terms, it is shown that urban design can usefully connect spatial planning with architecture, and enhance an evidence base, through systematic evaluation of spatial complexity of urban sites. The thesis contributes case studies and evidence to expand and deepen exploration of spatial complexity theories of cities, and also enhances urban site evaluation and visualization methods for urban description, prescription and design. As a result, it is shown that Irish urban design research and practice can respond to increasing challenges by employing data-intensive, integrative evaluation tools.

The importance of evaluating at appropriate scales of resolution is revealed in this study. A related issue is that urban site boundaries must remain abductively set, in evaluating spatial complexity of urban sites, as small changes in boundary can impact on evaluated results. A related issue is that none of the three urban sites evaluated manifest optimal evaluated spatial complexity, and that indicators need to be visually interpreted as part of an iterative process of understanding through multiscalar explorations and evaluations combined. Furthermore, in different urban site types, particular indices have higher explanatory value as regards distinct and contrasting variations in levels of spatial complexity. In examining spatial complexity of landscapes, Laterra (et al)(2005:56) found that combinations of configuration indices have higher explanatory value than composition ones. In this study compositional, configurational and system indices all have higher or lower explanatory value,
depending on the history of the site and also its possible future. So, for example, in the Liberties urban morphological complexity has high explanatory value, while in urban Ballymun the configurational weaknesses stand out, while in Carmanhall, higher scalar level system dynamics\textsuperscript{231}, and lower level compositional issues, (for example, vacant sites, and juxtapositions of building density) are evident. The need for supplementary, multiscalar readings of the ‘spatial system’ above and below the scale of the urban site, especially in fast changing recently developed suburban and outer suburban sites, is also demonstrated in this study.

Comparability

The strengths of this combined exploration, evaluation and visualization method lie in linking measurement and evaluation across scales, identifying issues and criteria of spatial complexity which are comparable across urban sites, and connecting with previous Irish spatial research and evaluations across disciplines, scales and time. The result provides a graphical overview of whole spatial system of the city as well as parts including spatially complex urban sites. This study develops findings of DeKay (2013)\textsuperscript{232} who demonstrated that a nested, lattice-like network of levels of spatial complexity could be uncovered for building scales through design strategy maps, at nine levels, from materials to neighbourhoods. Dekay describes his level structure as having the potential to provide ‘a graphic overview of the whole knowledge base’ (DeKay, 2013). This study deepens this type of investigation at urban scale. Examples of

\textsuperscript{231} As a regional hub, Sandyford spatially has city-scale infrastructure junctions, such as proximity of a major junction of the ring motorway (M50) and the Eastern Bypass alignment (an as yet unrealised roads project to connect the port of Dublin to the ring motorway). Other city scale infrastructure, like major water reservoirs, and a tram line, as well as geographic closeness of large, fast-developing areas like Central Park, (a recent, high-density business development), and the future development of Cherrywood, (a large-scale, strategically zoned, greenfield to urban development) suggest spatial complexity of the context at higher scalar levels than the urban site, which is the focus of this study.

\textsuperscript{232} DeKay describes his use of design strategy maps to chart the knowledge base of climatic design as follows: ‘Each strategy is both a whole and a part; each organises and is made up of smaller strategies, and also has a context within a larger strategy. More complex strategies organise patterns of smaller ones. The strengths of this organisation lie in linking strategies across scales, identifying strategies potentially critical to the success of another, and providing a graphic overview of the whole knowledge base’ (DeKay, 2013).
comparing results of this study to previous researchers spatial evaluations across disciplines (from urban design) include landscape evaluation (Laterra et al., 2012)(Cushman 2010, 2016)( Leitão, 2012) spatial planning (Nedovic-Budic et al, 2016), and geography (NIRSA), and local spatial data analytics (McArdle, 2014). At multiple scales related to Dublin, because all spatial data generated in this study is geolocated, and represented in the same or divisible grid cell sizes, this study is comparable to previous Irish spatial data generated at various scalar levels such as national (CSO, Census, myplan), the region (Williams, 2004), economic core (Walsh, 2009), neighbourhood (Norton, 2016)(O’Dea, 2014). In summary, comparability is demonstrated through alignment of spatial indicators with previous Irish datasets and by geolocation on the Irish Grid CRS.

**Replicability**

At the outset, the relevance and transferability of the methods and findings of this study to urban design practice were described as core to this inquiry. Protocols (in Appendix B) set out all the necessary evaluation steps of this study, and refer to previous research methods and results for each of the nine recommended ‘steps’ to evaluation of spatial complexity of urban sites. In this way, another researcher can replicate the individual evaluation tasks, or a combination of steps which is most appropriate to different spatial scales and contexts. Less tools may be needed in less urban locations, or more extensive application of tools (eg. more pedestrian gate counts) could be needed in urban sites which are expected to be highly spatially complex, like historic city centres. In summary, ease of replicability of method is demonstrated in clear written Protocols.
8.2.4 Summary

The two exploration conclusions of this study are firstly, that concepts of assemblage and abduction define exploration, and secondly, that increasing complexity of urban sites is spatially uneven. The three spatial complexity evaluation conclusions of this study are, firstly: that spatial complexity theory can apply to urban design, secondly: that urban site cases extend understandings of spatial complexity, and thirdly, that mixed methods and tools enhance evidence and analysis of spatial complexity. In summary, certain complexity theories of cities can usefully be extended to exploration and evaluation of spatial complexity of urban sites for urban design. The three visualisation conclusions of this study are, firstly: that visualisation of spatial complexity enhances urban design evaluation, secondly: that data visualisation for urban design includes visualising spatial complexity, and lastly, that interpretative analysis contributes to urban design practice. The single integrative themed conclusion of this study is that integrative exploration, evaluation and visualisation reveal spatial complexity of urban sites.
8.3 Applications: descriptive, prescriptive, design

As regards the possible applications of the methods and tools of this study, while a primary aim is that this thesis would contribute case studies and evidence to expand and deepen spatial complexity theories of cities, it also intended to enhance urban site exploration, evaluation and visualization methods for urban description, prescription and design (See Section 3.2.5.3, ‘Audience for this study’). This section describes how this is achieved. This section also demonstrates how the spatial complexity evaluation tools, data and visualizations can work and be applied across scales. Berghauser Pont have demonstrated how an evaluation tool (SpaceMate) can be useful to urban description (Berghauser Pont & Haupt, 2009) and Marcus has discussed the need for descriptive methods in architectural research (Marcus, 2000), and these are the meanings of the term ‘description’ in this study. The role of urban design prescription in achieving optimal built environments for health has also been emphasized in the literature (Jackson, 2002)(Handy, 2002). The benefits to urban designers of evaluation are described as related to the generation of evidence, which is more specifically understood in the literature as associated with decision-making for design (see Section 2.3.3, ‘Exploration and evaluation studies for urban design’). Urban design-specific evaluation relies especially on visual aspects of tools, and clear representation of results. As regards prescription, Carmona has recently described ‘design governance’ as ‘an urban design sub-field’ arguing that the public sector could seek governance, rather than policy or regulation, to broaden place-shaping into a more inclusive process involving all parties. He discusses boundaries around the ‘opportunity space’ of urban design for development, whereby developers seek to minimize prescription (Carmona, 2016). In this context, the spatial complexity evaluation Toolbox and Databox proposed in this
study are intended to add clear, combined numerical and graphical understandings of urban design sites and options, to facilitate an iterative, transparent and replicable process of evaluation within the this ‘fuzzy space’ of urban development.

Marshall (2012a) has discussed how planning could generate functional complexity of cities. This section extends these propositions and demonstrates how urban description, prescription and design could relate to or generate optimal spatial complexity. As discussed in Chapter 4, defining these three key terms (description, prescription and design) is achieved by reference to a previous study, which relates diverse understandings of urban density to urban form, and derives a tool called ‘Spacemate’, described earlier (Section 4.4, density) (Berghauser Pont & Haupt, 2009) which claimed prescriptive, descriptive and exploratory applications. This study takes a more direct approach to describing ‘design’ uses of developed evaluation tools of spatial complexity of urban sites, in order for these to be clearly applicable for urban designers who are engaged in design practice. This is because, as Biddulph suggests: ‘if you are not engaged in design, you are not embracing urban design as a field’ (Biddulph, 2012:1).

In the following sections, one practice example of each of the three uses for spatial complexity evaluation is reported on: description for Liberties, prescription for Ballymun, and design for Carmanhall. The descriptive application, described in the Liberties, was one reason for the development of evaluation methods of spatial complexity in this research, given the researcher’s awareness of shortcomings of a policy planning document related to urban analysis for the area. The prescriptive application, described in the second site, urban Ballymun, is carried out in response to a need generated by an urban design project, as an urban design practice task undertaken
in 2010 by the researcher for the regeneration body of this urban site. The design application, described in the third site, at Sandyford, is carried out in response to an urban and spatial appraisal of the urban site of Sandyford, where land use has been changing rapidly from a suburban light industrial estate to a ‘patchily’ dense urban site, and where partially developed plots were stalled between 2008-2016. A major motivation for this study of how to enhance exploration, evaluation and visualization methods around spatial complexity of urban sites for urban description, prescription and design came from a series of site visits to Sandyford, in the autumn of 2009, in the months after the end of Ireland’s biggest economic boom (1988-2008).

In each case, it is demonstrated how the evaluation and visualization Toolbox and Databox enhance existing methods of urban analysis and design. The purpose of this section is to describe three applications of the exploration, evaluation and visualization methods developed in this study in three projects, and especially to demonstrate and report on the effectiveness of this spatial complexity approach to urban design analysis, evaluation and design for practice.
8.3.1 Description

The first application of the developed methods of exploration, evaluation and visualization of spatial complexity proposed in this study is demonstrated for the Liberties character area, Dublin, and concentrates on the descriptive aspects of a Local Area Plan\textsuperscript{233} (LAP), and how these could be improved through a focus on spatial complexity of urban sites. Over the development of the LAP document, the lack of appropriate evaluation of existing spatial conditions at Cornmarket, the most significant historic urban space in the area, became apparent. Four steps can be distinguished in this descriptive application of the developed evaluation method of this research. These steps are more fully recorded in the Spatial Complexity Evaluation Report document for Cornmarket (in Appendix G). Firstly, a desktop study of the LAP revealed an under-emphasis on significant urban spaces in the area, some of which are of primary importance to the city as a whole. As a second step, a historic research methods approach revealed a rich urban history of the urban site, including numerous claims for the primacy of this place in relation to the history and urban development of the city as a whole. The third step involved a spatial complexity evaluation of the Cornmarket site, including an emphasis on morphological development of the public space over time. Finally, as a fourth step, the Evaluation Report document includes visualization of results, and three recommendations.

\textsuperscript{233} The Local Area Plan (LAP) is described in Chapter Two, Section 2.3 as an example of current official approaches to urban analysis in Ireland in advance of urban design, and in the local area plan-making context. The making of Local Area Plans (LAP) in Ireland is a primary planning tool for the development of local area planning schemes, defined as ‘the principal statutory instrument for setting out a balanced understanding, vision and spatial strategies at local level’ (LAP Manual, 2012:2).
Cornmarket Spatial Complexity Evaluation Report

Fig. 8- 1 Extract page from Cornmarket Spatial Complexity Evaluation Report
In summary, the evaluation demonstrated that the descriptive aspects of a Local Area Plan could be improved through a focus on spatial complexity of urban sites. In particular three aspects were highlighted. In compositional terms, it is shown that the addition of graphical analysis of ‘public’ curtilage of ACA’s and protected structure clusters in historic urban sites can improve identification and evaluation of important historic public spaces. Following this analysis, the first recommendation of the Evaluation Report is an extension of the plan outline of the adopted ACA to include the entire historic urban space at Cornmarket, and visually represent this in three dimensions to improve legibility and communication aspects of this planning document.

In reviewing configurational aspects, and while a historic re-creation (graphically, using Depthmap) of configurational benefits of historic urban fabric and grain of medieval town plans could be demonstrated for this urban site, this was beyond the scope of the evaluation, except to point to the literature which supports this claim (Van Nes, 2001). It could be shown that recent development including road widening has partially removed the configurational coherence of the streetscapes. The second recommendation of the Evaluation Report therefore is for a configurational study of the historic streetscape and lanes of the area to be added to the LAP, to better describe the urban site. These spaces are shown in the report to have formed a significant contribution to the configurational coherence of the urban site in the past.

As regards the system aspects of the urban site at Cornmarket, the historical accounts referenced in the desktop study support the claim that this urban site was an origin site of Irish urbanity, and therefore key in system terms to public life, movement and urban culture. In visual terms, historic photographs are used as evidence items related to
historic vibrancy and public life at Cornmarket. The third recommendation of the Evaluation Report is for geo-referenced mapping of historic photographs to be included in the LAP. The Report argues that this additional documentation should be used to seek a return to city-level landmark status and thus the significant enhancement of the contemporary public realm in the Cornmarket area.

In summary, exploration, evaluation and visualisation of spatial complexity of this urban site improves on current method and practice of description in urban design evaluation, by combining the qualitative depth of a morphological approach with the synoptic quantitative advantages of a syntactical analysis method, as well as adding the systems viewpoint and observer perspective of fieldwork data.
8.3.2 Prescription

The regeneration project at Ballymun began in 1997 with the establishment of Ballymun Regeneration Ltd (BRL), a semi-state company owned jointly by the Department of Finance and Dublin City Council, the relevant Local Authority, to develop and manage the demolition of the existing tower blocks and the building of approximately 6,000 new homes, along with amenities. The regeneration project proposed by BRL, as described in the ‘Master Plan for the New Ballymun’ (BRL, 1998) document, was a 10-year regeneration plan encompassing physical, social, economic, environmental, cultural and process elements. The application described in the second site in urban Ballymun, as described in the introduction to this section, is carried out in response to a need generated by an urban design project, at Ballymun East, as an urban design practice commission. This design task was undertaken in 2010 by the researcher for a public client, Ballymun Regeneration Ltd., the regeneration body of this urban site.

The urban design task undertaken in 2010 by the researcher involved the preparation of an urban design framework plan for a key part of Ballymun, beside the Civic Centre of the regenerated town. The urban site at Ballymun East, which is partly located within the case site of this research, (the ‘urban Ballymun’ site, land area, 0.22km$^2$, or 55 acres) is 0.36 km$^2$ or 9 acres, so approximately one fifth of the size of the case study site of this research. The proposed framework plan did not explicitly prescribe urban design in Ballymun, opting instead for one masterplan design solution.
Fig. 8-2 Urban Ballymun prescription graphic
The steps that can be distinguished in this second, prescriptive application of the developed evaluation method of this research are now described. The Report sets out three steps to evaluation: Firstly, a desktop analysis, secondly, a Spatial Complexity Evaluation Report and thirdly, a visualisation of Prescriptions section. The first step involved a desktop analysis of the Ballymun Masterplan document (1998), to ascertain the level and extent of spatial evaluation of the urban site that happened prior to the preparation of the Masterplan in 1998. This analysis revealed that spatial investigation of existing urban form, land use mix and density were not prominent in the published document. From a desktop analysis of the Ballymun Masterplan document (1998) it was also clear that by 2010, certain urban design intentions of the regeneration master planners were not being carried out. As two urban design related examples, firstly the clear recommendation of the urban design masterplanners to avoid a single large new shopping centre as retail centrepiece of the regeneration was not followed, and secondly, the urban design strategy to promote the development of two-sided streets by single designers was not realized. Although the BRL Masterplan document was prepared in the absence of best practice guidelines for this type of document, the demonstration of adequate urban design evaluation in advance of the developing site of regeneration is not apparent in the Masterplan document.

Further, configurational and social analysis of the site was not undertaken, at a time when international best practice in configurational and social analysis and research into failures of social housing estates was available (Hillier et al, 1987)(Hillier et al,

---

234 The ‘Masterplan for the New Ballymun’ document, dated March 1998, states that the proposal of a regional sized shopping centre, as opposed to incremental growth of retail uses, would be a ‘high-risk strategy’ dependent on commercial viability and planning approval, stating that there is ‘historically a conflict between lively main streets and very large shopping centres (BRL, 2008:67).

235 Design guidelines were later introduced for Irish housing sites of a certain size (Urban Design Manual, 2009) Local Area Plans (2012), and urban streets and roads (DMURS, 2013).
1989)(Hillier et al, 1993)(Power, 1993, 1997). Finally, in relation to the system aspects of the site which would be regenerated, desktop analysis reveals that no baseline analysis of existing street pattern, extent of paths, or appraisal of pedestrian movement had been undertaken in preparation of the Masterplan.

The second step of this prescriptive application of the developed evaluation method of this research involved a Spatial Complexity Evaluation Report, which connected wider Ballymun evaluation to the specific urban site at the centre\textsuperscript{236}. Key evaluation indicators in each of the three issues categories were compared at both urban site scalar level (urban Ballymun) and a more general evaluation of the overall Ballymun development\textsuperscript{237}.

The third step of the Report involved a visualisation of Prescriptions section, outlining how planning designation as Key District Centre could in the future develop more appropriate prescription measures to ensure that the hierarchical position of the urban site in planning terms is matched by optimal evaluated spatial complexity terms for this location (See Figure 8-2). In concluding this section on possible prescriptive applications of spatial complexity evaluation of urban sites, it can be suggested that knowing evaluated levels of spatial complexity invites an urban design response, in that evaluated spatial complexity values of urban sites, in varying degrees, by implication confirm the requirement for a design approach to the complex issues discussed in the evaluation process.

\textsuperscript{236} The Key District Centre lands are called ‘urban Ballymun’ in this study and the Report.

\textsuperscript{237} Single criteria evaluations of some historical characteristics of the overall Ballymun development were also briefly checked, such as street network complexity of the original social housing estate in 1969 (0.15, according to Protocol 7), to contextualise the benefits to date of regeneration which took place between 1998 -2015.
8.3.3 Design

At one extreme, urban design has been criticized, as an ‘interventionary urban strategy’ (Boyer, 2011: 78), as lacking disciplinary definition (Cuthbert, 2003), and for its limitations in focus on aesthetic and formal aspects of environments (Madanipour, 2006) (See Chapter One, Section 1.2.2). However, on the other hand, the discipline is hailed as a ‘powerful tool for improving the human condition’ (Jackson, 2003:191) connected to the relation between human health, wellbeing and the built environment.

This study is informed by bringing together three themes: complexity, urban design and evaluation. As discussed above, the major trigger for this study of how to enhance exploration, evaluation and visualization of spatial complexity of urban sites came from an urban and spatial appraisal of the unfinished site of Sandyford, which originated as a primarily single-storey light industrial estate in outer suburban Dublin in the 1970’s. This impetus was generated by an academic fieldwork visit to Sandyford by the researcher, in the autumn of 2009, at the end of the most recent Irish economic boom. In the previous year, a Draft Sandyford Urban Framework Plan (2008), had been put on public exhibition, with proposals for large scale urban design change for the area, including a proposed 32-storey landmark building, as a ‘central regional landmark’²³⁸. Even taller structures were also proposed in private plans for the area around this time²³⁹.

²³⁸ Source: Panel 4, Fig. 7, Proposed Heights and Landmarks, Urban Initiatives Draft Sandyford Urban Framework Plan, 2008.
²³⁹ As outlined in Chapter Six, Sandyford’s sudden development was assisted by a large land allocation for a motorway junction between the Eastern Bypass, a key proposed link from Dublin Port to the edge of city at the M50 motorway, an already complete ‘C’-ring, to the north, west and south. Development in this site included the tallest building proposals nationally in 2003, of 65 storeys (Duffy, 2008:9), and changes of land use locally from rural directly to urban during the economic boom which ended in 2008.
In this context, the third application of the developed exploration, evaluation and visualization methods proposed in this study is demonstrated for the Carmanhall site, and concentrates on potential for improving urban design propositions through a focus on potential for optimizing future ‘designed’ spatial complexity of urban sites.

This design application of the method derives specific design ‘targets’ for urban design options to meet. Iterative urban design options can be evaluated to ensure alignment at multiple scales (plot, urban block, and urban site, the focus of this study). Although all nine criteria of spatial complexity cannot be tested at design stage, (footfall measurement of the design options is not possible, but could be projectively modelled) eight criteria can be assessed. Therefore a value for ‘designed’ spatial complexity can be arrived at, and compared for different design options. Two alternative urban design proposals for Carmanhall are part-evaluated in this application example, in compositional complexity (density) and system complexity (‘patterns’, that is, street network complexity). Due to time constraints, it is assumed for this desktop exercise that configurational complexity evaluation would follow the trend in the other two criteria evaluated.

The two alternative urban designs are firstly, the published Draft Sandyford Urban Framework Plan (2007), (Urban Initiatives/ Dún Laoghaire-Rathdown County Council, 2007) (A) and secondly, the adopted Sandyford Urban Framework Plan (2011), (Dún Laoghaire-Rathdown County Council, 2011) (B). These are described here as Urban Design Proposal A and Urban Design Proposal B respectively in this Section. (The background and general description of each Plan is contained in Appendix G, Applications Appendix).
Fig. 8-3 Site description and Optimal Design Density, Carmanhall

Source: Ubipix software/Author (top), Author, (bottom) See also Appendix G
The three steps that can be distinguished in this third, design application of the developed evaluation method of this research are now described. The first step involves a desktop analysis of the documents containing the design proposals to ascertain how these would vary the current ‘static’ evaluation of the urban site. The second step was to analyse the formal aspects of the ‘urban design proposals’ implied by both Urban Design Proposal A and B. The third step was to part-evaluate the two alternative urban design options for Carmanhall, in compositional complexity (density) and system complexity (street network complexity) and visualise results. This design application of the evaluation method found that indicating optimal future ranges of density and street network complexity, as examples, would help to direct urban design decision making. It is recommended as a result that clear ranges of optimal spatial complexity should be considered in urban design of urban sites, in an evidenced approach to guiding future urban development.

In concluding this section on possible design applications of spatial complexity evaluation of urban sites, it can be concluded that indicating optimal future ranges of density and street network complexity would help to direct urban design decision making. These design ranges help in setting an optimal and sustainable level of designed form appropriate to the hierarchical position of the urban site in evaluated spatial complexity terms. (Further detail recommendations and illustrations are contained in Appendix G, Applications).
8.4 Implications, limitations and recommendations

In considering implications, limitations and recommendations of this study, these three aspects are now described in relation to both urban design theory and practice.

8.4.1 Implications of the findings and conclusions

Firstly, the implications of answering the research question are in two parts: for theory, to contribute to an increased exploration and understanding of the theoretical concept of spatial complexity for urban analysis, evaluation and design theory, and secondly for practice, by leading to benefits of development of practical urban design evaluation tools for urban sites.

8.4.1.1 Implications for theory

This study contributes to an increased exploration and understanding of the theoretical concept of spatial complexity for urban design theory. Firstly, by making claims for the constitution of spatial complexity as an analytical concept in relation to urban design, and then testing this theory, findings and conclusions can be compared with separate theories of spatial quality for urban design (Khan, 2014:665) and spatial planning (Moualert, 2007, 2013). Together with distinctions from theories of urban complexity (Ewing et al. 2009), particular aspects of spatial complexity as developed have implications for urban design theory. Spatial quality as an urban design measure is subject to contested definitions (Schreurs, 2013), and has potential for bias in matters of its measurement and evaluation (Dewaelheyns et al., 2014). Urban complexity as an urban design measure is considered too broad for use in urban analysis (for urban design) and Salat suggests this is because ‘it is hard to handle’ (Salat, 2011:26) as a concept. Therefore, a theory of spatial complexity for urban design, which is tested
through examples, can improve robustness of theoretical definitions around urban
design evaluation.

Secondly, for urban evaluation theory, in a context where connecting theory to
evaluation and an evidence base for urban design is recent (Karimi, 2012), and where
evaluation theory for urban design is under-developed (Ratti, 2004) the implications of
connecting spatial complexity theory to urban design include increased attention to
evaluation in advance of urban design implementation. So while prior urban design
theories linking complexity to urban design have included Alexander’s theories of
functional complexity (1965), urban design process (1987) and ‘order’ (2002), Shane’s
and urban complexity (2000), and all have considered complexity to be an important
component related to urban design, practice impacts of these theories have been low.
Deepening concepts of spatial complexity for urban design in this study improves on
existing urban design theories linking complexity to urban design by connecting the
tests of the theory to cases.

While another study could uncover shared characteristics of these two fields of theory
(urban design theory, complexity theory) which emerged simultaneously in the mid-
twentieth century to respond to rapid change (Laurence, 2006),(Waldrop, 1992), this
thesis uncovers underlying correspondences between complexity theory and urban
design theory in order to advance knowledge about urban sites. Underlying alignments
in this sense include the need for interdisciplinarity in understanding and developing
theory (Simon, 1962), (Bachman, 2012), and the need to respond to dynamic
development processes through mixed methods and approaches of evaluation, testing

---

Shane’s theory of recombinant urbanism includes description of increasing urban or organisational complexity as follows:
‘Gleick’s depiction of the evolution of a complex system from simple beginnings provides a useful analog to city growth. Time
varies along the horizontal axis: size, scale, or organizational complexity along the vertical axis’ (2005:280). However, Shane’s
methods involve overly abstracting the urban process, and recategorising urban form according to labels, like ‘my city element triad
feedback loops and assemblages of objects, flows and ideas iteratively (De Roo, 2012), in opposition to fixed, masterplan type thinking (Rauws, 2015). In particular, complexity theory is argued to respond best to the need for a knowledge leap in planning, design and maintenance of cities, to rise to global urban challenges and crises (Marcus, Legeby, 2012). Complexity themes of this study, of temporality, relationality, and multiscalarity in urban design can be linked in this regard.

Recent calls for a focus on integrative spatial quality in urban design and planning seek to position this idea as an imperative and a normative concept for developing the analytical and diagnostic capabilities of urban design as a discipline (Khan et al, 2015). However, the definition of integrative spatial quality of evaluated urban locations has the limitation of seeming to be associated with only one aspect of the physical environment, that is, the qualitative or experiential response. Spatial complexity encompasses spatial quality and urban complexity, as well as landscape and architectural complexity, combining qualitative and quantitative approaches to evaluation.

It is claimed that in relation to definitional clarity of urban design as a field, “its very ‘vagueness’ could give it unique value” (Marshall, 2009: 55). In his commentary, Marshall is engaged in urban design theory or discourse, suggesting where the next developments will be. In this respect, open and abductive understandings of spatial complexity, arrived at through exploration, evaluation and visualisation, for urban description, prescription and design of urban sites, focuses urban design as a field on combining theory with better evaluations of real urban spatial conditions.
8.4.1.2 Concluding theoretical framing of spatial complexity

Figure 8-4. Scoping of spatial complexity
(1) Overall theoretical context or ‘paradigm’ of spatial complexity, (2) Theories around this study, (3) Scope of this study, (4) Compositional complexity concepts, (5) Configurational complexity concepts, (6) System complexity concepts.
In order to improve descriptions and classifications of urban sites for urban design, and
deepen current understandings of spatial complexity (which mainly relate in the CTC
literature to large scales), a concluding theoretical framing of spatial complexity of
urban sites is proposed in this section. This definition could serve as a future working
definition, developed in response to the research question, and proposed as one outcome
of this study.

While Krafta’s definition (‘the spatial component of urban complexity’) was used as a
working definition to undertake the exploration, evaluation and visualisation of spatial
complexity of urban sites, this can now be returned to for theoretic development. In
concluding this study, it can be confirmed that Hillier’s definition has been shown to
have more exploratory and explanatory meaning for urban sites than either Krafta’s or
Batty’s. On completion of this study, the theoretical concept of spatial complexity of
an urban site can be said to be related to Marshall’s description of the differences
between four types of organised complexity, including ‘artefactual complexity’, where
the whole is potentially ‘knowable’ (eg. a building), and system complexity (eg. a city)
where the whole is in fact unknowable (Marshall, 2012a:197). Although the boundaries
between these four types of organised complexity are considered ‘fuzzy’ in Marshall’s
analysis, it is implied that some of these four categories entail more complexity than

---

241 Krafta’s paper containing his definition, titled ‘Urban configurational complexity: Definition and Measurement’, was presented at the first International Space Syntax Symposium, the bi-annual meeting of space syntax researchers, in London in 1997. Given that it is likely that Bill Hillier, (the primary originator of theories of space syntax at the time) attended this meeting, interesting questions arise about possible relations between Krafta’s paper and the tone and content of Hillier’s own two ‘spatial complexity’ papers, of 1998 and 1999 (as reviewed in Chapter Two, Section 2.2.5, ‘Definition of spatial complexity adopted for this study’). However, it is not known how or whether the two different conceptions (Krafta’s configurational and mathematical emphasis, and Hillier’s multiscale and urban design focus) were in communication, and no generally accepted definition of spatial complexity emerged, neither in space syntax nor in urban design.

242 As well as focusing attention on the the scales ‘at which real (urban) design decisions are made’ (Hillier, 1998:782), Hillier’s theories of spatial complexity encompass spatial, social, and urban design theory and practice perspectives, while Batty’s theories operate at more abstract ‘science of cities’ scales, and Krafta’s definition is narrowly focused on configuration and mathematical understandings.
others. Following this exploration and evaluation of spatial complexity of urban sites, which took a relational, multiscalar approach, it can be proposed that while certain system aspects of urban sites can be known in full (eg. pedestrian movement complexity patterns) other, more artefactual related aspects, (eg. urban morphological complexity of urban blocks), can in fact never be fully ‘measured’, as different methods would derive separate types of results. In this context, abductive measures of spatial complexity of an urban site can be proposed to contain both artefactual and system aspects, while adding configurational aspects helps to bridge potential scalar divisions. In summary, it is concluded that, in a useful deepening of existing concepts, a theoretical definition of spatial complexity can be proposed for urban design, as an integration of compositional, configurational, and system complexity. Following this revised definition, the core conceptual frame of this thesis, that of spatial complexity, can usefully improve classification and description of artefactual/compositional, configurational and system aspects of urban sites in an integrative evaluation.
Fig. 8.5  Theoretical concept of spatial complexity of urban sites  
(adapted from Marshall, 2012a:197, Fig.1, ‘Four different kinds of organised complexity’)

8.4.1.3 Implications for practice

There is currently a gap between theory and practice in the development of sustainable urban development evaluation tools ‘where collaboration between academic and other institutions is most rare’ (Gil, 2013:323). Gil has described the challenge of developing an urban design evaluation framework for urban designers: ‘that integrates the technicalities of spatial urban analysis, the complexities of urban simulation, and the specificities of urban design to provide the designer with the creative means to explore quality urban design solutions’ (Gil, 2008:263). The three applications of evaluating spatial complexity developed in this study (descriptive, prescriptive, design) demonstrate applications of the research for practice in three distinct and contrasting case urban sites.
The practice-linked approach of this thesis considers exploration of spatial complexity to be most useful for urban design practice when considering the context of the urban site, and evaluation for urban site scale. This innovation in ways to consider spatial complexity for urban design contributes to new understandings of exploration and evaluation of spatial complexity in general, as previously ‘science of cities’ or CTC definitions predominated, and focused only on larger scales. Therefore, although limited to a single city (Dublin), this research represents, in Yin’s terms ‘the critical test of a significant theory’ (Yin, 2003b:41). Prior to this study, researchers have focused on singular aspects of spatial complexity: after this thesis it is hoped that future urban design researchers will adopt a more integrative and relational approach, focusing more on the specific urban design scales which are unique to urban sites, on characteristics and change in urban form over time (composition), on cross-scalar and topological aspects (configuration), and considering also system and network characteristics of urban sites, and ‘the changing parts’ (Alexander, 1966:403). In this way, important spatial aspects of urban sites are explored, evaluated and visualised in an integrative way, and embedded in urban design practice.

This study has focused on urban design for practice in the following ways;

Firstly, concentrating on the shape of the physical urban fabric, by confining the scope of case study evaluation to urban sites to local or neighbourhood scale in order to develop an evidence base for design practice.
Secondly, focusing on professional urban design, that is, the tasks undertaken by urban designers in practice. Preparation of feasibility studies, masterplans, and design codes are seen as key lead roles for urban designers in practice (Loew, 2012:8), as well as public space redesign, pedestrianisation schemes, and leadership roles in designing, improving and promoting compact, resilient urban sites. All of these tasks require evaluation, whether in advance of design, or iteratively as urban design tasks progress.

Thirdly, emphasising a specific scale, in which the scale of the urban site has been foregrounded, in order to avoid over-emphasis by urban design on landscape, planning or architectural scales.

Given that a perceived problem of urban design is the perception that it is ‘big-architecture’ (Carmona, 2010), a ‘subset’ of planning (Gunder, 2011:184) or design at whole-city scales (Frey, 1999) it could be possible to lose focus on the core relevant scales. The primarily three-dimensional, or ‘spatial’ characteristics of urban sites, comprising a relatively contained collection of urban blocks and streets are the focus of this study, (of approximately 1km sq grid cell) and have sufficient explanatory value in relation to defining evaluated spatial complexity for practice. Therefore, these geographical limits or ‘edges’ of urban design are proposed in this study as the appropriate upper size limit in order to concentrate on a specific scale. This is in order to concentrate on shaping the physical urban fabric, focusing on professional design, and emphasising a specific scale’ (Marshall, 2015). These suggested ‘limits’ help to both clarify the research question and the disciplinary base of this research, by limiting the object to the spatial and physical urban fabric. Suggesting a focus on design helps to clarify the scope of this research as only focusing on what urban designers need for theory and practice, and limiting the potential to attempt to address research problems of other allied disciplines like spatial planning or architecture. Emphasising a specific scale keeps attention on the urban site unit (like a neighbourhood) throughout. In this study, it is also important to clarify that the term ‘urban design’ refers also to urban analysis, as analysis of the urban environment fundamentally underpins urban design practice.

---

243 Marshall, describes this aspect as ‘(e.g. preparing a blueprint or some other expression of a solution prior to construction)’ (Marshall, 2015:10)

244 Though not the focus of this study, suggesting ‘edges’ of urban design disciplinarity potentially helps in coherently exploring, evaluating and visualizing spatial complexity of urban sites for urban design. Marshall (2015) suggests three ways that urban design could be more focused: ‘concentrating on shaping the physical urban fabric, focusing on professional design, and emphasising a specific scale’ (Marshall, 2015). These suggested ‘limits’ help to both clarify the research question and the disciplinary base of this research, by limiting the object to the spatial and physical urban fabric. Suggesting a focus on design helps to clarify the scope of this research as only focusing on what urban designers need for theory and practice, and limiting the potential to attempt to address research problems of other allied disciplines like spatial planning or architecture. Emphasising a specific scale keeps attention on the urban site unit (like a neighbourhood) throughout. In this study, it is also important to clarify that the term ‘urban design’ refers also to urban analysis, as analysis of the urban environment fundamentally underpins urban design practice.
to sufficiently explore, evaluate and visualise spatial complexity of urban sites for urban
design theory and practice. One related implication of this study is that urban design
practice may begin thinking differently about urban site boundaries, and ‘abductive’
spatial boundaries are suggested in this respect for site definition. As official boundaries
were mainly adopted in the cases studied here, some instances of a poor ‘fit’ between
fixed boundary and neighbourhood or urban site unit were investigated²⁴⁵.

Other implications of this study derive from some questions asked in Chapter Four.
Firstly, a useful conceptual framework of spatial complexity has been developed for
urban analysis and design, which informs decision-making in iterative urban design
processes in practice. Secondly, from a theoretical perspective, the issues which are
most important to consider in devising a conceptual framework of spatial complexity
for urban analysis and design inform practice, and can be adjusted in levels of
application as regards site suitability. Lastly, the question of weighting different issues
of spatial complexity of urban sites is answered, by treating all variables equally, and
this weighting is made visually accessible for use in practice.

In relation to the ‘community’ around evaluation of spatial complexity of urban sites for
urban analysis and design, a ‘communicative rationality’ approach to evaluation is
adopted. In this approach, the actors, considered to be ‘seeking consensus (more than to
achieve their own goals)’ (Alexander, 2009:48), can be defined as any evaluating agent,
from stakeholder, other designer, audience of completed designs, or for example,
residents or communities of an urban site. The conceptual framework around
exploration, evaluation and visualisation of spatial complexity of urban sites developed

²⁴⁵ For example, in Ballymun, the planning designation of Key District Centre has little meaning on the ground in spatial terms, as
the area has traditionally been understood as a collection of residential neighbourhoods, but these are also poorly spatially defined.
See Chapter Five, Section 5.4.2.2, ‘History of Ballymun’.
in this study is designed to be usable by any of these communities around evaluation. As an extension of this study, longitudinal or ‘live’ evaluations, such as extensions and deepening of ‘dashboard’ type digital platforms into a synthesis of real and digital representation of urban sites, a public, enabling type of ‘code/space’ (Kitchin/Dodge, 2004) could in future be conceived of for urban sites. In summary, although this study concentrates on ‘static’ evaluation of urban sites, further development of tools introduced here could include applying these exploration, evaluation and visualisation instruments in a historical or ‘multiple futures’ approach to these and other cases.

246 Spatial planning evaluation is associated primarily with ‘ex-ante’ (pre-construction) evaluation. In this study, evaluation of existing urban sites for urban design is concentrated on, that is, not considering any specific plan to develop or change an urban site, and with no recently completed development to evaluate. This study’s evaluation procedure is intended as a demonstration set of cases, to better enable evaluation of current spatial complexity levels of any urban site by common criteria. This type of evaluation is concentrated on to appropriately contain the scope of this thesis, and to concentrate on practical application of tools and methods, but the tools could also be applied in practice to a historic plan of an urban site, for example, or to a proposed urban design master plan proposal, but these aspects are not concentrated on here.

247 City ‘dashboards’ are described as ‘urban indicator and benchmarking projects’ which open up the data underpinning (urban) indicators and share them with citizens through online, interactive data visualizations. They ‘graph and map indicator data, providing detailed information about city performance and trends, without citizens needing to learn how to handle data or use specialist visualization software (Kitchin et al, 2015:6).

248 The book ‘Code/space Software and Everyday Life’ (Kitchin & Dodge, 2011) argues that the production of space is increasingly dependent on code, and that code is written to produce space. The authors call for a social science focused on explaining the social, economic, and spatial contours of software.
8.4.2 Possible limitations

As outlined in Chapter One, there are constraints on the comprehensiveness of any evaluation tool of an object as complex as the urban environment (Carmona, 2014a:5). Four potential limitations are now discussed: narrow disciplinarity, practice emphasis, case study method, and over-scientific approach. In this thesis, which conceives a research design to enable exploration, evaluation and visualisation of spatial complexity, there is a precise urban design disciplinary focus. Therefore the first limitation could be seen as disciplinary, as other allied disciplines like spatial planning are not concentrated on. However, as the CTC domain is currently predominantly planning-led, this study expands the discourse on complexity of cities to show how urban design connects across the spatial sciences, from architecture to landscape.

A second possible limitation could be that this study is ‘for’ urban design, rather than ‘about’ urban design\(^\text{249}\) and that therefore this study is not useful. However, urban design could benefit from more attention being directed to research for urban design (Biddulph, 2012:2), including instances of how theory can link directly to practice, and therefore this study is argued to be sufficiently important.

A third potential limitation relates to the fact that this is primarily a case study based enquiry, and not ‘an experiment’, or a ‘history’ (Yin, 2003b:10) for example. Although this topic is covered in more detail in Chapter Three (research design options), it is worth noting here why each was ruled out in the research design. Criticisms of case study method (lack of rigour, little basis for scientific generalisation, take too long and result in large documents)\(^\text{249}\) are offset in this thesis by combining exploration and

\(^{249}\) See Chapter One, Section 1.3.6, ‘Scope of this thesis’.
evaluation, with the latter viewed as similar to experiment in style. The exploratory nature is curtailed to the extent that evaluation is required to ‘prove’ or ‘enact’ the theory, and therefore the evaluation brings potential for scientific generalisation in a short report\(^{250}\).

A fourth potential limitation is an over-emphasis on scientific methods and theory, to the exclusion of development of other tools and methods useful to urban design practice. In an architectural critique of Jenck’s book on complexity and architecture discussed earlier (Jencks, 1997), the argument is made that Jenck’s ‘wants to discuss meanings and values but his methods, conceptual systems and other scientific tools are those of physics and the sciences of complexity’ (Passinmaki, 2013:21). This is a potential criticism or limitation of this thesis. This study does explore theoretical meanings and values of spatial complexity for urban design. Jencks’ architectural theorist approach proceeds from descriptions of scientific theory to illustrating and describing selected constructed architecture examples, which the author (Jencks) believes display examples of the theoretical concepts. In contrast, this study explores the concept of spatial complexity in order specifically to then proceed to discuss tools and methods of evaluating this characteristic at urban design scales for urban sites and practice. Evaluation methods are proposed in this study which can be replicated, leading to confirmation or otherwise of results, as well as the possibility of enhancement of methods devised here by other researchers. Thus, the scientific theory is joined to particular scales of evaluation and practice-relevant ways of considering meanings and value of spatial complexity for urban design theory as well as practice.

\(^{250}\) The potential of the rich narrative depth of a history of the urban sites was considered in the research design, but this was decided against, even though a research gap exists in relation to the urban histories of the case sites. This history could reveal qualitative detail arguably missing from more specifically ‘evaluative’ exercises, asking ‘how’ and ‘why’ questions. However, the applicability and transferability of the evaluation methods in particular to urban design practice were considered more relevant to the core research question, and to the aims of the research, including making recommendations on evaluation methods of spatial complexity for use in urban analysis and design practice.
In summary, these four potential limitations of the study (narrow disciplinarity, practice emphasis, case study method, and over-scientific approach) are refuted in this section. However, the designation of the scope of the study does limit the findings to objects of a certain size (urban sites), certain criteria of spatial complexity only (composition, configuration, system aspects) and certain disciplinary realms, (urban analysis and design) in order to usefully contribute to urban design theory and practice.
8.4.3 Recommendations for future research

A number of areas are now suggested for future research related to this work. Some recommendations for future research are related to limitations of this study.

Research linking landscape and urban design

While a potential limitation of this study is the emphasis on urban design, it has been shown that landscape has developed useful measures and methods for spatial complexity. In particular, work in the fields of ecosystem services and landscape metrics could be further researched for links to urban design understandings of spatial complexity.

Research on embedded and larger cases

While a potential limitation of this study is the emphasis on particular case scales, associated with case study method, further embedded cases, as well as exploration of spatial complexity at larger scales for case sites, is likely to reveal useful information on evaluated spatial complexity, and the importance of linking across scales of evaluation.

Research which digitises and monitors these evaluations

While most visualisations of this study were of the infographic and exploratory data visualization types, computerising spatial complexity, by connecting these evaluations to a dashboard type platform, would enhance achievement of communication and dissemination goals, and updating of data electronically could improve relevance of results.
8.4.4 Contributions

This study improves on previous research in three ways, related to theory, a tool, and cases:

- Firstly, for (urban design) theory, by describing underlying theories of spatial complexity and deepening these for urban design. This improves on current theory by extending this concept from complexity theories of cities (CTC) to urban design, overcoming a failure within urban design to investigate complexity.

- Secondly, for the domain of the spatial sciences, development of an evaluation tool which provides an objective measure of spatial complexity which can be used within, between and across urban sites. This improves on current evaluation methods by addressing a lack of integrative evaluation at the scale of the urban site.

- Thirdly, for the discipline of urban design, generation of multiple case evaluations of spatial complexity, forming a new source of empirical evidence for urban analysis and design practice. This improves on current urban design, which lacks an evidence base, by increasing understandings of the benefits of spatial complexity to the urban built environment.

In this way, the primary contribution of this study is to deepen spatial complexity theory, developing a conceptual framework and evaluation tool for exploration, evaluation and visualisation of spatial complexity of case urban sites, which forms a new base of empirical evidence for urban analysis and design.
8.5 Concluding Remarks

This study showed that whereas the links between geography and complexity were first made in the 1970’s, arguably the complexity ‘turn’ did not reach planning till the mid 2000’s, and given the relatively recent ‘urban design turn’ of the early 2000’s, complexity theory and urban design theory have only recently begun to interact in a general way. This concluding Chapter returned to a summary of the findings of this study on links between complexity, urban design and evaluation. This Chapter is linked to the findings and discussion of the previous chapter by synthesizing the outputs in a wider context. It demonstrates that the purpose, issues, criteria and propositions of this study have been fulfilled in the description of the data analysed in Chapters Five and Six. This advances the overall argument of this study by showing how exploration and evaluation of spatial complexity of urban sites can be achieved. In particular, the data analysis techniques proposed in Chapter Three are used to structure the reporting of the conclusions of this study, including observation of theoretic patterns and cross-case synthesis. Then, as part of the concluding section, the implications of combining complexity and urban design theories in exploring and evaluating spatial complexity of urban sites are described, including increased understanding and potential applications for improvement of spatial complexity levels where appropriate. In conclusion, as a deepening of existing concepts, a theoretical definition of spatial complexity is proposed for urban design in this study, as an integration of compositional, configurational, and system complexity.

This study is summarised as an integrative theory approach to evaluating spatial complexity for urban design, combined with proposed new evaluation methods for use in urban design. The relevance of spatial complexity for urban design practice is also
outlined. This Chapter also includes a review of possible limitations of the methods employed, and a discussion of recommendations for further research on spatial complexity. The strengths of this combined exploration, evaluation and visualization method lie in linking evaluation across scales, identifying issues and criteria of spatial complexity which are comparable within, between and across urban sites, and providing a graphical overview of whole ‘object’ of the research (the city) as well as units and parts of spatially complex urban sites. DeKay (2013) demonstrated that a nested, lattice-like network of levels of spatial complexity could be uncovered for building scales through design strategy maps, at nine levels, from materials to neighbourhoods. DeKay describes his level structure as having the potential to provide ‘a graphic overview of the whole knowledge base’ (DeKay, 2013) and this study achieves the same objective for spatial complexity of urban sites.

In relation to the nature and significance of spatial complexity as a concept, it can be concluded from this study that the specific nature of spatial complexity is derived from three aspects. Firstly, it includes an exploration aspect, related to both space and time. This includes definition of a spatial unit (in this case an urban site) and a time (in this case contemporary existing spatial conditions in an urban site), and an awareness of spatial and temporal conditions surrounding the selected spatial unit. Secondly, as regards evaluation, it can be concluded that both quantitative and qualitative understandings need to be developed and integrated, involving three issues and nine criteria. Thirdly, as regards visualisation, infographic as well as digital visualisation are important in defining spatial complexity as a concept and in describing the essential and unique characteristics of this aspect of an evaluated site. Following from this description of the nature of the concept, it can also be concluded that the significance of
the concept of spatial complexity as developed in this thesis is that it is a dynamic evaluation measure, improving on previous (single) measures of urban sites such as urban complexity measures, spatial quality measures, and single ‘topic’ measures, such as compositional, configurational or system aspects. Other complexities related to urban sites such as sensory complexity, aural complexity, social, economic, and even policy/management complexity, (all of which have been previously studied) fail to sufficiently capture the measurable but constantly shifting dynamics of urban sites in the ways that the proposed Toolbox and Databox of this study achieve, by conferring a single, unique ‘signature of spatial complexity’ of an urban site, for a certain spatial unit, at a fixed point in time.

As a possible future development of this research, it is also clear that a historic time trajectory of shifting spatial complexity levels can be worked back for a spatial unit, and that larger or smaller spatial units can be evaluated below or above this evaluated spatial unit, and that the other units can act like hierarchical nestings of the chosen spatial unit. This facility to move across space and time confers a powerful nature and significance on this conceptualisation of spatial complexity, and this study’s proposed evaluation tool, especially for urban design. However, possibly the most meaningful aspect in a wider sense is the immediacy of understanding by a broad audience of the ‘signature’ aspect, as this is displayed through designation of a single unique colour ‘fingerprint’, which can be deconstructed (mathematically, through use of RGB colour chart) into three issues and nine criteria measured. This means that as well as pinpointing a qualitatively rich identity on an urban site through associating it with just one particular colour, all constituent issues and criteria of spatial complexity can be separated quantitatively, compared, examined in a single dataset, and used individually as well as
collectively to measure, over time, enhancements, alterations or losses of this evaluated ‘signature’ of spatial complexity.

In pinpointing more explicitly the most significant single contribution of this study, the advancement of the concept of spatial complexity is foregrounded, because it is in this area that new knowledge can most directly effect the improved evaluation and therefore usefulness for urban designers in describing, prescribing and designing in urban sites. Other aspects of the contribition of this study, such as establishing the methodological framework for a system of analysis, generating new evidence or insights into urban site locations, and the invention of visualisation formats for supporting design, all act in support of the core contribution, which is to situate the concept of spatial complexity within the discipline of urban design.

In concluding this study, a brief review of the core stated purpose and aims is returned to in order to reflect on how this study has addressed its primary objectives. The purpose of this study as outlined in Chapter One, was to define and operationalise the concept of spatial complexity for urban design theory and practice. The two assessment criteria are: firstly, does the study define the concept of spatial complexity for urban design theory and practice? And secondly, does the study operationalise the concept of spatial complexity for urban design theory and practice? Chapters Five, Six and Seven in particular demonstrate that these two criteria have been met in the study:

- The concept of spatial complexity is defined for urban design theory through development of a conceptual framework, including relevant issues and criteria of evaluation, and an exploratory investigation of one city and three case contexts.
• Operationalisation of the concept of spatial complexity for urban design practice is demonstrated through evaluation and visualisation of spatial complexity of three case sites.251

Foregrounding evaluation of the three issues and nine criteria of spatial complexity has demonstrated in detail both the meaning of the theoretical concept of spatial complexity, and the operationalisation of the concept for urban design practice. This responds to a perceived lack of a cohesive and robust ‘diagnostic and analytical apparatus’ of the discipline of urban design (Marshall, 2012b:268). In summary, it has been shown that an integrative exploration, evaluation and visualisation approach successfully reveals distinct and contrasting levels of spatial complexity in one city.

251 A total of six data analysis techniques are employed in this study. Data analysis techniques are described in Chapter Three, Section 3.3.7: data transformation, instrument development, examining multiple levels, matrix preparation, pattern matching, and cross-case synthesis. The first four techniques uncover ‘evaluatory’ result, and two further ‘exploratory’ data analysis procedures, pattern matching and cross-case synthesis, are employed at higher level interpretation of results.
A Note on Appendices (Volume Two)

Seven Appendices are collected in Volume Two of this study: Morphology of cases, Evaluation Protocols, Glossary of Terms, Pedestrian Movement Fieldwork, Syntactic Analysis of Dublin, Visualising Spatial Complexity, and Applications Reports. Volume Two is less text-driven than Volume One of the study, and contains graphical outputs, fieldwork data, and descriptions of evaluation protocols including diagrams, for example. Each Appendix is now briefly described.

Appendix A    Morphology of cases (description)

Description, as part of investigating urban morphological complexity of urban sites, includes in this study the need for full description of the urban morphological development of the cases, and this emerged as a requirement of the research. However, the primary description tool, (a textual, theory-driven and historical interpretative analysis), was considered to form a more appropriate qualitative background analysis, rather than a foregrounded central argument. For this reason, the first Appendix is a descriptive account of the morphology of the cases, including development of the historical background of the three case sites.

Appendix B    Evaluation Protocols

Protocols describe the method for evaluating spatial complexity of urban sites, under three headings (or ‘issues’) composition, configuration, system, and under three criteria evaluation categories within each heading. All of the nine consequent urban design evaluation methods are described here by an individual ‘protocol note’, in order that each could be used separately alone. However, as described in this thesis, an integrative
evaluation of spatial complexity proposes that all nine criteria are evaluated together for an urban site.

Appendix C  Glossary of Terms

Commonly accepted terms and generally understood units of analysis are used in this research. However, some technical terms related to exploration, evaluation and visualisation methods need precise definition, and certain core theoretical concepts of the research are also described in this Glossary of Terms.

Appendix D  Pedestrian Movement Fieldwork

A brief introduction to concepts of measurement of pedestrian movement complexity and description of pedestrian gate count and timelapse video fieldwork for the three cases forms the basis of this Appendix.

Appendix E  Syntactic Analysis of Dublin

This Appendix describes the approach to syntactical analysis of urban sites taken in this study, including conceptual background, data collection, analysis, limitations, and relevance. The ‘Dublin Axial Map 2012’ dataset is described in detail, compared to other cities, and used to derive evaluations of configurational complexity of the three urban sites of the study, and each result is described in detail.

Appendix F  Visualising Spatial Complexity

Visualisation, one of the three primary parts of this study of spatial complexity of urban sites, involves large amounts of graphical and representational material, related to the
exploratory impressions and evaluation results of the study. These are collected in Appendix F.

Appendix G  Reports on Applications of the methods

This Appendix contains three Reports: on description, prescription and design applications of the spatial complexity evaluation methods developed in this study.

Appendix H  Case study research design options

The literature on case study unit selection has no clear recommendations of numbers of cases which it is appropriate to select. Therefore, in this Appendix, (related to Chapter Three, Section 3.3.4, ‘Number of cases’), this text outlines the options considered and the detail decisions taken in this study as regards number of cases in case study research design.
Permissions

Space Syntax

The dataset referred to throughout this study as the ‘Dublin Axial Map 2012’, was supplied to the researcher in May 2014 by Space Syntax Ltd., London, the author of the data. The supplied dataset is known to Space Syntax Ltd. as the Dublin Spatial Network Model. Conditions of use include restrictions to academic and non-commercial purposes, and that no part may be copied or distributed. The Dublin Spatial Network Model is copyright of Space Syntax Limited 2014. All relevant images in this study are deemed to contain the term ‘Spatial network model of Dublin copyright of Space Syntax Limited 2014’.

Os Map Licence No.

Documentation in this study includes Ordnance Survey Ireland data reproduced under OSi Licence number APL0000115. Unauthorised reproduction infringes Ordnance Survey Ireland and Government of Ireland copyright. © Ordnance Survey Ireland, 2011.

Myplan

All images from www.myplan.ie are used in accordance with terms and conditions outlined in Department of the Environment, Community and Local Government website, at ‘Conditions of Use’ section (http://www.myplan.ie/viewer/).

Google

All Google Maps, Google Earth and Street View images used in this study are reproduced for academic purposes only, under Terms of Service as indicated in: https://www.google.com/intl/ALL/help/terms_maps.html, and Attribution Guidelines for Google Maps and Google Earth as indicated in: https://www.google.com/permissions/geoguidelines/attr-guide.html
List of Publications

Conference Contributions (with prior peer reviewed paper)


Mee, A (2015), ‘Complex adaptive urban design systems’, *Definite space fuzzy responsibility (AESOP Annual Congress 2015)*, Prague, Czech Republic. (Nomination by peer reviewers for ‘best paper’)


Conference presentations


Mee, A (2012), Attendee, Aalto University, Summer Academy, Finnish Academy of Fine Arts, Helsinki, Finland.
Other Publications


Other Journals
Mee, A (2013), 'Particle Urbanity', Architecture Ireland (No. 271).

Peer Reviewed Posters

Invited Seminars


Mee, A (2014), Spatial Complexity and Chaos. Invited Seminars, Complex and Adaptive Systems Laboratory (CASL), UCD.
Bibliography

Note: Bibliographical references of the Appendices are contained in Volume One.


Boyko CT, Cooper R, Davey CL, et al. (2010) *Informing an urban design process by way of a practical example*.


Burke NT. (1972) Dublin 1600-1800: a study in urban morphogenesis.


Dekay M. (2012) Using design strategy maps to chart the knowledge base of climatic design: Nested levels of spatial complexity. 28th International PLEA Conference. Lima, Peru: Pontificia Universidad Catolica del Peru (PUCP).


Hillier B. (1996) *Space is the machine; A configurational theory of architecture*, USA: Cambridge University Press.


Knafl KA and Breitmayer BJ. (1989) Triangulation in qualitative research: Issues of conceptual clarity and purpose. *Qualitative nursing research: A contemporary dialogue*: 193-203.


Larkham P, Jones, Andrew (2015) *International Seminar on Urban Form (ISUF).*


Exploring, evaluating and visualising spatial complexity of urban sites

Alan Mee, B.Arch, MRIAI

Submitted in fulfilment of the requirements for the award of Doctor of Philosophy

March 2017

Dublin School of Creative Arts
Dublin Institute of Technology (DIT)

Supervisor: Dr. Noel Fitzpatrick,
Gradcam, Dublin School of Creative Arts, DIT

Volume Two (of Two)
Table of Contents

Appendix A  Morphology of cases ................................................................. 1
   Introduction ......................................................................................... 2
   1.0 Urban morphological complexity ........................................... 6
   2.0 Liberties character area .............................................................. 8
      6.2.1 Liberties morphological description ................................ 9
      6.2.2 Liberties morphological complexity .................................. 22
   3.0 Urban Ballymun ........................................................................ 31
      6.3.1 Ballymun morphological description .................................. 31
      6.3.2 Urban Ballymun morphological complexity ..................... 44
   4.0 Carmanhall .............................................................................. 53
      6.4.1 Carmanhall morphological description ............................... 53
      6.4.1 Carmanhall morphological complexity .............................. 61
   5.0 Techniques for deriving morphological regions ....................... 70

Appendix B  Evaluation Protocols .............................................................. 73
   1.0 Composition protocols ................................................................. 76
      1.1 Urban Form (Protocol 1) .......................................................... 76
      1.2 Land-Use Mix (Protocol 2) ...................................................... 89
      1.3 Density (Protocol 3) ................................................................. 92
   2.0 Configuration protocols ................................................................. 96
      2.1 Integration (Protocol 4) ............................................................. 96
      2.2 Choice (Protocol 5) ................................................................. 97
      2.3 Intelligibility (Protocol 6) ......................................................... 98
   3.0 System protocols .................................................................... 99
      3.1 Patterns (Protocol 7) ............................................................... 99
      3.2 ‘Paths’, (Protocol 8) ............................................................... 101
      3.3 ‘People’, (Protocol 9) ............................................................. 104
   4.0 Note on deriving exploratory complexity maps ....................... 110
   5.0 Note on visibility cluster analysis .............................................. 115

Appendix C  Glossary of Terms ................................................................. 117

Appendix D  Pedestrian Movement Fieldwork ......................................... 131
   Introduction ..................................................................................... 132
   1.0 Liberties character area Fieldwork ........................................... 135
      Timelapse results ....................................................................... 135
      Gate counts results .................................................................... 137
   2.0 Urban Ballymun Fieldwork ...................................................... 139
      Timelapse results ....................................................................... 139
      Gate counts results .................................................................... 141
   3.0 Carmanhall Fieldwork .............................................................. 143
      Timelapse results ....................................................................... 143
      Gate counts results .................................................................... 145

Appendix E  Syntactic Analysis of Dublin .................................................. 147
   Introduction ..................................................................................... 148
   1.0 Dublin Axial Map 2012 ................................................................ 156
   2.0 Numbers of axial lines .............................................................. 161
Addendum : Case results visuals

Introduction

Appendix F  Visualising Spatial Complexity

Introduction

Appendix G  Applications Reports

Introduction

Appendix H  Case study research design options

Introduction

Addendum : Case results visuals
List of Figures

Figure AA-1 Sketch of streets in power law distribution evaluation 9
Figure AA-2 Categorization of the Liberties character area 15
Figure AA-3 Plan sub-units of the Liberties character area 16
Figure AA-4 Categorization of the Liberties plots 20
Figure AA-5 Liberties character area outline and LAP boundaries 21
Figure AA-6 Power law distribution of Liberties streets 23
Figure AA-7 Passive volume ratio of Liberties streets 24
Figure AA-8 ABCD street type of Liberties streets 25
Figure AA-9 Plot types of Liberties 26
Figure AA-10 Plots per hectare of Liberties 27
Figure AA-11 Urban blocks per hectare of Liberties 28
Figure AA-12 Junctions per km sq. of Liberties 29
Figure AA-13 Table of urban Ballymun streets (PLD evaluation) 31
Figure AA-14 The plan-units of Ballymun 36
Figure AA-15 Tissue sample analysis of Ballymun 41
Figure AA-16 Overall Urban Ballymun context 42
Figure AA-16 Plot Taxonomy and Plot Type for Urban Ballymun 43
Figure AA-17 Power law distribution of Ballymun streets 45
Figure AA-18 Passive volume ratio of urban Ballymun 46
Figure AA-19 ABCD street type analysis of urban Ballymun 47
Figure AA-20 Plot type analysis of urban Ballymun 48
Figure AA-21 Plots per hectare of urban Ballymun 49
Figure AA-22 Urban blocks per hectare of urban Ballymun 50
Figure AA-23 Junctions per km sq. of urban Ballymun 51
Figure AA-24 Table of Carmanhall streets (PLD evaluation) 53
Figure AA-25 Carmanhall Plan Units 57
Figure AA-26 Plot Taxonomy and Plot Type for Carmanhall 58
Figure AA-27 Morphogenesis at Carmanhall (top) 60
Figure AA-28 Power Law Distribution of Streets Carmanhall 62
Figure AA-29 Passive volume ratio Carmanhall 63
Figure AA-30 ABCD street type analysis Carmanhall 64
Figure AA-30 Plot type analysis Carmanhall 65
Figure AA-31 Plots per hectare Carmanhall 66
Figure AA-32 Urban blocks per hectare Carmanhall 67
Figure AA-33 Junctions per km sq. Carmanhall 68
Figure AA-34 All cases: Plot pattern and spatial complexity compared 69
Figure BB-1 PVR Image from (Salat, 2011) 85
Figure BB-2 Sample Image of gate count location, Liberties character area 108
Figure BB-3 Sample Image of gate count recording sheet, Liberties character area 109
Figure DD-1 Pedestrian footfall and local choice 135
Figure DD-2 Sketches of street complexity analysis, Ballymun 139
Figure DD-3 Gate count location Carmanhall: view (l), and plan (r) 143
Figure EE-1 Sample of configurational data limitations (1) 154
Figure EE-2 Sample of configurational data limitations (2) 155
Figure EE-3 Dublin City configuration compared 156
Figure EE-4 Dublin Axial Map 2012 157
Figure EE-5 Dublin Axial Map 2012 Attributes Summary 158
Figure EE-6 Dublin Axial Map 2012 Overall Integration 158
Figure EE-7 Dublin Axial Map 2012 Liberties highlighted 167
List of Tables

Table AA-1 Table of Liberties streets (PLD evaluation) 8
Table AA-2 Morphological periods of the Liberties 13
Table AA-3 Morphological periods and Plan Units of the Liberties 14
Table AA-4 Morphological periods categorization, Ballymun context 35
Table AA-4 Scheer’s urban morphological tissue definitions (Scheer, 2001, 2003) 40
Table AA-4 Morphological periods of Sandyford 59
Table DD-1 Indicators of Pedestrian Movement Network Complexity 134
Table EE-1 Dublin whole city attributes compared 159

Note: Bibliographical references of the Appendices are contained in Volume One.
Appendix A  Morphology of cases

Urban Analysis and Design Evaluation

(PhD Appendix)

For

Evaluation of spatial complexity of urban sites
Introduction

As part of investigating urban morphological complexity of urban sites, the need for full description of the urban morphological development of the cases emerged as a requirement of the research. However, the primary description tool, (a textual, theory-driven and historical interpretative analysis), was considered to form a more appropriate qualitative background analysis, rather than a foregrounded central argument. For this reason, the first Appendix is a descriptive account of the morphology of the cases, including development of the historical background of the case sites.

The guiding ‘paradigm’ in urban compositional analysis in this study is the urban morphology analysis paradigm (Gauthier, 2006). The primary compositional theory considered in this paradigm, urban morphology, is defined as “the study of the physical or built fabric of urban form, and the people and processes shaping it” (Larkham, 2015:676). Urban morphology is employed as a research method to examine time-dependant changes in urban form in the urban built environment, though it has been described as ‘not well understood or used in planning or urban design practice’ (Kropf, 2014:70). As this study focuses on a static evaluation of urban sites, the urban morphological description of development of the urban sites has been recorded in this separate Appendix, to provide background to the more empirical evaluation of urban morphological complexity in Chapter Six.

In this study, different methods apply, depending on the urban context. Here, three are proposed. Two of these are considered suitable to the contexts of the case sites, (which are described in more detail in Chapter Five). These two methods are, firstly Conzenain (historico-geographical approach), secondly, typological (or typomorphological)
analysis. A further, third, set of methods are considered as suitable to the three case sites, to evaluate urban morphological complexity ‘metrics’. Other morphological analysis approaches are ruled out, as either too abstract (eg. cellular automata or ‘cell’, see Oliveira, 2015:73), or too mathematical (eg. fractal morphology analysis, see Haghani, 2009) for use in urban design practice. The three methods are now briefly described, with reasons for their selection.

The first urban morphological analysis method adopted in this study, the Conzenian historico-geographical analysis method, categorises components of the urban landscape according to the methods of historical geographer, M.R.G. Conzen (Conzen, 1981: 80). These methods were developed through his extensive research on towns in England and elsewhere, and based on his field surveys and archive research. Conzenian historico-geographical analysis of urban structure/form is employed here at macro scale, as distinct from the other three major approaches identified in urban morphology: spatial analytical, configurational, and process typological (Kropf, 2009:109). Historico-geographical analysis methods are chosen in preference to the others partly because the level of detail remains at the macro scale (unlike for example, process typological) so connections between the case sites and the larger context can be easily demonstrated. Configurational aspects are analysed later in this exercise, as the second of three issues of spatial complexity evaluated. Spatial analytical approaches involve extensive modeling exercises, which are beyond the scope of this research. The Conzenian approach, like the complexity sciences approach, emphasizes a historical narrative as part of a holistic explanation for observed phenomena.
In particular, the method involved is defined as ‘map regression’, or comparative chronological analysis, whereby growth of settlement (changes in extent) is identified, which also helps to identify character areas. Map regression involves analysis of a chronological sequence of historic maps reproduced at the same scale, in transparent overlays, to allow for identification of growth in the settlement and internal modifications to street, plot or building patterns. This is considered to be a fundamental tool of urban morphological analysis and in assists in understanding the complexity of the built environment (Kropf, 2011:397). In this case of applying the map regression method, a few qualifications are required. Historically understood plan units (See Glossary of Terms, Appendix C) are derived here (in this Appendix) mainly from secondary sources, and are combined in a new way to constitute a ‘timelapse’ type visual representation of change over time in the city. This is important because observation of increasing numbers, geometrical variety and compositional complexity of the plan units helps to demonstrate an overall reading of one aspect of spatial complexity as it is changing, whether increasing or decreasing, over time. Conzenian historico-geographical analysis methods are seen as suitable approaches to this study for more historically urban, inner-city conditions of Dublin (Liberties).

The second urban morphological analysis method adopted in this study, typological (or typomorphological) analysis, has been defined as ‘the study of urban form derived from typical spaces and structures’ (Moudon, 1994:289). It is considered to encompass all scales of the built landscape, and to characterize urban form as a dynamic and continuously changing entity. Relevant research for this thesis includes typomorphological analysis at architectural scales (Caniggia, 1976), typological analysis of American urban form (Scheer, 1998, 2001, 2010, 2104), and the analysis of
other American suburban landscapes (Moudon, 1994). Typological (or typomorphological) analysis methods are seen as approaches suitable to this study for less historically urban, suburban (Ballymun) and outer suburban conditions of Dublin (Sandyford).

One criticism of the morphological analysis approach is that: ‘urban morphology is a recent field of scientific enquiry with a restricted research community, not comparable to those of other social sciences let alone those of the natural sciences’ (Serra, 2013:2). Serra further succinctly summarises Marshall’s criticisms of current ‘uncertainties’ regarding ‘which morphological attributes to consider, (on) the definition of the desirable degree of resolution of the classification, on the classification criteria themselves or even on the lack of consistency of the adopted terminology of types (Marshall, 2005)’ (Serra, 2013:2). For these reasons, the first two urban morphological analysis methods described are confined to analysis of the case contexts only (in Chapter Five), in advance of the third method, the empirical evaluation of urban morphological complexity of urban sites, which is applied to each of the three cases.
1.0 Urban morphological complexity

The concept of urban morphological complexity is briefly discussed here in advance of presenting results for the three case contexts. In defining this concept, Conzen’s historico-geographical approach to town-plan analysis seeks to uncover the morphological complexity of the town, based on an analysis of the plan, and especially the development of the settlement over time, regarded as a ‘time sequence’ (Conzen, 1960:9). This is connected to ‘map regression’, a concept discussed later in this Appendix. However, Conzen does not expressly define the concept of urban morphological complexity. Adolphe (2001) investigates urban morphological complexity in relation to environmental performance of cities, defining this as related to five ‘morphological indicator’ indicators (physical consistency, spatial consistency, measurability, legibility and comparability) (Adolphe, 2001:184). However, Adolphe also argues that urban morphological complexity ‘can be reduced to a model with nine dimensions: density, rugosity, porosity, sinuosity, ‘compacity’ (compactness), contiguity, occlusivity, solar admittance, and mineralization’ (Adolphe, 2001:186), which does not help to clarify a concept of urban morphological complexity, but shows it is open to multiple and sometimes confusing interpretations. As well as five ‘morphological indicator’ indicators and nine ‘dimensions’, Adolphe also develops a ‘data format, consisting of ‘six classes of object’ (Adolphe, 2001:193). Adolphe also develops mathematical equations related to the indicators, dimensions and classes, and concludes that a model based on indicators of environmental performance can uncover the influence of urban morphological complexity on outdoor climatic conditions. However, in general, this approach would not be usable for urban design practice, due to over-complicated structure. Haghani (2009) studied urban morphological complexity, stating:
The uniqueness of each urban form can be identified by measuring the level of complexity that it exhibits. Aerial photos used as a means of remote sensing data for textural urban analysis can provide a vast amount of information about underlying morphological complexity including building density, street frequency, street size, characteristic building materials, density, type, clustering of vegetation, etc, which can be analysed together or separately at any required city scale (Haghani, 2009:271).

Haghani investigated urban morphological complexity using fractals (2009) and later discussed the concept in relation to urban investigation methods (Haghani, 2013:60) but again fails to define the term. He does however agree with Ley (2012) that both quantitative and qualitative indicators are necessary in the evaluation of urban morphological complexity. Cooper explores urban morphological complexity through fractal based townscape evaluation techniques including analysis of street vistas, street elevations, skylines and building lines (Cooper, 2000). In conclusion, urban morphological complexity is an ill-defined concept for urban analysis, but could be extended for use in urban analysis and evaluation in urban design practice.
2.0 Liberties character area

<table>
<thead>
<tr>
<th>Street Number</th>
<th>Name</th>
<th>Width</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Covered market</td>
<td>30m</td>
<td>A (1)</td>
</tr>
<tr>
<td>2</td>
<td>High St</td>
<td>28m</td>
<td>B (2)</td>
</tr>
<tr>
<td>3</td>
<td>Nicholas Patrick St</td>
<td>28m</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Bridgefoot St</td>
<td>23m</td>
<td>C (3)</td>
</tr>
<tr>
<td>5</td>
<td>St Lukes Ave</td>
<td>22m</td>
<td>D (1)</td>
</tr>
<tr>
<td>6</td>
<td>Bridge St Upper</td>
<td>20m</td>
<td>E (2)</td>
</tr>
<tr>
<td>7</td>
<td>Thomas St</td>
<td>20m</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Oliver Sean St</td>
<td>19m</td>
<td>F (5)</td>
</tr>
<tr>
<td>9</td>
<td>Cook St</td>
<td>18m</td>
<td>C (1)</td>
</tr>
<tr>
<td>10</td>
<td>Coombe Court</td>
<td>16m</td>
<td>H (1)</td>
</tr>
<tr>
<td>11</td>
<td>Marrowbone Lane</td>
<td>14m</td>
<td>I (1)</td>
</tr>
<tr>
<td>12</td>
<td>Mount St</td>
<td>13m</td>
<td>J (7)</td>
</tr>
<tr>
<td>13</td>
<td>Coombe</td>
<td>13m</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Shalboson St</td>
<td>13m</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Garden Lane</td>
<td>13m</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>John Dillon St</td>
<td>13m</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>Dillon Place Sch</td>
<td>13m</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>St Nicholas Place</td>
<td>13m</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Francis St</td>
<td>12m</td>
<td>K (9)</td>
</tr>
<tr>
<td>20</td>
<td>Parlios</td>
<td>12m</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>William Kee</td>
<td>12m</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>Reginald St</td>
<td>12m</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Great St</td>
<td>12m</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Catherine St</td>
<td>12m</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Agh St</td>
<td>12m</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>Garrison Hall</td>
<td>12m</td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>Thomas Davis St Sch</td>
<td>12m</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>Dean Swift Sq</td>
<td>11m</td>
<td>L (2)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Street Number</th>
<th>Name</th>
<th>Width</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>29</td>
<td>Lodi St</td>
<td>10m</td>
<td>M (2)</td>
</tr>
<tr>
<td>30</td>
<td>Marshall Lane</td>
<td>10m</td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Appetite Inn</td>
<td>10m</td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>St Augustine St</td>
<td>10m</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>St Johns Lane West</td>
<td>10m</td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Marks Alley West</td>
<td>10m</td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>Squallion</td>
<td>9m</td>
<td>N (2)</td>
</tr>
<tr>
<td>36</td>
<td>John St</td>
<td>9m</td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>Thomas Court</td>
<td>7m</td>
<td>O (5)</td>
</tr>
<tr>
<td>38</td>
<td>Hatchng Lane</td>
<td>7m</td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>East St Insh</td>
<td>7m</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>Swifts Alley</td>
<td>7m</td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>St Imnert St</td>
<td>7m</td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Powers Sq.</td>
<td>6m</td>
<td>P (5)</td>
</tr>
<tr>
<td>43</td>
<td>Havelor St West</td>
<td>6m</td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Intire Alley</td>
<td>6m</td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>Mount Place</td>
<td>6m</td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>Schooling Lane West</td>
<td>5m</td>
<td>Q (4)</td>
</tr>
<tr>
<td>47</td>
<td>St Michael's Close</td>
<td>5m</td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Back Lane</td>
<td>5m</td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Cl Pangay Su.</td>
<td>5m</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Havelor Lane</td>
<td>4m</td>
<td>S(2)</td>
</tr>
<tr>
<td>51</td>
<td>Wise St</td>
<td>4m</td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>Baxa Court</td>
<td>4m</td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>St Catherine La W</td>
<td>3m</td>
<td>S (2)</td>
</tr>
<tr>
<td>54</td>
<td>Havelor Sq.</td>
<td>3m</td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>Moorway Yard</td>
<td>2m</td>
<td>T (5)</td>
</tr>
<tr>
<td>56</td>
<td>Comerack Alley</td>
<td>2m</td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>Schooling Lane West</td>
<td>2m</td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>Swan Alley</td>
<td>1m</td>
<td>U (1)</td>
</tr>
</tbody>
</table>

Table AA-1  Table of Liberties streets (PLD evaluation)
6.2.1 Liberties morphological description

Conzenian urban morphological analysis methods are employed in this section, (see Section 4.3.1.1, which also describes why this analysis method is appropriate to this historic urban context). Two particular aspects of Conzenian analysis which reveal evidence of compositional complexity of the urban context are described: firstly, town plan analysis, and secondly, analysis of derived plan-units of the Liberties\(^1\). The purpose of this section on the Liberties urban quarter, as the morphological context of the Liberties character area (the case site), is to make a descriptive evaluation of the

---

\(^1\) According to Conzen, ‘plans’ are any large-scale maps showing essential detail of (town) layout in recognizable and measurable form (Conzen, 1968:115). The term ‘town plan’ means ‘the cartographic representation of a town’s physical layout reduced to a predetermined scale, but in the literature it has also come to denote the physical layout itself’ (Conzen, 1968:116). In defining town plan analysis, Conzen states: ‘streets, plots and buildings integrate in space and time to form individualized combinations of a dynamic rather than an static nature, recognizable in the town plan as distinct plan units. These again combine to form the major plan divisions of a town. Recognition and comprehension of the whole plan structure in these terms form the subject of town-plan analysis’ (Conzen, 1968:117).
compositional complexity of this specific urban site context as well as the case site, through a narrative account. This is based on urban morphological analysis, and forms the background to more purely quantitative evaluations of the later sections of this analysis of the case. Compositional analysis theory and methods, including urban morphological analysis techniques, (see Chapter Four, Section 4.3.1.1) deal with primarily compositional and geometrical aspects of form as represented, for example in scale plans of urban sites, featuring absolute position, lengths, areas and orientation. In the first unit of study introduced here, a local character area is contained within a historic inner city neighbourhood, the Liberties quarter. The analysis presented here does not depart from the official planning designation or geographical outline of the local character area called ‘Liberties’ in the relevant official designation. It is evident that ‘the greater the morphological complexity of an area, the greater will be the variations between different attempts to delimit character areas’ (Birkhamshaw et al, 2012:6). Although this observation could also apply to town plan and plan-unit analysis, it is the prior lack of focus by research on these aspects of the Liberties which is of interest, because it can demonstrate spatial complexity, and therefore value, of the historic urban environment. Results demonstrating the presence of morphological patterns are now presented in these two parts.

Firstly, in relation to morphological description of the Liberties as context for the later urban morphological complexity ‘metrics’ or evaluation in this Chapter, in brief introductory terms, the urban site described here as the Liberties\(^2\) is partly located within the original medieval town plan of Dublin, south of the Liffey, the river which

\(^2\) The urban site defined as the Liberties in this Thesis, as described in Chapter Four, is based on the Character Area spatial definition contained in the Liberties LAP, 2009, and so not an exact historical definition, although there are numerous variations on exact geographical definition (for example, see ‘Liberties and Environs’ Map in Casey’s book, (2006:598), as compared with McCullough’s more spatially specific description, (McCullough, 2007:100)).
divides the city into north and south sides. Previous study of urban form of Dublin using a morphological approach and town plan analysis has included Simm’s studies of medieval Dublin (1979, 1992), and her analysis of primary (or origin) plan units of Medieval Dublin in conjunction with Brady (2001). The Liberties is considered to form part of the second morphological plan unit of development of Viking-age Dublin city, (Brady, 2001:153) developed following the first (origin) plan unit, which includes a small area north and west of Dublin Castle (See Fig. AA-2). Originally a medieval suburb, located just outside of the original walled city, the Liberties area is west of, and close to, the crossing points of ancient routes leading from the rest of the country towards the walled city of Dublin. ‘Áth Cliath’ is the name given to the likely primary original secular settlement in Dublin, located in the north-east part of the present Liberties. This settlement was located directly south of, above, and close to the first ford (river crossing) of the Liffey. Hence, this location has been an origin site of historic urbanity in Ireland.

A morphological approach to analyzing the layout and character in the first century of the Liberties area, described as ‘the western suburb of medieval Dublin’ (Duddy, 2014:157) emphasizes the growing street pattern, the emergence of streetscape and contiguous nature of burgage plots in the area (Duddy, 2014). The Dublin Environmental Inventory project (1993)(which included buildings of the city centre) was influenced by Conzen’s method of dividing the urban fabric into plots, streets and plan forms (Kealy, 2008:41) and considered inner city Dublin (within the canals). Burke’s study of morphogenesis³ (Burke, 1972) is an exception to the other studies

³ The definition of morphogenesis – ‘the study of the origin of urban areas’ is contained in Conzen’s seminal study of the town of Alnwick (Conzen, 1960).
mentioned, in including detail original graphical mapping of the development of the historic urban form in Dublin. The other sources are primarily historico-geographical descriptive and interpretative accounts of buildings and streets, including change over time, with limited analytical mapping of the urban site of Dublin or the Liberties as a whole (with the exception of McCullough (2007), who extensively describes the urban history of the area in visual, mapping and written form). In conclusion, previous study of urban form of the Liberties using town plan analysis has been limited.

**Town plan analysis**

This first aspect of analyzing the town plan normally comprises three elements: streets, plots and buildings (Conzen, 1960:4)(Slater, 1990, 2005)(Simms, 1992). However, Kropf (2014) argues that neither Conzen nor Caniggia (with Maffei) resolved the status or hierarchy of importance of the urban block (or ‘street block’ in his description), another possible element of analysis. Kropf also does not locate this important element in his proposed compositional hierarchy of built form (Kropf, 2014:54). However, other urban design researchers give prominence to the urban block (Panerai et al, 2004) (Llwyellyn Davies, 2004) and some consider the geometrical qualities (length, width, size) of the urban block to be important in the analysis of the city generally (Jacobs, 1961:191), in making more precise morphological categorization (Steadman, 2014:341), and in projective urban design (Llwyellyn Davies et al, 2004)(Tarbatt, 2012:23). For this reason the compositional analysis of the urban block is also undertaken as a fourth element in this study, and regarded as a separate and important aspect of compositional complexity.
### Morphological periods of the Liberties

<table>
<thead>
<tr>
<th>Morphological Period</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>One To 1600</td>
<td>As regards the first morphological period, the years immediately after Dublin’s Charter of urban liberties of 1192 are considered important in the genesis of the area, as one of its provisions was that citizens could build outside the town walls (Casey, 2005:15). Casey describes a ‘medieval peak’ in city population around 1300, of 11,000 persons approximately, and relates this to the Henrician Reformation (c.1540) which ‘followed more than two centuries of morphological stagnation in Dublin (Casey, 2005:17). The end of the first morphological period, the years to 1600, can therefore be associated in urban form terms firstly with the development of the medieval city, and secondly with a long period of stagnation up to around 1600. Speed’s map (1610) is generally regarded as the earliest extant map of the city, (Casey, 2005:16) and provides a bird’s eye view of the late medieval city at the close of this first morphological period of the Liberties. Thomas street, Francis street, St. Thomas Abbey, and three proto-urban blocks to the north of Thomas street close to the city wall are the first period’s major urban form features.</td>
</tr>
<tr>
<td>Two 1600 – 1660 ‘Early Renaissance’</td>
<td>In the second morphological period of the Liberties (1600-1660), the consolidation of Francis Street, as a part of St Sepulchre Liberty, is apparent. In this period, as well as the emergence of the south east suburbs of Aungier Estate and Stephens Green, (Burke, 1972, Fig.13) and the development of the north-western suburbs of the walled city, north of the river, (Burke, 1972, Fig.14), the area of the east side of the Liberties was consolidated as an industrial quarter around the Poddle river.</td>
</tr>
<tr>
<td>Three 1660-1727 ‘Renaissance’</td>
<td>The third period (1660- 1727) is associated with the laying-out of Meath Street and surroundings, as part of the separate Liberty of St. Thomas (end of 1600’s), and by the development of Newmarket (1670’s onwards). At the start of the third period, Craig describes a population growth of ‘at least five or six times, and perhaps more’, between 1660 and 1710, (from less than 15,000 to 75,000), and suggests this growth was associated with industrial development and expansion, which he argues took place largely in the ‘haphazard industrial suburb round Cork Street and the Coombe’ in other words, the Liberties. He then describes how ‘the large weavers’ colony to the south-west put a stop to fashionable interest in that quarter’ (Craig, 1952:84).</td>
</tr>
<tr>
<td>Four 1727-1800 ‘The Age of Improvement’</td>
<td>The fourth morphological period (1727-1800) is characterised mainly by urban consolidation, between the separate liberties and west of Meath St. And includes the formation of intermediate streets, lanes and development of new buildings, a development phase. Numerous initiatives of the Wide Streets Commissioners for the proposed area street widenings and controlled reorganisation of public spaces (Burke, 1972, Fig. 25) including around Christchurch, Cornmarket and the north end of Meath Street, around the Poddle, and provides a bird’s eye view of the late medieval city at the close of this first morphological period of the Liberties. Thomas street, Francis street, St. Thomas Abbey, and three proto-urban blocks to the north of Thomas street close to the city wall are the first period’s major urban form features.</td>
</tr>
<tr>
<td>Five 1800-1898</td>
<td>As regards the start of the fifth morphological period, numerous authors agree on the clear division, in urban historical (Craig,1952), architectural (Casey, 2005) terms around 1800, into periods before and after the Act of Union (1801), after which the Irish Parliament was absorbed into that of the United Kingdom. Tenements1 are a feature of urban historical descriptions after this date (McCullough, 2007)(Burke, 1972), right up to 1880, the date of the commencement of ‘planned industrial workers’ and ‘social’ housing’ (DCT, 2008:7) in the Liberties quarter. Therefore the years 1800-1880 are described as the tenement stage. The second stage can be called ‘modernist city’, used not in the sense associated with an architectural movement or style, but in a broader sense related to urban and spatial form. Together, the tenements stage and modernist stage form the fifth morphological period proposed (1800-1888).</td>
</tr>
<tr>
<td>Six 1898-2008 Growth Period</td>
<td>The final (sixth) morphological period (1898-2008) covers the late C20 Irish economic boom, which had significant impacts on the morphology of the liberties area, mainly in the widespread introduction of new forms, the most prominent of which are large footprint apartment blocks, and impacts of road widenings on plot numbers and types.</td>
</tr>
</tbody>
</table>

---

1 Tenements are described by Brady & Simms as ‘a common housing form in many cities (other than Dublin) especially in Scotland. The name derives from the medieval burgage plot, and came to denote the house built at the head of the plot. It came to be associated with high density high-rise buildings, built to maximize plot use’ (Brady & Simms, 2001:187). In Dublin, unlike other cities, few tenements were purpose built, and were more likely to comprise large ‘filtered down housing of the rich who had abandoned once favoured areas’ (Brady & Simms, 2001:187). While well established in the poorest areas of the city (like the Liberties) by the beginning of the nineteenth century, by 1900, there were over 6,000 tenement houses in Dublin, on which one-third of the entire population lived (Keane, 1994:1).  

2 The Thomas Street and Environs Architectural Conservation Area Report refers to ‘a unique concentration of planned industrial workers housing schemes in the area’, dating from the late C19 and early C20 (Dublin Civic Trust, 2009: 7).
### Table AA-3  Morphological periods and Plan Units of the Liberties

#### Liberties Morphological periods and Plan Units Table

<table>
<thead>
<tr>
<th>Relevant City Plan Unit</th>
<th>Liberties Plan Unit Types</th>
<th>Number of Plan sub-units</th>
<th>Morphological Period</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. City Plan Unit One</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. City Plan Unit Two</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. City Plan Unit Three</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Urban Fringe Belt</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Newmarket (See Note 2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Mid-Late Victorian Infill</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Meath St. to Francis St.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Late Victorian Infill west of Meath St.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Pre-modern residential accretions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artisans Dwellings, Meath St.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Pre-modern residential accretions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Artisans Dwellings, John Dillon St.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Modern residential accretions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Patrick St. (outside ACA)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note 1: Only City Plan Unit Two is within Liberties Character Area

Note 2: Definition of Fringe Belt unit as ‘non-planned’ (Von Der Dollen, 1990:321) suggests Newmarket should not qualify as such, but planned existing remaining frame is minimal.
The plan-units of the Liberties

The second aspect of town plan analysis which demonstrates the presence of morphological patterns is the plan-units. From the definitions and descriptions of complexity of urban form in Conzen’s writings (Conzen, 1960, 1968, 1982) and other urban morphological sources (Whitehand, 1981, 2007, 2014) it is apparent that evidence of both quantity and quality of individual plan-units is one way to demonstrate (spatial) complexity of the town plan in a historic townscape. For example Conzen, in describing thirteen major and forty-nine sub-types of plan-units in the small market town of Alnwick, shows how these ‘give a general idea of the morphological complexity’ of the town (Conzen, 1960:108). Analysis leads to an assessment of the current compositional complexity of town plan, through (1) assessment of quantity, (2) number of hierarchical orders and (3) clustering, and therefore it is argued, complexity of plan-units. As regards quantity, in the Liberties there are ten plan-units overall (including one intra-mural) identified in this analysis of historic maps and fieldwork observation.

![Diagram of Liberties Plan Units]

**Figure AA-2  Categorization of the Liberties character area**

Nine plan units are indicated (See also Appendix Table AA-3 of Liberties Plan Units)
Plan sub-units

As regards number and hierarchy, approximately seventy plan sub-units identified in the Liberties character area (See Fig. AA-3). Presence of plan sub-units is a second indicator of compositional complexity of the town plan in this urban site. The land area is low, at 0.34 km$^2$ (84 acres). As a rough comparison, Oliveira’s study of Rua de Costa Cabral, covers an area of 0.35 km$^2$ (87 acres), and contains fourteen first-order plan-units (which he calls morphological regions) and approximately 134 ‘sub-regions’ (equivalent of plan sub-units) (Oliveira, 2015:77). In another comparison, Baker and Slater’s study of medieval intra-mural Worcester identifies 12 plan-units (Baker and Slater, 1992:50), in a land area of 0.40$^2$ km, approximately twice the size of walled medieval Dublin.

![Plan sub-units of the Liberties character area](image)

**Figure AA-3  Plan sub-units of the Liberties character area**

Seventy identified plan sub-units are indicated (See also Appendix Table AA-3, of Liberties Plan Units)

---

4 Plan sub-units are identified following Oliveira’s method of considering the ground plan, building fabric (both age and volume/height) and land use (though to a lesser extent)(Oliveira, 2015:76).

5 According to Oliveira, Rua de Costa Cabral is a part of the city of Porto developed in the nineteenth century, containing twelve street blocks, and 671 plots (Oliveira, 2015:74). The area is close to a periphery motorway which circles the city, and has a distinct difference in urban character and form when compared to the Dublin urban site.
Plan units discussion

As regards the first proposed indicator of compositional complexity, the Liberties can be considered, in broad terms, to have a similar quantity of plan-units to a typical part of urban Oporto, but less than the medieval plan of Worchester, and so can be regarded as compositionally complex in terms of quantity of plan-units. As regards the second proposed indicator of compositional complexity, number of hierarchical orders, in the Liberties case, unlike the Porto study (which identified four hierarchical orders of sub-unit) only three hierarchical orders are identified, which may be an indicator of low spatial complexity, relative to other locations, subject to further analysis by others. While some older and more complex plan-units have high numbers of sub-units (eg. Plan-unit 1, Thomas Street, with 25 sub-units), the literature suggests that presence (quantity) of morphological plan sub-units alone is not an indicator of compositional complexity. Other criteria for identifying regions of intermediate rank (and thus evaluating complexity) should also be considered, such as the nature and quality of the building fabric, and land-use (Oliveira, 2015:77). For example, in the Liberties, as regards building fabric, plan-units 7 and 8, both purpose designed social and industrial workers housing of high architectural quality, have no plan sub-units, as they were conceived of as ‘urban design units’. Nearby, plan-unit 9 also has no plan sub-units, but this plan-unit is mostly the result of a once-off development of Section 23 tax-incentive apartment blocks in leftover sites after roads widening, and in the absence of a coherent spatial plan for redevelopment of vacant sites. The architectural quality of this type of apartment block has been criticized, including the small sizes of accommodation, long corridors and lack of balconies (McDonald, 2000:269). So, while the former sub-units are officially categorised as residential conservation areas, in recognition of

---

5 Section 23 is a tax-incentive scheme first initiated under the 1986 Urban Renewal act, (Kitchin et al, 2012:1313) and involves designation of certain areas of cities, towns and other locations in Ireland for tax incentives to aid development and urban renewal (Williams, Boyle, 2012:6).
architectural, historical and urban design qualities, the latter sub-unit has been excluded from the current designation of the Thomas Street and environs Architectural Conservation Area (ACA), implying a lower design quality of the development. Similarly, in relation to land-use, while plan-units 7 and 8 are primarily high-density low-rise residential areas, plan-unit 1 has a diverse mix of commercial, institutional, residential and amenity land-uses. As regards the third proposed indicator of compositional complexity, clustering of plan-units, this analysis should ideally reveal high numbers of plan-units in close proximity to each other in certain (historic or architecturally) highly complex and heterogeneous urban environments. Thus, clustering is understood in this study as an indicator of spatial complexity of the urban site. In the Liberties, three sample clusters are identified from a qualitative visual analysis of boundary lines to illustrate that clustering exists in the area (See Fig Aa-3). One further minor outcome of the analysis of plan-units reveals minimal overlap in spatial designation terms between the official LAP character area boundary (the case site boundary) and the plan-units as identified in this study’s analysis (See Fig AA-5). This could indicate that current official urban design designation of the urban site does not follow rigorous morphological analysis. In conclusion, all three indicators suggest compositional complexity.

Plot Pattern Analysis

The second aspect of the town plan analysed is the plot pattern. Plot is defined as ‘a parcel of land representing a land-use unit defined by boundaries on the ground’ (Conzen, 1961:128). It is a plan element. Conzen’s statement that ‘The full complexity of topographical development of towns demands that urban morphological investigation
proceed at the most detailed level possible’ foregrounds his forensic approach to analysis. His further claim makes clear his position on the plot:

‘modern study of the historical townscape has established that the individual plot is the most appropriate spatial scale at which to ground the investigation of morphological processes, because it represents the smallest expression of undivided ownership, and therefore decision making, within the townscape’

(Conzen, 2004:74)

Tarbatt contrasts the position of the plot in common law jurisdictions (such as England, Wales and Ireland), where ‘the pattern of land division is effectively a product of competing interests’ with that of USA and Australia, where ‘regulation of subdivision (into plots) by a central authority facilitates the compilation of an urban cadastral map, and more importantly, allows the implications of subdivision on built form and on the overall pattern of subdivision to be considered’ (Tarbatt, 2012:22). In considering compositional complexity, the plot is the smallest unit of analysis of the town plan. Here the method to study the plot involves making graphical representations of geometrical qualities by abstracting only the plot outlines, extracted from planning application files, historic map analysis, and fieldwork. The Liberties character area contains 1,070 separate individual plots, equating to 3,147 plots per km sq. Plot size and density, as indicators of intensity, are measured in one urban design study, and contribute to a group of other quantitative analysis tools for neighbourhoods (Song, Knaap, 2004) and this aspect is captured in the later compositional analysis of the next section. Liberties character area plot size and composition varies widely, from a single large urban block which is also just three plots at Cornmarket, (St. Audeons Churches and grounds, and a public park) to a small number of 3m wide plot frontages, some of

---

7 This method is described in more detail in Appendix B, ‘Urban Morphological Analysis Protocol’ (1AA), Taxonomy Protocol.
the narrowest widths in the city. There is also a notable diversity in plot composition characteristics: frontage (width), configuration and length. (See Fig. AA-4, as demonstration of one embedded case unit around Cornmarket)

Figure AA-4  Categorization of the Liberties plots

See also Fig. 6-2, Chapter Six, Volume One, for plan layout.

Building arrangement

The third aspect of the town plan analysed, the buildings pattern, in town-plan analysis, is defined as: ‘the arrangement of existing buildings, ie. their block-plans\(^8\) in a built-up area viewed as a separate element complex of the town plan’ (Conzen, 1969, p. 123). Many buildings have diverse characteristics: non-uniform plan types, varying numbers of floors, different numbers of individual households. The distribution of basements is also uneven, and architectural styles vary substantially within the urban site.

\(^8\) Separately, Conzen defines ‘block plan’ as follows: ‘The area occupied by a building and defined on the ground by the lines of its containing walls. Loosely defined as the ‘building’ in town-plan analysis. It is a plan element’ (Conzen, 1969, p. 123). This should not be confused with the building plan. Source: www.urbanform.org, accessed 040516.
Conclusion

Conzen concludes on the Alnwick study that ‘Instead of working backwards from the present confused picture, our morphological analysis has followed the growth of the plan’, in order to overcome the ‘difficult methodological problem’ of the ‘complexity of the existing street-system, plot pattern and building arrangement’ (Conzen, 1960:119). This analysis of the Liberties, without including a full historical analysis of the town plan (of Dublin), has followed a similar approach. In summary, in relation to this second aspect of morphological analysis of the historic plan-units of the Liberties, it can be concluded that plan-unit quantity is high, and that although number of hierarchical orders is relatively low, in international terms, that clustering is evident, and therefore in overall terms that plan-unit analysis reveals high compositional complexity of the case urban site.

Figure AA-5  Liberties character area outline and LAP boundaries
Extents of nine plan units (top l), Liberties character area outline, (top r) and locations where boundaries coincide (bottom).
6.2.2 Liberties morphological complexity

Seven selected measures of urban form, and more specifically ‘metrics’ of urban morphological complexity, are reported on for of the Liberties character area in Chapter Six, ‘Three Case Evaluations’, Section 6.2.2. The seven measures are introduced in Section 4.4.2. ‘Compositional Criteria of spatial complexity’. Here more detail of the result is reported for each measure here: firstly, ‘power law distribution’ of streets (Salat, 2012), secondly, ‘passive volume ratio’ of urban blocks (Salat, 2012), thirdly ‘ABCD street type analysis’ (Marshall, 2005). The fourth, fifth, sixth and seventh measures are: plot type, plots per hectare, blocks per hectare, and junctions per km sq.
1. **Power law distribution of streets**

The power law distribution measure of streets, an evaluation of compositional complexity, evaluated according to Protocol No 2, and is now described for the Liberties Character area. Roads, streets and lanes have been considered to be within the definition of ‘street’ for this analysis, in order to capture the diversity of public thoroughfare type existing in the area. As regards results, while the optimal curve (indicated in red) is not achieved by the line representing evaluated streets in the urban site (blue line), there does appear to be an overall increase in numbers of smaller streets, as compared with larger streets, although the smallest street type, the lane, is mostly missing. From a review of historical accounts and maps, it is evident that these lane types, commonly associated with the area from medieval times onwards, have progressively been closed off or amalgamated into larger urban blocks in the area. In conclusion, though not optimal, the power law distribution of streets analysis indicates a compositionally complex urban site.

![Figure AA-6](image)

**Figure AA-6**  Power law distribution of Liberties streets
2. Passive volume ratio

Salat argues that complex urban fabrics display a much higher passive volume ratio than ‘simple’ ones, and that an increase in passive volume ratio can be an indicator of increased urban complexity of urban blocks (Salat, 2012:104). The estimated passive volume ratio of the urban blocks of the Liberties character area is indicated as approximately 95% (based on Protocol 1C). The estimate is based on visual analysis of a figure ground map at scale 1:1000, and a general awareness of the urban block and building patterns in the area (not including basements), which are generally historic or mid-twentieth century structures, with a recent group of high density apartment blocks around courtyards.

Figure AA-7 Passive volume ratio of Liberties streets
3. **ABCD street type analysis**

This evaluation method categorises street patterns according to quantitatively analysed features of the components. It also has clear applicability for urban design practice. ‘ABCD typology’ analysis is part of Marshall’s wider aim to ‘quantify pattern’ (Marshall, 2005:98), by developing a system of pattern classification of streets, ‘relating to desired formations of urban streets’ (Marshall, 2005:83). Here, in order to be useful for evaluating spatial complexity of urban sites, ‘A’ type patterns are considered to have highest compositional complexity, and ‘D’ type patterns lowest. Using the method outlined in the relevant protocol, results show the Liberties is an ‘A-B’ type area, suggesting high compositional complexity in the street pattern. Berghauser Pont et al (2015:11) have shown that ‘denser, more compact and ‘griddy’ types of streets’ have higher intensity of people walking on the streets.

**Figure AA-8  ABCD street type of Liberties streets**

---

9 However, a separate street network complexity analysis method developed by Marshall (2005) is also used later in this evaluation to more precisely quantify complexity, in connectivity and system terms. Also, Marshall’s separate discussion of configuration related to ABCD classification (Marshall, 2005:98) is not discussed here, in order to concentrate on compositional aspects. Marshall’s concentration on ‘complexity and connectivity’, rather than ‘complexity and composition’ means that the claim of higher compositional complexity of ‘A’ type patterns is not discussed by Marshall.

10 A map at 1:1,000 scale is used to analyse at the scale of the Liberties character area urban site within a red line. The map indicates urban block outlines, and ‘T ratio’ and ‘X ratio’ indicators are generated (Marshall, 2005:98) on the map. (See Protocol No 1D, Appendix B). Then, ‘Cell ratio’ and ‘Cul ratio’ are generated (Marshall, 2005:98) on a separate but similar base map, and results are combined to generate (a) a Nodegram, (b) combined plot ‘box’ (Marshall, 2005:101).

4. **Plot type**

Plot type analysis is used to measure quantitative characteristics of neighbourhoods, and in one study numbers of single-family plots (own-door houses) is an indicator (Song, Knaap, 2007:9). Norton examined one geometric aspect of plot type in Dublin, frontage width, finding clear bands in plot frontage dimensions (Norton, 2016:37). Nedovic-Budic et al (2016:154) measures urban form and land-use for Dublin, but concentrates on the number of residential addresses at a single level (ie. ground floor), and represents this data at large resolution (1km x 1km cell). In this evaluation, the interest is in compositional aspects of plots at urban site scale of resolution, so observed ‘clusters’ of plot types of high and low compositional complexity are studied, as indicated through geometrical aspects. In the Liberties, from a visual analysis of superimposed plots, (taken from an embedded case site around Cornmarket (see also Fig. AA-4, and Fig 6-2, Vol 1) the plot type indicates high relative geometrical complexity of the urban form.

![Figure AA-9 Plot types of Liberties](image-url)
5. **Plots per hectare/ urban grain measure**

Plot size and density, as indicators of intensity, are measured in urban design studies, and contribute to a cluster of other quantitative analysis tools for neighbourhoods (Song, Knaap, 2004). The average width, area, and frontage of traditional Dublin plots are discussed by Norton, in relation to urban grain and diversity of urban centres (Norton, 2016), but these primary urban units have not previously been studied in relation to indicators of spatial complexity for urban design. Norton (2016) has developed a method of measurement of urban grain in Dublin, and provided baseline measures for five different types, related to net plot density per hectare within urban blocks. Using the same measure, the Liberties character area, with 31 plots/ha, has a ‘moderately fine’ description, a relatively high grading in Dublin terms, and thus an indicator of compositional complexity.

---

**Figure AA-10**  
Plots per hectare of Liberties

---

12 Norton distinguishes between ‘fine urban grain’ (small plots comprising 300sqm or less) and ‘coarse urban grain’ (large plots comprising more than 300sqm) (Norton, 2016:115). He also develops a grading matrix for urban grain, dividing types into five categories (Norton, 2016:37).
6. Blocks per hectare

Blocks per hectare (Dempsey, 2008:255), is a commonly used measure in urban analysis and design, selected to help to define a comparable difference in compositional characteristics of urban sites. Norton (2016:143) adopts a density-based approach to analysis of urban blocks per hectare, finding that in two Dublin instances distinct and contrasting conditions occur\(^\text{13}\). The Liberties character area contains 46 urban blocks in 34.2 hectares, that is 1.34 blocks/ha, a figure which is moderately high in Dublin terms, and therefore indicates compositional complexity.

\[\text{Figure AA-11} \quad \text{Urban blocks per hectare of Liberties}\]

\(^{13}\) Norton analyses two areas, finding that Grafton Street area has a finer pattern, with some 15 blocks in a gross study area of 11.4 ha, while the Henry Street area has a much coarser pattern of urban blocks, with 3 blocks in a gross study area of 10.6 ha (Norton, 2016:143).
7. **Junctions per km sq.**

Junctions per km sq. are argued to be an indicator of a ‘successful urban area’ with ‘over 250 in an area of one square mile’ (259 hectares) indicating ‘success’ (Montgomery, 1998:107), that is, approximately one junction per hectare\(^{14}\). In this evaluation a high number of junctions indicates high urban morphological complexity.

The Liberties character area contains 59 junctions, in 0.342 km sq. (34.2 hectares), so 172 junctions per km sq. Nedovic-budic (2016) measure internal connectivity of road segments in Dublin, indicating 326-645 internal connections between road segments per km sq (Fig.5, Pg 156) in the Liberties character area, a useful cross-check of this indicator. This is located in the highest quintile of their five bands, which run from 0-645\(^{15}\). Both indicators suggest high compositional, and therefore urban morphological complexity in the Liberties character area.

![Junctions per km sq. of Liberties](image)

---

\(^{14}\) Clifton et al (2008:28) also consider this as one measure of network connectivity. The quantity of junctions per km sq. is also a measure in urban analysis for design (Clifton, Song, Knaap, 2008:9).

\(^{15}\) The different spatial resolutions of the two indicators as well as the different aspects measured mean that an exact comparison between figures is not possible. Nedovic-budic et al (2016) count the exact number of road segments which meet at each junction (see Fig. 4, Pg 156.)
3.0 Urban Ballymun

6.3.1 Ballymun morphological description

This study uses the term ‘urban Ballymun’ to describe the area officially designated ‘Key District Centre’ by Dublin City Council (see red line outline in Fig. AA-13). The purpose of this section on the Ballymun area, as the morphological description of Urban Ballymun, the case site, is to make a descriptive evaluation of the compositional complexity of this specific urban site context, through a narrative account of this aspect. This is based on urban morphological analysis, and forms the background to more purely quantitative evaluations of the later sections of this analysis of the cases. In the second unit of study introduced here, an urban centre is contained within a collection of outer city neighbourhoods, collectively known as Ballymun. The analysis presented here does not question the official planning designation or geographical outline of the
‘key district centre’ area called Ballymun, described in this study as ‘urban’ Ballymun. This urban morphological analysis concentrates on two aspects which can reveal evidence of compositional complexity of the context and urban site: firstly, analysis of morphological periods (Conzen, 1960) of Ballymun and secondly, urban tissue categorisation and analysis, (Scheer, 2001, 2003). The reasons to employ these techniques are, firstly, that analysis of morphological periods of Ballymun uncovers the multiple stages of development and spatial change in the area, which is centrally related to the compositional complexity of the urban site context. A morphological period is defined as any cultural period that exerts a distinctive morphological influence upon the whole or any part of a town\textsuperscript{16}. This description of morphological periods provides a synoptic explanation of the development of the urban form, which can then be evaluated for levels of spatial complexity, and therefore concentrates on formal or spatial aspects of urban morphology only. Conzen’s method has been applied here, following the morphological process of Ballymun over time, in order that the diversity of (physical or spatial) features is better understood and described (Conzen, 1960:119). Rates of change in urban form are also discussed by Conzen (Conzen, 1981:82) and, as a consequence, are argued in this study to impact on evaluated complexity of the contemporary urban environment. It is in response to this fact that morphological periods are proposed in this analysis of the urban site of Ballymun, in order to structure the understanding of the observed urban site, and to address the core research question, that is, how to evaluate spatial complexity of urban sites. Secondly, the reason to employ urban tissue categorisation and analysis is in order to reveal the compositional character and complexity of the area (Scheer, 2001, 2003), and in order to relate this aspect to international examples.

Morphological periods of Ballymun

Firstly, as regards analysis of morphological periods (Conzen, 1960) of Ballymun, five morphological periods are identified, starting from the ‘pre-urban’ history of the site, seen as running up to 1965, the year a ‘new-town’ type social housing development began construction on the rural site. The second morphological period, coinciding with the construction period of the original high-density, a partly high-rise housing estate of 3,021 dwellings transformed the morphological footprint, instantly conferring a modernist, car-based urban pattern on the landscape. While the architectural complexity of the development was high, involving Ireland’s first (and only, to date) high-rise social housing project, and a predominance of apartment-type accommodation, comprising both 15-storey ‘tower’ blocks (seven) and 8-storey ‘slab’ blocks (nineteen), the urban complexity was low. In morphological analysis terms, urban design categorisation tends to divide the urban space system into two types, ‘traditional’ (historic city) and ‘modernist’ (free-standing buildings in landscape settings) (Carmona et al, 2003:61). However, Ballymun in this second morphological period is more appropriately described as ‘proto-modernist’, since the surrounding urban context of a city was absent in many generally understood spatial and organizational aspects, including urban structure, transport, and neighbourhoods. In this sense, the development was of low urban complexity, lacking basic amenities such as parks and a community facilities (Rowley, 2014:416). A third morphological period involved the extension of the original social housing stock in the form of low-rise terraces, further reducing the urban, architectural and spatial complexity of the site. A fourth morphological period involved vacancy and decline in quality of building fabric, and hence a reduction in the potential that successive urban development and growth could enhance urbanity. The fifth morphological period begins with the regeneration project from 1997, which was
considered to be completed in 2015 (BRL, 2015) and included low and medium rise development, conforming to a post-modern urbanism template (Hebbert, 2008:31). Regeneration involved enhancement of the urban fabric in overall terms, but architectural complexity could be considered to have increased minimally, as many low-rise ‘own-door’ housing units replaced high-rise apartment blocks for example. In the contemporary regenerated town, multiple understandings of the spatial unit which comprises ‘Ballymun’, and urban definition of boundaries, have sometimes been a barrier to coherent identification and urban development of the location. So for example, while five separate neighbourhoods were envisaged in the 1998 Masterplan for regeneration, no plan was made specifically at the time for the urban site which this study calls ‘urban Ballymun’ (the area officially designated ‘Key District Centre’ by Dublin City Council). Pritchard, a leader of the masterplanners of the regeneration, wrote in 2008 that: ‘Main Street- the emerging sixth community- is still evolving’ (Pritchard, 2008:15). Correctly identifying the urban site as key to enhancing the town’s appeal, Pritchard suggested that this area would not properly develop until after a public transport solution was implemented for Ballymun. In official planning terms, residents of this recently developed Main Street area, the more ‘urban’ part of the regeneration project, are generally seen to belong to primarily low-density residential-type neighbourhoods, but not to an urban, medium-density apartment dwelling community. In conclusion, five urban morphological periods categorise this urban site context, indicating a sudden development of proto-urban development of high architectural (but low urban) complexity in the second morphological period. There was a general decline in spatial complexity of the urban site in the intervening years to 1997, and a general increase in spatial complexity of the area as a result of a regeneration policy from 2007 to 2015.
Morphological Periods Table of Ballymun

* Historic Map Library, Richview, UCD
** ‘in the early 1900’s there were only six dwellings at Ballymun’ (Somerville Woodward, 2002:6)
*** BRL Fig. Gr. Map, 1964
**** (Somerville Woodward, 2002:9)
***** (Somerville Woodward, 2002:17)

<table>
<thead>
<tr>
<th>Morphological Period</th>
<th>Description</th>
<th>Source (Relevant Map dates)</th>
<th>Plan Units</th>
<th>Streets (1)</th>
<th>Buildings (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One 1965</td>
<td>Pre-urban development Ballymun area**</td>
<td>Historic Map 1964***</td>
<td>One</td>
<td>(field patterns)</td>
<td>St. Pappin’s Church (1864)<strong><strong>, School, Santry Court Demense (1702)</strong></strong></td>
</tr>
<tr>
<td>Two 1965-1968</td>
<td>Ballymun Social Housing Project</td>
<td>Author 1969*</td>
<td>Two</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Three 1968-1977</td>
<td>Extension of Ballymun (low-rise) Housing</td>
<td>Author 1977*</td>
<td>Three</td>
<td>Four</td>
<td></td>
</tr>
<tr>
<td>Four 1977-1997</td>
<td>1977-1985 Vacancy and dilapidation phase</td>
<td>1985 Surrender Grant Scheme</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2007-2015 Regeneration: Phases Three, Four, Five</td>
<td>Author 2012*</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table AA-4  Morphological periods categorization, Ballymun context
Figure AA-14 The plan-units of Ballymun

Plan–unit outlines of regeneration development outside of urban Ballymun (ie. red outline of Key District Centre designation)(top) and aerial view of pre-regeneration (left) and post-regeneration (right).
Urban tissue categorization of Ballymun

Secondly, urban tissue categorisation and analysis in this case context is based on Scheer’s theories and methods of urban tissue analysis (2001, 2003), which are considered most appropriate to analyse the contemporary spatial condition of this outer suburban landscape. Scheer theorises suburban and edge city form with an emphasis on the American 20th century city, and argues that traditional urban morphological analysis methods need to be supplemented to examine the more recently developed urban and suburban formal conditions. In arguing that classic urban morphological methods presuppose a strong relationship between the basic building types, lots (plots), blocks and streets, she claims that these approaches were developed especially to explain traditional European cities. More recently developed suburbs are argued, in this analysis, to have less clear relationships of nested hierarchy (where the larger parts like urban blocks, are composed of aggregations of the smaller parts, like plots). Streets and blocks are argued for example to not necessarily be related to building type, and the relationship between building, plot and street is argued to be much weaker than in the historic urban centre (Scheer, 2001:29). In response, Scheer proposes methods developed by ecological scientists to study complex ecosystems, whereby the various components are organized by the rate at which they change. So, for example, geographical or landscape features such as rivers are seen as least likely to change, whereas individual trees will respond much more rapidly to environmental change. The analogy with the city suggests that whereas streets and roads are very persistent over time, individual plots and buildings are much more likely to change, and land use is even more likely to evolve rapidly.

Scheer proposes ‘site, paths (streets and footpaths), plots, buildings and objects (eg. trees, signs)’ in that order as the components of analysis of the suburban landscape, with
the first of these least likely to change rapidly, and so on. Scheer describes how, ‘as in the ecological model, the more slowly a layer changes, the more it conditions changes in layers that change more quickly’ (Scheer, 2001:29). So, for example, the relative permanence of a large site can influence negatively the possibility of new paths in an area, while disturbances or discontinuities in older, more slowly changing layers can be very powerful, such as road widening affecting every plot alongside. The ‘spatial matrix’\(^\text{17}\) of paths and plots, understood as the ‘web’ resulting from combining all public routes with all private plots and urban blocks, is seen as remaining resistant to change because of the social, economic and political power required to change it.

The urban site of Ballymun is a case of an embedded spatial matrix (the original public housing project of the 1960’s) around which a regeneration project grew (1997-ongoing), with uneven spatial and urban design consequences.

In analyzing a suburban location, Scheer defines three distinct patterns of block, lot and building aggregations, or ‘urban tissues’\(^\text{18}\). Firstly, ‘static tissues’ (primarily single family homes), the most extensive type, are defined by distinct and ordered plot to building relations, and remaining relatively stable in relation to change. Secondly, ‘campus tissues’ (‘tracts of buildings that are developed with several buildings, but not subdivided into separate properties’) and thirdly, ‘elastic tissues’ described as: ‘thickening of the existing settlement pattern, evolving from rural to urban almost

\(^{17}\) In a later paper, Scheer explains this aspect as the ‘boundary matrix’, defined as ‘the combination of plots and the linear paths of public rights of way, describ(ing) lines and spaces that are measurable and traceable over time, even if they have no physical substance’ (Scheer, 2016:14).

\(^{18}\) The concept of urban tissue is associated in urban morphological analysis with the Italian School, and particularly Caniggia and Maffei (1979). Kropf’s opinion is that Caniggia and Maffei define simple tissue as ‘a single street’. However, Samuels considers that in Caniggian analysis, urban tissue is ‘the assemblage of aggregated buildings, spaces and access routes’ (Samuels, 1982:3)(source: ISUF Glossary). Kropf develops the concept of ‘tissue’, by using the word ‘street’ for simple tissue, and adding a definition of urban tissue as ‘more complex combinations of streets’ (Kropf, 2014:50). In this thesis the distinction is important, because evidence of spatial complexity in compositional and formal terms could be demonstrated through the identification of patterns of urban tissue, so Kropf’s definition is adopted. In these terms three ‘orders’ of tissue could be identified, exhibiting increasing levels of complexity: no streets (low complexity), street (medium complexity), and urban tissue (high complexity).b
imperceptibly as farmhouses were joined by other roadside structures’ (Scheer, 2001:33). Elastic tissue, in Scheer’s analysis, occurs especially along pre-urban paths, and are the least likely type of infill of the suburban landscape to endure over time. Although, in one paper, Scheer employs these urban morphological analysis methods to gain an understanding of the complexity of changing the nature of the ‘commercial strip’ along American highways (Scheer, 2003), explicit definitions of how this complexity manifests are absent. In analyzing Ballymun here, the focus is on extending Scheer’s analysis to explicit evaluation of the spatial complexity of the urban site. Figure AA-15, showing tissue analysis and Scheer’s categorization applied to the urban site, shows how much of area is ‘static’ morphological tissue, (very little) how much is campus, (a central set of clusters), and elastic (a majority). The static clusters are isolated from each other, and from a more mixed urban form type. The campus clusters are dominant in the area, which indicates low numbers of land owners (and plots). From a review of the emergent morphologies in the area, it is apparent that static-type urban form seems to be transforming into elastic-type to the north of the urban site. This is important because instability inherent in elastic type morphology would suggest areas of low complexity, with few paths or infill streets, and plots of highly varied sizes in poorly planned tissue. In conclusion, the particular spatial incidence of the three tissue types, (static, campus and elastic) in urban Ballymun suggests low compositional complexity of the site.
<table>
<thead>
<tr>
<th>Tissue Type</th>
<th>Definition</th>
<th>Characteristics</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Static</td>
<td>&quot;Static&quot; refers to long term endurance of this tissue type. (Scheer, 2001:35).</td>
<td>- Plots and paths are planned together. - Built in a short time period. - <em>subdivided</em> plots are small, and consistent size in each area of tissue. - Each plot usually contains a primary structure, without <em>aggregation</em> or further subdivision. The most &quot;stable&quot; of the three types.</td>
<td>(Scheer, 2001).</td>
</tr>
<tr>
<td>Campus</td>
<td>*Large tracts of land owned by single entities and developed with multiple buildings.&quot; (Scheer, 2001:34).</td>
<td>- The pre-urban plot is not subdivided and contains more than one significant structure. - <em>Internal</em> paths are organised as private streets. - Examples include airports, universities, schools, apartment complexes and office parks.</td>
<td>(Scheer, 2001).</td>
</tr>
<tr>
<td>Elastic</td>
<td><em>Thickening</em> of the existing settlement pattern, evolving from rural to urban, usually along pre-urban paths. (Scheer, 2001:34).</td>
<td>- The tissue is not pre-planned. - Plots tend to be highly varied in size. - The least &quot;stable&quot; of the three types. - Elastic tissues tend to &quot;cling tightly to the superstructure&quot; (i.e., &quot;do not generate infill streets&quot;, etc.) (p. 35). - Rapidly changing elastic tissues are structurally disordered at the level of the plots and paths, and deeply conditioned by their relationship to the superstructure&quot; (p. 36). - The buildings (in this tissue type) are of different types and sizes and likely to vary widely in age due to rapid turnover and obsolescence. - These tissues are formed almost exclusively along an arterial road which is the main through connector of the district.</td>
<td>(Scheer, 2001).</td>
</tr>
</tbody>
</table>

Table AA-4 Scheer’s urban morphological tissue definitions (Scheer, 2001, 2003)
Figure AA-15 Tissue sample analysis of Ballymun

(1) Tissue analysis and categorisation according to Scheer’s method (2001, 2003) Ballymun (l), and Urban Ballymun tissue samples classified: ‘static’ (original, 1965-69) (r), bottom (2) left, ‘campus’, bottom right, ‘elastic’.
Figure AA-16 Overall Urban Ballymun context

(1) Overall Ballymun context (l), case site and number of urban blocks in urban Ballymun (r),
(2) case in context, (3) aerial view of urban Ballymun.
Figure AA-16 Plot Taxonomy and Plot Type for Urban Ballymun

Sample graphic of development of taxonomic analysis of figure ground plan outlines of urban plots in the Urban Ballymun. In this approach, four plot types are organised, according to size, visual analysis and pattern matching. Centroids of the plot area are devised through visual approximation, and these are placed on a ‘cross-hair’ x and y axis. Plot outlines are overlaid to visually indicate relative complexity of compositional and geometric pattern. In this way the relative spatial complexity of plots of this case can be quickly visually compared with the other two cases.
6.3.2 Urban Ballymun morphological complexity

Seven selected measures of urban form, and more specifically urban morphological complexity, are reported on for of the urban Ballymun area in Chapter Six, ‘Three Case Evaluations’, Section 6.3.2. The seven measures are introduced in Section 4.4.2. ‘Compositional Criteria of spatial complexity’. Here more detail of the result is reported for each measure here: firstly, ‘power law distribution’ of streets (Salat, 2012), secondly, ‘passive volume ratio’ of urban blocks (Salat, 2012), thirdly ‘ABCD street type analysis’ (Marshall, 2005). The fourth, fifth, sixth and seventh measures are: plot type, plots per hectare, blocks per hectare, and junctions per km sq.
1. **Power law distribution of streets**

Salat’s (2011) method of assessing complexity of an urban site by examining the power law distribution of types (widths) of streets is shown, and it can be seen that there are fifteen streets of varying widths in the site, including boundary streets or roads. When the widths are plotted, while a reasonable spread of street widths seems to emerge as size reduces, once a certain level of width is reached (14m) the smaller width streets are not present, so the curve drops instead of rising, becoming sub-optimal in these terms\(^\text{19}\). According to this analysis, the case site of urban Ballymun is a non-complex urban site. The power law distribution (PLD) of streets graph for urban Ballymun (pink line) indicates a sub-optimal distribution of streets of varying sizes\(^\text{20}\), unlike the optimal curve (in red), and therefore this indicator of compositional complexity has a low evaluation.

\[\text{Figure AA-17 Power law distribution of Ballymun streets}\]

\(^{19}\) Salat argues that the complexity of the urban structure of cities has a direct impact on urban structural efficiency and resilience (Salat, 2011:26).

\(^{20}\) Evaluated ‘street’ widths in urban Ballymun vary from a maximum width of 35m, (Ballymun Main Street, seen as ‘modernist road widths’ as they derive from the 1960’s modernist housing project) to the 8m wide street (title PS2 in Step 1 Ballymun key map, Appendix A). The latter is a (currently unnamed) privately owned, but publicly accessible street, which could be described as a ‘postmodern urbanism street’, one of the recently developed elements of regeneration (Hebbert, 2008).
2. **Passive volume ratio**

In the analysis of complex urban fabrics of urban Ballymun, high passive volume ratio could be an indicator of increased urban complexity of urban blocks (Salat, 2012:104). The estimated passive volume ratio of the completed urban blocks of urban Ballymun is indicated as approximately 80% (based on Protocol 1C). The estimate is based on visual analysis of a figure ground map at scale 1:1000, and a general awareness of the urban block and building patterns in the area, which are generally regeneration-era or mid-twentieth century structures, with a recent group of high density apartment blocks around courtyards. However, in evaluating the case site, the fact that at least 50% of the urban site is vacant, awaiting development, means that passive volume ratio is a poor indicator of compositional complexity in partly developed urban sites.

![Figure AA-18: Passive volume ratio of urban Ballymun](image)

**Figure AA-18** Passive volume ratio of urban Ballymun
3. **ABCD street type analysis**

Using the method outlined in the relevant protocol, results show the street pattern type at urban Ballymun is close to a ‘D’ type area, suggesting ‘consistent road geometry, curvilinear or rectilinear formations, mostly meeting at right angles’ (Marshall, 2005:89). In compositional terms, this is the extreme opposite pattern type to the ‘A’ type, associated with the historic city, and likely to be of high compositional complexity in the street pattern. As the original (1960’s) road layout of Ballymun followed a modernist ‘New Town’ approach, and much of this infrastructure remained in place during regeneration, this is not an unexpected result.

![Diagram](image)

**Figure AA-19**  **ABCD street type analysis of urban Ballymun**

21 A map at 1:1,000 scale is used to analyse at the scale of the Liberties character area urban site within a red line. The map indicates urban block outlines, and ‘T ratio’ and ‘X ratio’ indicators are generated (Marshall, 2005:98) on the map. (See Protocol No 1D, Appendix B). Then, ‘Cell ratio’ and ‘Cul ratio’ are generated (Marshall, 2005:98) on a separate but similar base map, and results are combined to generate (a) a Nodegram, (b) combined plot ‘box’ (Marshall, 2005:101).
4. Plot type

Plot type in urban Ballymun is affected by the initial development of the social housing project of the 1960’s, the remaining buildings of which are still not fully demolished. While all of the site of urban Ballymun was in public ownership until regeneration from 1997 onwards, some plots have transferred to private ownership, as part of a regularization and rebalancing of the local social, economic and environmental conditions. From a visual analysis of the 31 individual plots of the urban site, it is apparent that geometric characteristics of plots vary widely, from small single house type, with orthogonal layouts, to very large complex shaped remnant plots from tower or slab blocks of the original housing estate. In this respect, the urban site can be regarded as one of medium compositional complexity.

Figure AA-20 Plot type analysis of urban Ballymun
5. **Plots per hectare/ urban grain measure**

Using the Norton urban grain (2016) measure, the urban Ballymun area, with 1.25 plots/ha, has a ‘coarse’ description, a low grading in Dublin terms, and thus an indicator of low compositional complexity. The regeneration of a suburban ‘New Town’ social housing estate at Ballymun has not succeeded in altering the relatively coarse urban grain which was a feature of the 1960’s layout.

![Figure AA-21](image)

**Figure AA-21**  Plots per hectare of urban Ballymun
6. **Blocks per hectare**
Taking the constructed parts of the urban Ballymun area, within the Key District Centre there are 5 urban blocks in 22.5 hectares, that is 0.2 blocks/ha, a figure which is very low in Dublin terms, and therefore indicates low compositional complexity. Undeveloped sites which are related to ongoing regeneration in the area (ie. vacant, post-demolition of flats) are not counted in this analysis. So while the roads layout suggests a certain compositional complexity, the ongoing vacancy and stalled regeneration reduce complexity according to this indicator. The site coverage of buildings mapping is thus a better reflection of urban blocks than a simple ‘back of footpath’ outline graphic.

![Image of urban blocks per hectare of urban Ballymun](image)

**Figure AA-22**  Urban blocks per hectare of urban Ballymun
7. **Junctions per km sq.**

In this evaluation, as in the other cases, a higher number of junctions indicates high urban morphological complexity. The urban Ballymun area contains a total of 20 junctions, in 0.225 km sq (22.5 hectares), so 89 junctions per km sq, a medium quantity in Dublin terms. Nedovic-budic (2016) measure internal connectivity of road segments in Dublin, indicating 94-167 internal connections between road segments per km sq in the urban Ballymun area, (Fig.5, Pg 156) a useful cross-check of this indicator of compositional, and therefore urban morphological complexity. This is located in the medium quintile of their five bands, which run from 0-645.

![Junctions per km sq. of urban Ballymun](image)

**Figure AA-23**  Junctions per km sq. of urban Ballymun
4.0 Carmanhall

Figure AA-24  Table of Carmanhall streets (PLD evaluation)

6.4.1 Carmanhall morphological description

The purpose of this section on the Sandyford area, as the morphological context description of Carmanhall, the case site, is to make a descriptive evaluation of the compositional complexity of this specific urban site context, through a narrative account of this aspect. This is based on historical, graphical and theoretical analysis, and forms the background to more purely quantitative evaluations of the later sections of this analysis of the cases. In the third unit of study introduced here, a proposed future neighbourhood, Carmanhall, is contained within a strategic planning regional hub, Sandyford. The analysis presented here does question the official planning designation or geographical outline of the proposed future neighbourhood, and extends the outline of the urban site for reasons explained in Chapter Five, Section 5.4.3.3 (‘Current Planning/policy context’). The analysis concentrates on two aspects of urban morphology, which can reveal evidence of compositional complexity of the urban site:
analysis of morphological periods, and urban tissue categorization. Firstly, analysis of morphological periods of Sandyford uncovers the multiple stages of development and spatial change in the area, which is centrally related to the compositional complexity of the urban site context. Secondly, urban tissue analysis and categorisation reveals the character and complexity of the area (Scheer, 2002, 2003) and relates this aspect to international examples.

As regards morphological periods of Sandyford, seven distinct periods are indicated, and six related plan-units (See Table AA-4). As outlined in Chapter Five (Volume One, Section 5.4.3), the planning policy context of the case site is as a former industrial estate, which expanded into residential use due to public transport infrastructure provision without an overall master plan. The first two morphological periods are associated with the initial change from rural farmland to light industrial estate, from the 1970’s onwards. The development of office HQ buildings in the light industrial estate, from the early 1980’s on, was the beginning of the evolution of three types of morphological pattern in the area, as the predominant building type became more complex. The sixth morphological period is associated with an Irish economic boom (1988-2008), and plans for buildings of up to 65 office storeys were discussed. Although this period has only one physical remnant\(^\text{22}\), it still exerts a distinctive morphological influence upon the urban site, in the form of vacancy and dereliction resulting from financial losses made when this period ended. The last, current morphological period, associated with the start of ‘spatial’ regulation over-development in the area, began with the adoption of the Sandyford Urban Framework Plan in 2011.

In plan unit terms, McGibbon has described the current Sandyford area as lacking

\(^{22}\) The Sentinel building, located at the west edge of the Carmanhall neighbourhood, on Carmanhall Road, is a 14 storey, partially completed office building (in 2016), where construction work stopped in 2009.
certain urban design elements, such as streetscape, permeability, public spaces, and ideal mix of uses at area scale. It is also considered that many industrial estate design characteristics are still present on the site, such as wide roadways and sightlines to facilitate large vehicles (McGibbon 2006). Although distinct and contrasting formal conditions are evident between the plan-unit areas, (that is, streets, plots and buildings integrate in space and time to form individualized combinations) large variations exist between compositional characteristics of different plan-units. The most extreme example is between vacant or derelict sites adjoining high-density, large inner urban type perimeter urban block development, at Carmanhall Road between south and North sides at Beacon South. As an ‘embedded case’ further investigation of Beacon South would reveal extremely complex architectural design, over a total of 18 storeys in some parts. Currently, the official definition of the settlement as ‘town’ has status under certain public mappings (eg. myplan.ie zoning classifications) though not in others. It has been described by the Local Authority for the area as ‘a collection of disparate, poorly connected (industrial) estates’ in its 2011 Sandyford Urban Framework Plan, which has an aim to re-cast the area as a ‘business district’ (the Sandyford Business District). In conclusion, the seven morphological periods and six plan-units do indicate a recent history of spatial change, and a dynamically changing urban site. However, the resulting compositional or morphological complexity is concentrated in individual sites rather than being evident at the resolution of the overall urban site of the Carmanhall neighbourhood.

As in the case of Ballymun, morphological analysis based on Scheer’s theories and methods of urban tissue analysis (2001, 2003) are considered most appropriate to

23 Block A4 of Beacon South is and 18 storey residential tower, including 2 basement storeys (Source, ‘A Beacon of Engineering’, Article, Irish Construction Industry Magazine, author, Tim Murnane, Pgs 82-83, July/August 2007 Issue.)
analyse this proposed future neighbourhood, which is within a strategic planning regional hub. As regards urban tissue categorization\textsuperscript{24}, while the surroundings of Sandyford are primarily static tissue, including the predominant urban form type, of low-density housing estate, some infrastructure elements such as motorway, reservoirs, and rail interrupt the morphological footprint, and emergent new development patterns associated with regional accessibility are appearing on the fringes of the urban site. However the primary tissue type is campus style development, a remainder from the original light industrial estate layout of the 1970’s. Morphological characteristics of this tissue type, in Scheer’s terms, include large tracts of land in single ownership, developed into multiple buildings, with internal paths organized as private streets and spaces. While architectural complexity of the resulting developments is possible, and has been achieved in some locations, it is the urban scale implications as regards morphological complexity which are of interest in this study.

While Scheer does not quantify complexity of different tissues associated with the outer suburban form analysed, other characteristics of campus style development suggest low urban complexity. For example, single ownership of large parts of the urban site could predetermine the economically viable diversity and mix of agents on a land parcel, and exercise control that is not in the public interest. Scheer also points out that ‘the smaller the lot (plot) the more likely it is to force the building into a relationship with the street and with its neighbours’ (Scheer, 1998:308). The implication is that smaller plots can influence relationships between formal aspects of streets and therefore compositional complexity levels. In the case of Carmanhall, it is evident that a few landowners dictated a drive towards large site redevelopment based on high-density housing

\textsuperscript{24} See Scheer’s definitions of ‘static’, ‘campus’ and ‘elastic’ urban tissue types in Appendix A, ‘Urban Tissue Categorisation of urban Ballymun’.
models, some of which then failed to be completed due to an economic downturn. One result has been a series of demolitions of existing warehouses and light industrial buildings, leading to vacant and derelict sites at the centre of a developing regional and urban hub, which effectively reduces the formal complexity of parts of the urban site. However, other large sites developed inner urban type perimeter blocks of high architectural complexity. The morphological pattern of the urban site is extremely uneven, and the identification of morphological periods and plan-units helps to uncover a spatial history of the location at multiple scales. In seeking a general conclusion as regards the urban morphological complexity of the urban site, and given that only two parts of the six urban blocks on the site are completed as designed, the neighbourhood of Carmanhall is still one of low morphological complexity, seen at this scalar resolution.

The plan-units of Sandyford

![Sandyford Plan Units and morphological periods](image)

Figure AA-25 Carmanhall Plan Units
Figure AA-26  Plot Taxonomy and Plot Type for Carmanhall

Sample graphic of development of taxonomic analysis of figure ground plan outlines of urban plots in Carmanhall. In this approach, three plot types are organised, according to size and visual analysis and pattern matching. Centroids of the plot area are devised through visual approximation, and these are placed on a ‘cross-hair’ x and y axis. Plot outlines are overlaid to visually indicate relative complexity of compositional and geometric pattern. In this way the relative spatial complexity of plots of this case can be quickly visually compared with the other two cases.
### Morphological Periods Table of Sandyford

<table>
<thead>
<tr>
<th>Morphological Period</th>
<th>Description</th>
<th>Source (Relevant Map dates)</th>
<th>Plan Units</th>
<th>Streets (1)</th>
<th>Buildings (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>One - 1969</td>
<td>Pre-urban Sandyford area Bray/Dundrum Railway line, 1854, Stillorgan Station, Dublin and Wicklow Railway Company, Stillorgan service Reservoirs (1862)**</td>
<td>Historic Maps 1829 1854 1897 1958 1966 1969*</td>
<td>One (field patterns) enclosed Arkle Square</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Five 2001-2007</td>
<td>High buildings proposals stage</td>
<td>(Brady, 2002) 2007* 1.5 acre publicly accessible 'concourse'</td>
<td>Five</td>
<td>Beacon South Quarter (2003 on..)</td>
<td></td>
</tr>
<tr>
<td>Seven 2011 - 2015</td>
<td>Stagnant/ minimal development stage</td>
<td>Author 2012, 2013** Unfinished Housing sites**</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

* Historic Map Library, Richview, UCD  
*** Stillorgan Industrial Park (on 1985 Street Map) (also called Stillorgan Business park, and Stillorgan Industrial Estate, (McGibbon, 2006:125)  
**** Industrial Heritage Association of Ireland Tour Notes, 2011  
***** by the end of 2004, Sandyford had developed into a substantial office node with an office stock totalling over 161,600 sq. m‘(MacLaran, Kelly, 2007:79)

---

Table AA-4  Morphological periods of Sandyford
Figure AA-27  Morphogenesis at Carmanhall (top)

Also (middle) street view of industrial estate (foreground) and contemporary (background) building typologies, and tissue analysis and categorisation for Carmanhall, according to Scheer’s method (2001, 2003), (bottom).
6.4.1 Carmanhall morphological complexity

Seven selected measures of urban form, and more specifically urban morphological complexity, are reported on for of the Carmanhall area in Chapter Six, ‘Three Case Evaluations’, Section 6.4.2. The seven measures are introduced in Section 4.4.2. ‘Compositional Criteria of spatial complexity’. Here more detail of the result is reported for each measure here: firstly, ‘power law distribution’ of streets (Salat, 2012), secondly, ‘passive volume ratio’ of urban blocks (Salat, 2012), thirdly ‘ABCD street type analysis’ (Marshall, 2005). The fourth, fifth, sixth and seventh measures are: plot type, plots per hectare, blocks per hectare, and junctions per km sq.
1. Power Law Distribution of Streets

The power law distribution of streets graph for Carmanhall (green line) indicates a sub-optimal distribution of streets, which are almost all of one size. Unlike the optimal curve (in red), this street network was all developed around the same time, using a template suited to industrial estate planning, to facilitate heavy goods vehicles and turning circles. Therefore according to this indicator of compositional complexity, Carmanhall has a low evaluation.

![Power Law Distribution of Streets](image)

<table>
<thead>
<tr>
<th>Street Number</th>
<th>Name</th>
<th>Width</th>
<th>Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Carmanhall Road</td>
<td>25m</td>
<td>A (1)</td>
</tr>
<tr>
<td>2.</td>
<td>Blackthorn Drive/Ave</td>
<td>20m</td>
<td>B (2)</td>
</tr>
<tr>
<td>3.</td>
<td>Blackthorn Road</td>
<td>20m</td>
<td>B</td>
</tr>
<tr>
<td>4.</td>
<td>Corrig Road</td>
<td>15m</td>
<td>C (5)</td>
</tr>
<tr>
<td>5.</td>
<td>Three Rock Road</td>
<td>15m</td>
<td>C</td>
</tr>
<tr>
<td>6.</td>
<td>Ravens Rock Road</td>
<td>15m</td>
<td>C</td>
</tr>
<tr>
<td>7.</td>
<td>Ballymoss Road</td>
<td>15m</td>
<td>C</td>
</tr>
<tr>
<td>8.</td>
<td>Arkle Road</td>
<td>15m</td>
<td>C</td>
</tr>
</tbody>
</table>

Figure AA-28  Power Law Distribution of Streets Carmanhall
2 Passive volume ratio

In analysing complex urban fabrics of Carmanhall, high passive volume ratio (PVR) could be an indicator of increased urban complexity of urban blocks (Salat, 2012:104). However, in evaluating the case site, the fact that at least 40% of the urban site is comprised of light industrial warehouse type structures awaiting development, means that passive volume ratio is a poor indicator of compositional complexity in this partly redeveloped ‘future’ neighbourhood site, considered as a spatial unit. There are also large ‘gap’ sites of unfinished development, stalled since the economic crash of 2008-9. The estimated passive volume ratio of the completed urban blocks of Carmanhall is indicated as approximately 90% (based on Protocol 1C)\textsuperscript{25}. Although the PVR is high for some recently completed buildings, significant areas are vacant, so the indicator is assessed as ‘medium’.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{passive-volume-ratio-carmanhall.png}
\caption{Passive volume ratio Carmanhall}
\end{figure}

\textsuperscript{25} This estimate is based on visual analysis of a figure ground map at scale 1:1000, and a general awareness of the urban block and building patterns in the area (including basements), which are generally second or third generation office type buildings or high-density apartment blocks (See Appendix A Morphology of Cases Description). The primary usefulness of this indicator is in highlighting the passive volume ratio of recent developments in the area, (which contain large amounts of ‘internal floor area’) as they may be initial indicators of development trends towards or away from future compositional complexity of the urban site.
3. **ABCD street type analysis**

Using the method outlined in the relevant protocol\textsuperscript{26}, results show the street pattern type at Carmanhall is a strongly ‘C’ type area, suggesting low compositional complexity in the street pattern. This locates the urban site on the edge of the Nodegram triangle, far from the centre, which indicates complexity. While the original laying out of the roads infrastructure in this area is associated with a 1970’s type light industrial estate, and associated configurational characteristics of loop roads, T-junctions, culs-de-sac, there is also a grid layout to the initial development. Current planning proposals to facilitate development of the Carmanhall neighbourhood make no proposals to alter this roads infrastructure and street pattern type.

**Figure AA-30**  **ABCD street type analysis Carmanhall**

\textsuperscript{26} A map at 1:1,000 scale is used to analyse at the scale of the Liberties character area urban site within a red line. The map indicates urban block outlines, and ‘T ratio’ and ‘X ratio’ indicators are generated (Marshall, 2005:98) on the map. (See Protocol No 1D, Appendix B). Then, ‘Cell ratio’ and ‘Cul ratio’ are generated (Marshall, 2005:98) on a separate but similar base map, and results are combined to generate (a) a Nodegram, (b) combined plot ‘box’ (Marshall, 2005:101).
4. Plot type

In analysing patterns of plot type at Carmanhall, the interest is in compositional aspects of plots at urban site scale of resolution, so observed ‘clusters’ of plot types of high and low compositional complexity, as indicated through geometrical aspects. In Carmanhall, from a visual analysis of superimposed plots, (taken from the taxonomy of plots of the urban site, see also Appendix A), the plot type indicates low relative geometrical complexity of the urban form, with mainly orthogonal rectangular plots. As discussed in the urban morphological context analysis, this geometry is a spatial inheritance from the light industrial estate formation of the development from the 1970’s onwards.

Figure AA-30  Plot type analysis Carmanhall
5. **Plots per hectare/ urban grain measure**

While the emergence of the Sandyford context as a regional hub in Dublin terms has led to extreme changes in building type, use and design as compared with the previous light industrial estate usage, the number of plots in the Carmanhall area has not changed substantially over time. In effect, the low compositional complexity of the light industrial estate, in terms of urban grain, has persisted during the change from light industrial use to the emerging status as high density residential neighbourhood. Using the Norton urban grain (2016) measure, the Carmanhall area, with 0.7 plots/ha, has a ‘coarse’ description, a very low grading in Dublin terms, and thus an indicator of very low compositional complexity.

![Figure AA-31  Plots per hectare Carmanhall](attachment:image.png)
6. Blocks per hectare

Quantifying urban blocks in the Carmanhall area involves strictly adhering to a selected definition of the term ‘urban block’. As outlined in the Glossary of Terms of this study, (Appendix C) the adopted definition in this study is ‘a polygon of urban land fully surrounded but not traversed by road segments’ (Peponis et al, 2007:2). Therefore, the requirement for ‘streets’ to contain the urban block does not apply for example, but the necessity for road segments (including private roads) not to traverse the urban block applies. There are 6 urban blocks in 31.4 hectares, that is 0.19 blocks/ha, a figure which is very low in Dublin terms, and therefore indicates very low compositional complexity.

![Figure AA-32 Urban blocks per hectare Carmanhall](image)
7. **Junctions per km sq.**

In this evaluation, as described for the other cases, a higher number of junctions indicates high urban morphological complexity. The Carmanhall area contains 21 junctions, in 0.314 km sq (31.4 hectares), so 67 junctions per km sq. Nedovic-budic (2016) measure internal connectivity of road segments in Dublin, indicating 35-93 road segments per kmsq in the Carmanhall area, (Fig.5, Pg 156) a useful cross-check of this indicator of very low compositional, and therefore urban morphological complexity. This is located in the second lowest quintile of their five bands, which run from 0-645.

---

**Figure AA-33 Junctions per km sq. Carmanhall**
Figure AA-34  All cases: Plot pattern and spatial complexity compared
5.0 Techniques for deriving morphological regions

In the absence of other useful texts for actual derivation of morphological regions (plan units), this note is largely devised from reading ‘Morphological Regions in English Medieval Towns’, Part One, Section Three, (1992:43), Baker N.J., Slater, T. R., in ‘Urban Landscapes International Perspectives’ (ed.s Whitehand, J.W.R., Larkham, P.J., (1992). As other descriptions of these methods are rare, complexity of form is addressed specifically in this source, and measuring complexity is the core aim of this study, much of the original author’s text is quoted directly, and referenced accordingly.

Whereas Conzen did not concentrate on techniques for deriving morphological regions in the analysis of towns, Baker and Slater do focus on this aspect (Baker and Slater, 1992:43). They argue that plan analysis, on its own, is not a means of establishing morphological regions. They argue that this analysis and categorization also does not allow for closely dating the plan units that are discerned, as precise dating relies on other documentary evidence like archaeology. Their paper addresses the lack of ‘a precise, verifiable and repeatable method for plan unit definition’ (Baker and Slater, 1992:45) and for the delimiting of morphological regions, by proposing a number of procedures: compiling the plan, plan unit derivation, and subsequently interpreting the plan units. In compiling the plan, their technique (which is followed in this thesis) involved preparing a base map document based on the largest scale ordnance survey historic map available for the area (in their case, 1:500, 1886, Worcester), and to show all divisions between buildings on the street frontages for the distance that they ran back from the frontage without significant deviation or interruption. Other aspects of the
Baker and Slater’s observation of their completed plan of late-medieval Worchester in advance of plan-unit derivation is that it is of ‘extreme complexity’. They note ‘there are few signs of regularity which might suggest organized, large scale planning; rather the plan appears to be the product of piecemeal growth. The street spaces vary greatly in width, straightness and orientation, and the characteristics of the plots lining them are diverse’ (Baker and Slater, 1992:49). In describing how to recognize plan unit components, it is remarked: ‘areas exhibiting a ‘measure of morphological unity’ may be defined at very different scales- from the whole intra-mural area down to a minor plot series’ (Baker and Slater, 1992:49). It is also possible that ‘no clear boundary between plan units, or plan seam is distinguishable’. They then state; ‘In the Worchester study, the scale of plan-unit definition was that of the individual street or street block’ (Baker and Slater, 1992:51). In definitional terms, Baker and Slater’s identified plan units, in morphographic terms are described as follows: ‘the area occupied by plots associated with a street or streets where the orientation, shape and dimension of those plots and street(s) can be clearly differentiated from their neighbours and have one or more internal characteristics in common. Function can sometimes be taken as a defining characteristic where it is apparent but, for the medieval period, this is unusual’ (Baker and Slater, 1992:51). In identifying exact boundaries it is stated that: ‘Temporal change poses a particular problem for plan unit definition.’ (Baker and Slater, 1992:52). This
includes seams which may have moved over time, and locations where no archaeological evidence exists, and is especially a problem in corner plots. The authors affirm that plan units ‘are fluid; liable to change in extent as well as in their internal character; and their analysis and cartographic representation therefore demand a consistent and explicit approach to the problems of reconstruction and chronology’ (Baker and Slater, 1992:53). Baker and Slater also ask the question of whether it is appropriate (if at all) to use non-morphological criteria, citing examples of land use, secular and ecclesiastical boundaries. This question is particularly relevant to the Liberties, where historic spatial boundaries of the six separate Liberties are all but lost in the urban fabric. Baker and Slater urge caution, especially related to parish boundaries, but do describe a very useful example of defining a plan unit which would not meet Conzen’s criteria of ‘a measure of morphological unity’, Worchester Cathedral close. The authors decide that the ‘legal separateness and distinctive boundary’ of the ecclesiastical site determine its definition as a plan unit.

In interpreting plan units in Worchester, Baker and Slater comment: ‘a proportion of the defined plan units are interpreted as representing planned urban extensions created over a short period of time; others are interpreted as a result of piecemeal development taking place over an unknown period of time’ (Baker and Slater, 1992:56). Baker and Slater state that (as Conzen had stated 30 years earlier), the town plan is the most resistant to change of the three systemic form complexes used in the definition of morphological regions (plan type, building type and land use) and that it is therefore sensible to begin any study in the regionalization of a medieval townscape (into plan units) with an analysis of the plan (Baker and Slater, 1992:64).
Appendix B  Evaluation Protocols

Urban Analysis and Design Evaluation Protocols

(PhD Appendix)

For

Evaluation of spatial complexity of urban sites
Introduction

Evaluation Protocol Definition and Description

Overview and Background

Protocols in this study describe the method for evaluating spatial complexity of urban sites, under three headings (or ‘issues’) composition, configuration, system, and under three ‘criteria’ evaluation categories within each heading. Each of the nine consequent urban design evaluation methods is described here by an individual ‘protocol note’, in order that each could be used separately alone. However, as described in this thesis, a holistic evaluation of spatial complexity proposes that all nine criteria are evaluated together for an urban site. A protocol, as regards research, is defined in scientific and medical terms as: ‘the method or procedure for carrying out an experiment, investigation, or course of medical treatment; the detailed instructions for this’ (OED). Here, the protocol is intended for use by an urban researcher or urban design practitioner in evaluating an urban site. These were developed in the early part of this study in accordance with Yin’s recommendations (see (Yin, 2003:68), Ch 3, ‘Preparing for data collection’).

This Appendix on evaluation protocols for urban urban site appraisal, analysis or evaluation, is being prepared in order to allow for the evaluation of urban sites by other urban design researchers seeking literal replication of the findings for the three urban case sites studied in this thesis. (See Appendix H, Section 1.1.4, ‘Multiple-Case Research Design’, which contains the statement: ‘Literal replication would be possible for another researcher, and for other cases in which the 'conditions' are similar to those found in each of the three evaluation cases here, once the stated research protocol for evaluation of spatial complexity for urban sites (see Attached Appendix) is followed’.)
Urban site-specific appraisal

Procedures and conventions of evaluation and visualisation are not established to date in urban design practice, and this is one reason to describe this set of task protocols in systematic form. Some urban design conventions around urban site appraisal and analysis, for example, the ‘site-specific appraisal’ contained in (Carmona et al, 2003) have been adopted in this study. These include: record general impressions, record site’s physical characteristics, examine relationships between site and surroundings (Pg 244, Carmona, Heath, Oc, Tiesdell, 2003) (Adapted from Chapman &Larkham, 1994:44). However, these procedures are quite arbitrary and without specific direction in what information is to be gathered, and where which methods or tactics are employed, as they are not related to clear research questions, so additional urban site appraisal and analysis techniques were developed for this study, related to compositional, configurational and system aspects of urban sites.
1.0 Composition protocols

1.1 Urban Form (Protocol 1)

Urban Morphological Analysis Protocol (1A)

Introduction

The purpose of urban morphological analysis procedures described in this protocol is to evaluate levels of compositional complexity of urban sites. This characteristic of all urban sites can be analysed using varying methods. Different morphological analysis approaches and methods are considered appropriate to different types of morphology (Moudon, 1994) and different scales of analysis. Historic urban form is primarily associated with Conzenian methods, while architecture level studies derive from the Italian school of morphology. Here historico-geographical (Conzenian) methods are selected for a historic urban site, where the emphasis is on change over time. Secondly, a typological (Scheer, 1998, 2001, 2010, 2104) or typomorphological (Caniggia, 1976) approach is adopted for less historically urban, suburban and edge of city conditions. A separate approach derived in this study is a taxonomical approach, concentrating on geometrical aspects of urban blocks, plots and streets, and applied to a historic as well as contemporary urban sites.

Step 1

Undertake collection of formal data. Sources include historic maps, archaeological evidence, interpretative historical accounts, archive material, fieldwork, but also, increasingly, digital sources such as blogs, Goolge Streetview and planning web sources such as www.myplan.ie which provide overlay mapping. Here, as well as visits to the site, Google Earth and Google Street View are used to confirm plot and plan unit boundaries. In this approach, resulting decisions on plan unit boundaries, for example,
can be recorded on screen grabs of views from the air, as abductive outlines which can be re-confirmed or refined in due course.

**Step 2**

Establish scope of diachronic (same place in different time periods) and synchronic (different places in the same time period) framework for analysis of cases. Establish and describe common patterns in the study area and across study areas. See note at end of Appendix A on ‘Techniques for deriving morphological regions’.

**Step 3**

Record a written account of development and testing of ‘theories of change’ over time from the data studied.

**Step 4**

Record a written account of linking the results of the physical analysis to conditions not directly related to urban form (or non-formal conditions).

**Note 1**

These four steps are adapted from Scheer, (2016), as these are considered to reflect the epistemological methods of ‘acquiring, analysing and validating knowledge’ in the urban morphology field (Scheer, 2016:7).
Urban Morphological Analysis Protocol (1AA)

Taxonomy Protocol (Blocks)

A taxonomy, defined as ‘the scientific classification of types’ (OED) is undertaken on urban blocks, streets, and plots in the urban site, based on analysis of the 1:1000 OS 2012 map, represented as a figure-ground plan. Figure-ground plans show the footprints of buildings and the pattern of unbuilt voids in unbuild sapce (Hebbert, 2016). Analysis of the figure-ground plan is common in urban design, and involves the graphic distinction being made in two dimensions (plan) and in black and white between constructed space (buildings, urban blocks in black) and public space (in white). Sometimes important buildings interiors are included, (eg. Nolli’s Map of Rome, 1748, and Rowe & Koetter’s Collage City, 1983). According to Cuthbert, ‘In urban design the figure–ground concept constitutes the fabric of the city where a harmonious ground plan may be arrived at through a balancing of spatial relationships and contexts in order to generate requisite variety within a larger whole’ (Cuthbert, 2007:193). However, Cuthbert is critical of this method, suggesting it is employed in one case ‘to justify urban design theory solely in terms of its spatial arrangements’ (Cuthbert, 2007:194).

Cuthbert also states: ‘There are no assumptions of any significance that can be made from figure–ground relationships apart from throwing geometry, form, and structure into higher relief, none of which means anything without some supporting concepts’ (Cuthbert, 2007:194). In this exploration of spatial complexity, the supporting concepts relate to evaluating spatial complexity of urban sites. Building on established figure-ground analysis methods for urban design, the graphic technique employed in this protocol was first used by the artist Armelle Caron, in an analysis of world city blocks, titled ‘Tout bien rangé, Anagrammes graphiques de plans de villes’ (Caron, 2012). In
this creative practice approach, urban block outlines are extracted as graphic outlines from an overall city plan and arranged orthogonally according to size, appearing in lines, thus revealing the similarity or otherwise of geometric properties of each block. This can be seen as an indicator of heterogeneity or difference, and ‘order’ or ‘disorder’ in overall analysis of city block composition. Here, it is used to visually indicate geometric similarity (ie. size, length, width, orthogonality) or otherwise between urban blocks, (or streets or plots) within an urban site.

Step 1
The technique involves outlining each urban block in Illustrator on a separate layer, and then placing each block on a grid background. Here, for urban blocks, a grid of 120m wide by 180 m high has been used.

Step 2
Urban blocks having similar geometric characteristics are grouped, in the following five ‘type’ definitions:
1. large non-orthogonal, (one or two 90 degree angles, large block)
2. medium non-orthogonal, (one or two 90 degree angles, medium block)
3. square part-orthogonal (two 90 degree angles min, square shape)
4. part orthogonal (two 90 degree angles min, non-simple shape)
5. rectangular –orthogonal (3 or 4no. 90 degree angles, rectangle shape)

Step 3
In order to visually ‘collect’ into a taxonomy or ‘a structured set of types’ (Marshall, 2005:90), a horizontal and vertical centre line is indicated. Each block is considered for locating a centroid, which for non-orthogonal blocks is done ‘by eye’. Then each group of blocks is overlaid one on the other, with an ‘average type’ highlighted, to give a

27 (120m is the recommended maximum urban block length to ensure permeability in new Irish urban blocks, according to the Irish ‘Design Manual for Urban Roads and Streets’ (Dept of Tourism, Transport, and Sport, 2013: 44).
visual impression of compositional complexity within a ‘type’. The taxonomy protocol for a street follows a similar set of steps.

**Taxonomy Protocol (Plot Type)**

This protocol follows similar procedures as the urban block analysis, but derivation of plots is arrived at in a different way. Here, the method is derived from Conzenian methods with particular guidance from (Baker and Slater, 1992:49)(See separate Note in Appendix A, ‘Morphology of cases description’). A combination of sources including historic map reading, planning application file examination, digital map examination (eg, www.landdirect.ie, Irish property registration website, displaying certain deed map boundaries) and extensive fieldwork in each site is suggested before plot outlines are derived.
Power Law Distribution Measurement Protocol (1B)

Introduction

The urbanism literature agrees on the importance of size diversity, or ‘universal distribution of sizes’ (Salingaros, 2004:3) of some important constituents of urban form, whether the overall urban components (Salingaros, 2004:3), urban blocks (Jacobs, 1961), or streets (Salat, 2012). Here, street width in urban sites is chosen, as an easily defined variable which can be represented visually in a communicable way, and tested in the iterative urban design process.

Definition

Power Law Distribution ‘imposes a mathematical relationship between the size of a given element and the number of elements of this size: few big elements, more medium-size elements, and a big number of small elements.’ (Salat, 2012:29)

Method

The task is to evaluate and represent visually a measured, quantified relationship between different street widths of an urban site. For an urban site of medium size (See Note 1):

Step 1

Refer to official sources for street names, extent of streets, etc which in Ireland can vary substantially depending on jurisdiction. For Dublin, the O.S. Geohive is a reliable source (so ideally keep visual .png evidence of maps searched), though in two of the urban sites studied, no official names apply to numerous streets, and hence streets in the demonstrated evaluation often have the designation NNSX (No Name Street No X), in order to keep an accurate record of street measured. It is a good idea to keep a
‘graphical note’ 28(see sample sketch, street ‘units’ marked in blue) of researchers ‘decision’ as regards extent of street, as this can be subject of qualitative analysis of maps, site visits, and site knowledge generally, and rushed or unrecorded decisions in this regard can have negative impacts on overall results.

Step 2
Ideally, take a printed 1:1000 Ordnance Survey map of the urban site, black and white copy, and mark in red, midway along the length of the street, the scaled, measured width in metres, to nearest 5 cm (eg. 12.45m). In defining street width, many of the ‘streets’ measured in this Thesis do not contain buildings, or have large ‘gap’ sites awaiting development. The requirement here is to use the official map in conjunction with site awareness to deduce the land ownership, or plot definition, and measure to the ‘back of footpath’ line of the map. This can sometimes be a matter of judgement, but as long as the decision is recorded clearly in red, with clear crossed lines over the black and white boundary line, another researcher can see the decision taken. Many online measurement tools are now available to carry out this type of task, but need close adherence to systematic methods of recording if used. My method involves taking a screen grab (.png file) of all ‘digitally’ measured locations (filed alongside other measurement records)

Step 3
Number all the measured street widths in a chart in some logical order, (eg. widest first) , then categorise each width as a type (35m ,Type A) and add the number of each street of this width counted (5) in Chart.

28 ‘Graphical notes’ can be seen as something halfway between a written note and a graphic sketch, and are of particular use for urban design, where visual judgement of graphical material, or pattern recognition, happens in an abductive or tentative way. Traditionally this method involved in hand drawn notes on sketches, but digital methods allow instant overlayering of data and notes to digital images, in apps (Layar, etc) and software packages (eg. 4dwalk). As an aside, in my teaching, I notice a reluctance of students of the digital age to engage in tentative or sketchy annotation, which I argue, impairs full and critical reflection on visual images, whether self-generated or received.
**Step 4**

Prepare Power Law Distribution of Streets Chart (Street width, x axis, Multiplicity, y axis) and plot on a chart as indicated in Fig. 16. ‘Paris road size distribution’ (Salat, 2012:35).

**Note 1**

Case study unit sizes in this Thesis are between half and two thirds the geographical extent of a ‘preferred’ mixed development neighbourhood site, which would be approximately 120 acres (Urban Design Compendium, 2007:40).

**Terms:** ‘Street’ (See Glossary)

**Relevant Sources:**

See related conceptual explanation in Section 3.2, Urban structure/form, Pg 164.

Also, (Salat, 2012:29). Other related readings include (Salingaros, 2004:3), (Jacobs, 1961:191), (Carmona, 2003:80).

**Indicator:** Graph curve, possible mathematical number per urban site (See Equation 1, (Salat, ‘Energy Efficiency’ paper (A), 2012:30). and (‘Assessing Cities’ paper (B), Salat, 2012:602)
Passive Volume Ratio Measurement Protocol (1C)

Introduction

The literature on the relation between environmental quality at urban site scale, complexity and urban design suggests a gap in understanding at the ‘in-between’ scales of urban design, and an over-emphasis on factors such as air quality and noise to the exclusion of built form assessment at the scale above buildings. Here, quantitative measurement of passive volume ratio of urban blocks at this scale is chosen, as an easily defined variable, which can be represented visually in a communicable way, and tested in the iterative urban design process.

Definition

Passive volume ratio in a building has been defined by Salat as ‘the ratio of the volume of passive zones within a building (normally 6m) over the total volume of the building’ (Salat, 2012:34). Salat states: ‘the more complex the urban tissue, the higher the passive volume ratio.’

Method

The task is to calculate and represent visually a measured ratio of the volume of passive zones within a building (normally 6m from the outside face of the floor plate) over the total volume of the building of an urban block. Take a printed 1:1000 Ordnance Survey map of the urban site, black and white copy, which allows measurement and setting out of a 6m line in plan from front façade of building to inner face in a perimeter block, or back façade of a building.

Relevant Sources: (Salat, 2011:34)
Figure BB-1  Image from ‘Urban Complexity, efficiency and resilience’ (Salat, 2011:34)
ABCD Street type Measurement Protocol (1D)

This evaluation method categorises street patterns according to quantitatively analysed features of the components. It also has clear applicability for urban design practice. ‘ABCD typology’ analysis is part of Marshall’s wider aim to develop a system of pattern classification of streets, ‘relating to desired formations of urban streets’ (Marshall, 2005:83). ABCD typology is described as having been developed ‘with the intention of reflecting typical street patterns that are encountered in different kinds of urban analysis’ (Marshall, 2005:84). It is further described by its originator as ‘one of a series of qualitative descriptors that culminate in a systematic classification system’ (Marshall, 2005:84). Here, in order to be useful for evaluating spatial complexity of urban sites, ‘A’ type patterns are considered to have highest compositional complexity, and ‘D’ type patterns lowest. ABCD typology has been defined as ‘a classification system to differentiate between different kinds of street morphologies’ (Berghauser Pont, Marcus, 2015:3).

Method

Step 1

Decide resolution and scale of urban site within a red line, indicated on a map (1:5000 min) including streets on the boundary. Map should indicate urban block outlines.

Step 2

Carry out, and record ‘T ratio’ and ‘X ratio’ generation (Marshall, 2005:98) on map.

Carry out, and record ‘Cell ratio’ and ‘Cul ratio’ generation (Marshall, 2005:98) on a separate but similar base map.

Step 3

Combine results for an urban site on (a) a Nodegram, (b) combined plot ‘box’ (Marshall, 2005:101).
Plot type

In this evaluation, the interest is in compositional aspects of plots at urban site scale of resolution, so observed ‘clusters’ of plot types of high and low compositional complexity are studied, as indicated through geometrical aspects. Properties in single ownership, or multiple ownership properties with single plot outlines evident from back of public pavement, at ground floor level are deduced from OS mapping at 1:1000 scale, and sources such as property deed mapping on the Property Registration Authority website (www.prai.ie). Individual plots are then extracted and aligned to an ‘x’ and ‘y’ axis on a grid, to assess geometrical character. In overlaying plots of equal semi-transparency for an area or urban site, levels of difference between size, orthogonality, shape and occurrence become vially evident, and ‘clusters of complexity’ of plot type emerge in urban sites.

Plots per hectare/ urban grain measure

Moudon (1988, 1994) includes analysis of urban grain in her approach to typomorphological study of the urban built environment. Using grain as a proxy for distribution of different types and sizes of elements, she claims that complexity of the urban built environment can be measured by distinguishing between ‘coarse’ and fine grained’ environments (Moudon,1994:185). Norton (2016) has developed a method of measurement of urban grain in Dublin, and provided baseline measures for five different types\(^\text{29}\), related to net plot density per hectare within urban blocks. The method involves a recording on an OS 1:1000 map deduced plot boundaries and numbers per block. Historic mapping, digital mapping of recent planning application files (http://www.dublincity.ie), the Property Registration Authority website (www.prai.ie),

\(^{29}\) Norton distinguishes between ‘fine urban grain’ (small plots comprising 300sqm or less) and ‘coarse urban grain’ (large plots comprising more than 300sqm) (Norton, 2016:115). He also develops a grading matrix for urban grain, dividing types into five categories (Norton, 2016:37).
Google Earth, and Streetview, as well as fieldwork observation help in making decisions on plot boundary.

**Blocks per hectare**

Urban blocks per hectare (Dempsey, 2008:255), is a commonly used measure in urban analysis and design, selected to help to define a comparable difference in compositional characteristics of urban sites. The following urban block definition is used: ‘the land defined by the grid of streets’, in the Urban Design Compendium, (English Partnerships and the Housing Corporation, 2000:67).

**Junctions per km sq.**

The incidence of urban road or street junctions per km sq. are argued to be an indicator of a ‘successful urban area’ with ‘over 250 in an area of one square mile’ (259 hectares) indicating ‘success’ (Montgomery, 1998:107), that is, approximately one junction per hectare\(^{30}\). In this evaluation a high number of junctions indicates high urban morphological complexity. In this study, each junction is marked on a baseline map of the urban site, to confirm type counted. This is useful to show, for example, that junctions where car traffic and pedestrian only traffic meet are also counted.

---

\(^{30}\) Clifton et al (2008:28) also consider this as one measure of network connectivity. The quantity of junctions per km sq. is also a measure in urban analysis for design (Clifton, Song, Knaap, 2008:9).
1.2 Land-Use Mix (Protocol 2)

Introduction
The literature on the relation between land-use mixes, diversity and urbanity argues that a certain minimum land use mix is necessary to achieve active urban life (Montgomery, 1987). The selected method of evaluating land-use mix of urban form in this study is based on a method developed by Van Den Hoek (2008, 2009), called the ‘Mixed Use Index (MXI)’. Among many possible options, this land-use mix evaluation method is chosen because it visually represents high mix, which can also be interpreted as high complexity, at the centre of the triangle. It also provides a visual output which is easily comparable with other urban sites, and has been used in a number of other recent studies (Van Nes, 2012),(Ye, 2013),(Van Nes, 2014). As a result, urban sites in this study can be easily compared with other locations. Also, the site context and an embedded site could be evaluated using this method, showing how heterogeneity could vary around a case site depending on spatial resolution.

Definition
The Van Den Hoek concept of land use mix analysis involves quantifying land area of the different functional uses of land, and the relative occurrence (in percentage terms) of certain types of land or functional use in a given location. In this study, the different percentage makeup of three uses is calculated for urban sites: commercial, housing and amenities. This gives an indication of the land-use mix heterogeneity in an urban site. While Van Den Hoek measured land-use in metres squared of building plans, recent digital availability of data for urban sites studied in this Thesis makes mapped functions per address point usable as a proxy for land-use in square metres. Van Den Hoek (2008,
2009) represents the incidence of each of the uses visually as a percentage of a triangle, where each corner represents 100% of a single use. If an urban site has 33% of each use, it would appear in the centre of the triangle. Van Den Hoek (2010) has shown that historic city centres tend to be located in the middle of the triangle, whereas modernist housing areas and industrial/office locations tend to be located at the mono-functional edges. Van Den Hoek (2010) also claims that there is a clear relation between mono-functional areas and low density, and higher densities and mixed use (defined as a min. 10% of each of the three functions, housing, amenities and commercial). Ye (2013) divides designations of multifunctionality into ‘high’ (each function occupying a minimum amount of 10%), ‘medium’ (min. 10% of two functions) and ‘low’, located in the corner of the triangle, and comprising a single function (eg. 100 per cent dwellings).

**Method**

**Step 1**
Identify Address Points Layer and ‘Address points by building use’ layer in Myplan.ie mapping for Dublin (www.myplan.ie). Turn on only three uses: housing, amenities and commercial. The involves tabulating only certain categories and colours (so leave out ‘residential and commercial’, green) and leave on only Q, R, S (‘health, arts, other services’) amenities in ‘Organisations by NACE Code’ layer.

**Step 2**
Take a screen grab of the digital map and count each unit of use within the urban site boundary, keeping a visual record of all buildings counted.

**Step 3**
Prepare a graphical 60 degree triangle (Illustrator) indicating rising deciles of amenities on the left side, lowering deciles of housing percentage on the right side, and rising deciles of commercial use from right to left. Calculate the relative occurrence of each of
the three uses as a percentage within the boundary of the urban site, and locate a colour
coded ellipse as representation of approximate position of the urban site.

**Step 4**
Locate also post-war neighbourhoods, historic city centre, and post war office parks for
comparison purposes (see for example Van Den Hoek, 2010, or Van Nes et al, 2012:3).

**Note 1**

**Terms:**

**Relevant Sources:** As above.

**Note 1**
The Myplan.ie website is an emergent All-Ireland spatial database, and address points
for example, have only be available since March 2015. Many other characteristics of
address points are categorized in this mapping, but there are also large data gaps, for
example in the ‘Address points by building type’ category, which lists ‘bungalow, detached, duplex, semi-detached’, ‘temporary dwelling’ and ‘terraced’, as the six
building types, but not ‘apartment’. However, the data uploaded is advancing rapidly,
and there is sufficient granularity for this task for an urban site at this stage in Dublin
(Winter 2015).

**Note 2**
Norton (2016:112) has also recently developed the Mixed Use Index (MUI) which is
claimed to capture three dimensional land uses better than other methods, and uses a
grid-based approach (rasterisation). This method could suit an embedded case related to
this study, but is considered too focused on unnecessary detail at the resolution of the
urban site.

**Indicator:**

Monofunctional, bifunctional, multifunctional.
1.3 Density (Protocol 3)

Introduction

The predominance of the issue of density of urban form is a feature of the urban analysis (Glaster et al, 2001), (Dempsey, 2008) design (Dovey, 2014) and evaluation (Ewing, 2009) literatures, and density is primary component in urban description, prescription and design (Berghauser Pont, Haupt, 2009) with claims that this is the ‘the dominating variable in the geographic analysis of urban space’ (Marcus, 2007). Density is measured in many different ways in urbanism and urban analysis and design, from populations per acre or hectare, to numbers of constructed storeys of buildings. The concept of density in Dublin planning policy terms, (DCC Draft Devlpt Plan, 2017-22, pg 159) is understood as ‘units per hectare’ for example, referring to appropriate densities of units of new housing permitted or considered by the development plan for an area.

Definition

In this study, urban density is defined as the relation between two variables, site coverage and plot ratio, expressed in an urban block density graph. Each measure is commonly used in new development planning applications, and appears as a numerical index in application forms related to all proposed new development sites in the Dublin City Council area.

The proposed graph relates to a visual representation, the Radberg graph (Radberg, 1996) originally devised to relate urban density, urban form and environmental characteristics in a typological urban classification system. However, the logic behind
the graph is not fully apparent in published material. The adopted method of this study relates also to the definitions offered in Spacematrix (Berghauser Pont, Haupt, 2009), (eg FSI, Floor Space Index, is plot ratio) but simplifies those terms to the two most commonly employed terms in urban development in Ireland (site coverage and plot ratio).

Method

Step 1
Assess plot ratio and site coverage for each urban block in the urban site area. For plot ratio, this involves dividing the gross floor area of constructed buildings by the total site area, and can be expressed as for example 1: 2.64 (Steadman, in Carmona, 2014:205). For site coverage, this is is the percentage of the site covered by building structures, excluding the public roads and footpaths.

Step 2
In the case of the three urban sites of this study, as each has a local area plan context, with some urban analysis available, the plot ratios which sometimes appear in these documents can be used to validate calculated amounts. Baseline desktop data for calculation at urban block scale includes online planning application files, forms and drawings, onsite observation, and satellite photography and Google Streetview. These estimations are at the level of granularity of the urban block, and can be supplemented in embedded cases with information on individual buildings.

Step 3
Equalise plot ratios and site coverages across urban blocks through averages (total site coverages divided by number of blocks). The limitation of this approach is in unequally favouring results for large urban blocks, and including empty or undeveloped sites as
zero, but the numerical simplification is open to more detail examination for the embedded cases, and can be adapted or more precisely calculated with GIS software, (which the scope of this research does not include).

**Step 4**

Plot site coverage (x axis) and plot ratio (y axis), expressed in an urban block density graph. Note that Radberg, (1996), Berghauser Pont, Haupt, (2004, 2009), and Ye, (2013) all differ as regards relative metric distance in plotting the two factors FSI and GSI (X and Y axis). In the urban block density graphs shown in this study, a metric relation between the two has been shown (eg site coverage 20%= 1.0 plot ratio). However, this is a tentative, abductive measure.

**Note 1**

**Terms:**

Plot ratio ‘expresses the amount of floorspace in relation (proportionally) to the site area, and is determined by the gross floor area of the building(s) divided by the site area. Plot ratio is a tool to help control the bulk and mass of buildings (DCC, Draft Written Statement, Draft Development Plan, 2016-22, Ch 16, Pg 196)

Site coverage is ‘the percentage of the site covered by building structures, excluding the public roads and footpaths’ (DCC, Draft Written Statement, Draft Development Plan, 2016-22, Ch 16, Pg 196). It is considered as a control ‘for the purpose of preventing the adverse effects of over-development’ (ibid.)

**Note 2**

Norton (2016:188) has recently adopted a ‘density-based approach’ to analysis of density of businesses in two areas of Dublin, showing strong correlations between types of urban grain and business density. This method could suit an embedded case related to
this study, but is considered too focused on unnecessary detail at the resolution of the urban site.

**Relevant Sources:**

**Indicator:**

The results can be compared with the Spacemate diagram of Berghauser Pont, Haupt, (2004:56), and in particular the eight groups or clusters of urban morphology types, from A (low-rise strip development, lower left hand side of diagram), to H (high rise, low left hand side of diagram, above A). One caveat is that GSI includes more of the urban footprint (eg. to road centre lines) than site coverage.
2.0 Configuration protocols

For introduction, definition, and more detail on method for each of integration, choice and intelligibility, see ‘Appendix E, Syntactic Analysis of Dublin’. DepthmaxX software is used in this study to determine outputs. Axial lines in different colours represent highest (red) to lowest (blue) values in quintiles.

2.1 Integration (Protocol 4)

Step 1
Open relevant whole city map in DepthmapX, checking all backgrounds, colours, etc are set for appropriate visual outputs. Check Axial Map is ticked ‘on’ in Index. Ensure Integration (global) [HH] layer is on, (ticked on Attributes List). In particular, set DepthmapX classic (quintiles) as colour bands for all images. Highlight one street of the urban site to be evaluated, then holding down shift button, pick and highlight each separate other street considered within the urban site area.

Step 2
Open Scattergram\(^{31}\) in separate window, where highlighted streets will appear equally highlighted. Ensure variable showing for X-axis is Integration (global) [HH], and for Y-axis Integration (local) [R3]. Record Integration values in a Table, and record visual representations (.png files) (axial map with urban site highlighted, and Scattergram with urban site highlighted).

Relevant Sources: Space Syntax Textbook, (Al-Sayed, 2014)

Indicator: Chapter Four, Section 4.4.3, Table 4-4, indicates highest and lowest integration values of the Dublin Axial Map as indicators, for example, global range is from 0.8 (highest) to 0.30 (lowest).

\(^{31}\) A ‘scattergram’ defined by OED as a compound word of ‘scatter diagram’, is ‘a diagram having two variates plotted along its two axes, (used in statistics) and in which points are placed to show the values of these variates for each of a number of subjects, so that the form of the association between the variates can be seen’ (OED, accessed 041116). In space syntax, scattergrams are primarily used to the relationship between two continuous variables, and is useful to find how recognized clusters might have spatial distribution. (Al Sayed, 2014:58).
2.2 Choice (Protocol 5)

Step 1
Open relevant whole city map in DepthmapX, checking all backgrounds, colours, etc are set for appropriate visual outputs. Check Axial Map is ticked ‘on’ in Index. Ensure ‘Choice R100’ layer is on, (ticked on Attributes List). Highlight one street of the urban site to be evaluated, then holding down shift button, pick and highlight each separate other street considered within the urban site area.

Step 2
Open Scattergram in separate window, where highlighted streets will appear equally highlighted. Ensure variable showing for X-axis is Integration (local) [R100], and for Y-axis Choice (local) [R100]. Apply a regression line by pressing the R/ button, and area clusters which are highlighted will appear above of below the line.

Step 3
Record Choice values in a Table, and record visual representations (.png files) (axial map with urban site highlighted, and Scattergram with urban site highlighted).

Terms: ‘choice’, see Glossary of Terms

Relevant Sources: (Peponis et al, 1990)

Indicator: Chapter Four, Section 4.4.3, Table 4-4, indicates highest and lowest choice values of the Dublin Axial Map as indicators at different metric radii, related to the number of axial lines in the file.

---

32 A regression line is the best fitting straight line through a group of points on a scatter plot of x and y axes. In space syntax, the groups of elements plotted in a scatter plot (or ‘scattergram’) having the highest correspondence occur along, around and close to a regression line (al Sayed, 2014:59).
2.3 Intelligibility (Protocol 6)

Step 1
Open relevant whole city map in DepthmapX, checking all backgrounds, colours, etc are set for appropriate visual outputs. Check Axial Map is ticked ‘on’ in Index. Ensure ‘Integration [HH] layer is on, (ticked on Attributes List). Highlight one street of the urban site to be evaluated, then holding down shift button, pick and highlight each separate other street considered within the urban site area.

Step 2
Open Scattergram in separate window, where highlighted streets will appear equally highlighted. Ensure variable showing for X-axis is Integration (global) [HH], and for Y-axis ‘Connectivity’. Turn on Regression Line in order to read intelligibility values. Record intelligibility values in a Table, and record visual representations (.png files) (axial map with urban site highlighted, and Scattergram with urban site highlighted).

Terms: ‘intelligibility’, see Glossary of Terms

Relevant Sources: (El-Khouly, 2012)

Indicator: Chapter Four, Section 4.4.3, Table 4-4, indicates highest and lowest intelligibility values of the Dublin Axial Map. $R^2$ values are derived in the scatterplot, ranging between 0 and 1, where low is close to 0, and high is close to 1.
3.0 System protocols

3.1 Patterns (Protocol 7)

Street Network Complexity

For Introduction, Definition, Method see (Marshall, 2005: 125).

Step 1

Decide resolution and scale of urban site within a red line, and prepare a map, which should indicate urban block outlines (1:5000 min). Include streets on the boundary in evaluation. Indicate each route in one line, and assign a number to each ‘route’ identified in the network (see Note 1). Deduce ‘regularity’ of network, by assessing ‘continuity’, ‘connectivity’ and ‘depth’ qualities of each route in the network. (See Note 2)

Indicator: ‘Regularity’ or Irregularity’ of a network.

Step 2

Prepare a separate map, which should indicate urban block outlines (1:5000 min). Indicate clearly ‘links’ and ‘depths’ including allocations of ‘datum’ street, and assign different graphical symbols for each depth mapped.

Step 3

Prepare ‘Routegram’ to demonstrate the character of the individual route types (Marshall, 2005: 125).

Step 3

Prepare a ‘Table of values’, and identify ‘two further kinds of heterogeneity’, ‘recursivity’ and ‘complexity’. Then, in a ‘triaxial logic’ a ‘Hetgram’ can be prepared, which serves as a graphical representation of heterogeneity.

Step 4
Prepare ‘Netgram’, to demonstrate the character of a whole street network.

**Note 1**

See ‘Note on defining routes’ (Marshall, 2005: 118).

**Note 2**

‘The more different types of route a network has- relative to the total number of routes- the more irregular and complex it tends to be. This may possibly be equated with the ‘planned-ness’ of a layout’(Marshall, 2005: 149).

**Terms:**

A ‘Hetgram’ is a plot of relative positions of street network regularity, recursivity and complexity.

**Relevant Sources:**

**Indicator:** Complexity expressed as a number, eg. 0.15, from 0 to 1.
3.2 ‘Paths’, (Protocol 8)

Measuring Metric Reach of Paths

Introduction

This is a method for measuring ‘path network complexity’. Peponis et al (Peponis et al, 2008:883) originally formally defined and used ‘reach’ of a point as a way of measuring ‘the total street length covered by all paths extending out from that point that are no longer than a given threshold value’ (Peponis et al, 2008:881). This measure is argued to capture the density of networks and the density of intersections, and it is argued to have the advantage that large or small areas can be measured using the same method (Ellis et al, 2016:141). Here, metric reach is calculated from a centre point of the urban site, for a distance threshold of 500m (5 minutes walking distance) in all directions, which has also been used by Ellis et al, so results are comparable. Peponis et al (2008) use a 2 mile by 2 mile radius, to compare mean metric reach of older and newer urban areas, and find older urban areas have denser networks than new suburban areas.

Definition

Path network complexity is measured here by assessing the ‘metric reach’ of the network, defined as ‘the network length that can be covered walking in all possible directions from a point of origin for a specified distance threshold, and is essentially a means of measuring the density of available footpaths’ (Ellis et al, 2016:141). In this sense ‘path network complexity’ is seen as defined by density, measured using a quantifiable and repeatable method.

Method

This method can measure road or other networks as well as exclusively paths. Here, only public pedestrian paths are measured (which could be narrow lanes, etc). In one urban analysis study, measurement was carried out in ArcGIS (Ellis et al, 2016) as part
of a larger project for a wide urban landscape. Here, the urban sites are relatively small, so the exercise can be carried out by hand.

**Step 1**

Prepare an urban block outline map of the urban site, including pedestrian-only lanes. In some sites, ‘paths’ could be informally constituted ‘desire lines’ in grass or derelict sites, subject to the researchers evidence and intuition as regards intensity of use, and relative position (eg. close to an attractor, like a school). Fix a geographically located central point in the urban site on a scale map (1:5000) min.

**Step 2**

Assign (mark) 500m long walking routes along public footpaths in all directions. Start by marking in e, w, s and n directions, along and around blocks, to a max. length of 500m. Fill all other possible routes, counting each segment only once.

**Step 3**

Sum all routes, colour coding full 500m long, less than 500m (offshoot routes of main ones) and smaller segments, down to single segments, in different colours, for recording purposes. The total is expressed in No. of Kilometres, and density and network complexity can be inferred by the multiple of the maximum perimeter reached. (eg. 500m ‘distance threshold’ or ‘perimeter’, 8km total, = 16 times)

**Note 1**

Although the work by Peponis et al (2008) defining ‘metric reach’ is considered by Ellis et al ‘to draw on the work of space syntax (Hillier, 1999)’ (2016:137), and is associated with configurational evaluation, here the interest is in simply capturing network density of paths, and therefore the more ‘mathematical’ aspects, such as adding a directional reach assessment, are not selected. Other methods of capturing paths network complexity considered included some of the ‘six measures of connectivity’ suggested
by (Ellis et al, 2016), including ‘Pedshed’, ‘intersection density’, and ‘Link-node ratio’, but the small urban case site evaluated here was considered not to necessitate additional methods.

**Terms:** ‘reach’, ‘metric reach’

**Relevant Sources:** (Peponis et al, 2008), (Ellis et al, 2016).

**Indicator:** ‘times’

of ‘path network complexity’

No. of Kilometres, (in relation to a walkband of 500m)

(eg. 500m perimeter, 8km total, = 16 ‘times’)
3.3 ‘People’, (Protocol 9)

Measuring pedestrian movement network complexity

Introduction

In assessing pedestrian movement network complexity (People), Protocol No. 9 is now described. This protocol is titled ‘Measuring pedestrian movement network complexity’, and describes how to capture data as regards the network complexity apparent in pedestrian movement. This protocol involves two separate approaches. Two complimentary methods are used to collect pedestrian observation data: timelapse observation and gate counts.

Timelapse captures observations on the nature of uses of spaces over time, and is based on the ‘Photographing’ tool described in Gehl’s book, ‘How to Study Public Life’ (Gehl, 2013:31). There are numerous reasons to select timelapse as an observation tool. Gehl describes it as useful for systematizing and registering ‘indirect’ observations of the interaction between public space and public life. Indirect observations are described by Gehl as those involving cameras or other technical devices (Gehl, 2013:22). Whyte used timelapse to study how people use plazas in New York, finding for example that most of the people using them were young office workers who worked in the nearby buildings, and also that provision of good urban space tends to create demand and new habits of public life (Whyte, 1981:16). Other findings included the fact that shape is not a determinant of a busy public space (Whyte, 1981:26), a lack of correlation between size of public spaces and number of users (Whyte, 1981:27), and that as regards occupancy of public benches, capacity tends to be ‘self-leveling’, that is people tend to densely occupy without filling the full designed capacity of public seating (Whyte, 1981:70-71).
Gate counts are defined as ‘recording observations of people or vehicles moving’ (Vaughan, 2001:3), and are recommended for urban areas. It is suggested the method should be applied with rigour and consistency at an abundance of locations.

The desktop preparation, in advance of fieldwork, involves seeking background pedestrian data about the ‘case’ or urban site scale. Diverse sources of desktop digital data about pedestrian movement in Dublin are searched, and resulting information is collated graphically in order to formulate a mapped picture of the general pedestrian network complexity of the context of the three urban sites. In the second case evaluations, the method involves timelapse video for more precise description of pedestrian activity at the centre of the urban sites examined.

**Timelapse observation**

**Definition**

Whyte describes many technical aspect of making timelapse photography in his book ‘The Social Life of Small Public Spaces’ (1981). Whyte describes how it began: ‘We started by studying how people use plazas. We mounted timelapse cameras overlooking the plazas and recorded daily patterns’ (Whyte, 1981:16). This method can be described as an ‘observational protocol’ for ‘direct observation’ of case study sites for ‘evidence collection’ (Yin, 2003a: 92). A series of filmed records of the urban site ‘centres’ is made. The camera locations are identified after on-the-ground assessment of the perceived ‘centre’ of the ‘places’ (Cornmarket, Ballymun, Sandyford) from a fixed point at eye level, (facing a market ‘centrepoint’ in the small public space’).
Method

One 24 hour ‘rhythm’ period is captured in timelapse video, broken into eight sections, which are three hours apart in time (midnight, 3am, 6am, 9am, midday, 3pm, 6pm, 9pm). The footage is in the form of timelapse video footage shot on iMotion phone software (one shot per second approx., 3mins length per section), which is turn is reduced to a series of 160 stills approx (16 FPS, or frames per second), each appearing in output terms as a 10 second long piece of film.

Relevant Sources: (Ewing et al, 2009)

Gate counts

Definition

The ‘Gate Method’ has been described as ‘the workhorse of spatial observing techniques’(Vaughan, 2001:3) and has been used in the Space Syntax community because of its wide applicability in representing large amount so information both graphically and numerically. Simply defined as ‘recording observations of people or vehicles moving’ (Vaughan, 2001:3), it is recommended for urban areas or interiors, and it is suggested it should be applied with rigour and consistency at an abundance of locations. Space Syntax recommends choosing a number (minimum 25) and variety of street locations (well-used, moderately–used and poorly-used) in and around the area of study.

Method

Stand in a position facing the across a street, (with back to buildings or edge on one side), and draw an imaginary line or ‘gate’ across the street (ie. perpendicular to the buildings). Count people or vehicles crossing the line in both directions for a set period of time. Space Syntax recommends 2.5 or 5 minutes (Vaughan, 2001:3), and Gehl
recommends 10 mins (Gehl, 2013:31). Numerous other procedural details are clarified, like not counting any person who does not cross the imaginary line, and keeping precisely to the allotted time, by using a stopwatch. Rates can be multiplied to arrive at rates per hour (Vaughan, 2001:3), and so much be accurate, and in very busy locations can be lower (eg. 2.5 minutes). Different categories of people can be counted, such as children, tourists, men and women. Gehl, for example, emphasizes that counting women helps to indicate whether a public space is perceived to be safe or otherwise. In this study, adults, kids and tourists are counted, as an indicator of diversity of pedestrian populations, related to the research question. Diversity and complexity are related, and high levels of diversity suggest high levels of complexity (Page, 2010). Different times of the day, week, and year are recommended to count (Vaughan, 2001:5), and in this study, weekdays, weekends and mid-year days are selected, to give a temporal overview of the pedestrian movement patterns of the urban sites. Gate tally count sheet templates and a diagrammatic view of a ‘gate’ can be derived from (Vaughan, 2001:5) and samples for this study are indicated below.

**Note 1**

**Terms:**

**Relevant Sources:** (Space Syntax Observational manual, Vaughan, 2001:3)(Gehl)

(Ewing et al, 2009)
Bridge St. Gate Count Description

Plan and View, Bridge Street, Dublin 8. Both sides of footpath counted, on hill at City Wall markers.

Figure BB-2 Sample Image of gate count location, Liberties character area
Figure BB-3  Sample Image of gate count recording sheet, Liberties character area
4.0 Note on deriving exploratory complexity maps

This is a note on an exploratory technique to derive compositional, configurational, and system complexity maps of Dublin at whole-city scale, and by combining these three maps, to derive a single spatial complexity map of the city. As this is not an evaluation technique, and as it does not result from prior established methods of evaluation (like the nine previous evaluation protocols), this Note is treated in this Appendix as a report on an exploratory method developed specifically in response to one part of the research question of this study, which asks:

‘how can a combination of complexity theory and urban design theory contribute to an increased exploration and understanding of spatial complexity (composition, configuration and system properties), as well as to development of practical urban design evaluation tools and methods for urban sites?’

The aim in developing this complexity mapping method for urban analysis and design is to contribute to an increased exploration and understanding of spatial complexity through mapping analysis techniques for urban sites. As a base, and in order that this map can be accurately geolocated and re-inserted into a GIS package, a base map is set up at the Irish Grid coordinate reference system (CRS)(EPSG 29902), where most Irish data is set. This means for example, that Irish boundaries of CSO mapping of census data, as well as local authority mapping, can access this mapping through a GIS programme. QGIS (previously known as Quantum GIS) is chosen as an industry standard, freely available software package that is a cross-platform free and open-source desktop geographic information system (GIS) application that provides data viewing, editing, and analysis. As the aim in this study is to derive exploratory mapping only, at two large scale so the city (whole –city scale and case context scale) it is decided that
statistical clustering methods\(^{33}\) are not necessary, and that a simple means of spatial visibility clustering analysis can reveal concentrations of complexity at these scales, by observing and recording differences in spatial data at selected scalar resolutions, primarily from other mapped secondary sources.

**Pixel size**

System and other analysis also uses a grid of raster cells (or pixels) to represent data. A graphical review of pixel size in recent urban analysis literature (Fig. 4-9) shows a large range of sizes in use, related to specific research aims and questions, across landscape, geography, spatial planning and urban design. Norton has applied a grid-based approach for the first time to research on urban grain of Dublin for spatial planning and urban design, assigning values to grids of ‘rasterised pixels’ (20 x 20 m) (Norton, 2016:35). O’Dea has undertaken exploratory research into spatial values related to property price, location and data visualisation, at the scale of the street network (O’Dea, 2014:40). In particular, Nedovic-Budic (2016) favours overlaying postal addresses on a 1km x 1km grid to census data at this level of resolution in measuring the density aspect of urban form at community scale, representing all data in quintiles of colour. It is considered by the authors that ‘the mismatch between the census boundaries and 1 km x1 km grids prevent the use of census data’ (Nedovic-Budic et al, 2016:154).

**The Dublin Map**

The ‘Dublin Axial Map’ area as introduced in Chapter Five, represents a 20km wide and 16km high footprint of the Dublin urban area, which is geolocated to the Irish Grid using QGIS software. Approximately 267 (1km x 1km) cells are geolocated land cells

\(^{33}\) See separate Note on visibility clustering analysis below.
and approximately 53 cells are water. Irish research has used these cellular units, containing colours to indicate variations in spatial data. For example, (Nedovic-Budic, 2016) study of urban form at community level contains quintile colour indications of built form for these cells, including the year the cells were developed as urbanised areas (Nedovic-Budic, 2016:153) (Fig.2).

**Step 1**

In this study, in order to be compatible with other Irish datasets which use grid cell raster mapping to convey spatial information (for example MOLAND, CORINE,) cell size is set at 1km x 1km and a further additional cell size is added, of 0.5km x 0.5km grid cells, and visibility clustering analysis is undertaken at these two scalar levels. Firstly prepare in QGIS the Irish grid reference map of Dublin, with geolocated cells of 1km x 1km.

**Step 2**

Import QGIS Dublin map to Illustrator, and locate in separate layers, primary and secondary mapping data for each of the three issues and nine criteria of spatial complexity, developed according to the conceptual framework of this study. For example, data on urban morphological complexity, and specifically NIAH structures (architectural heritage) can be visually sorted into clusters by reference to www.myplan.ie at certain resolutions (see note in Chapter XX).

**Step 3**

Each issue of spatial complexity is considered in the conceptual framework of this study to contain three criteria of spatial complexity, so colour transparencies are set in Illustrator files to reflect quintiles of spatial complexity, from red (high) to green (low), in each of the nine criteria. This results firstly in a compositional complexity map for example, derived from three layers, each representing one criterion, on which
transparency of colour is divided into thirds. This allows the two other criteria of compositional complexity to be added on top of the first, potentially identifying a spatial ‘hotspot’ of compositional complexity, but also allow for singular exploration of urban morphological complexity, as a separate identifiable layer.

**Step 4**

Repeat the steps above for the three issues of compositional complexity. As the axial map of Dublin, the available configurational dataset is derived in vector (line) format, this involves deriving clusters by visual analysis at different scales of resolution, a technique already used in space syntax analysis, for example in interrogating scattergrams (Al Sayed, 2014:58).

**Step 5**

Repeat the steps above for the three issues of system complexity. As the available system dataset for Dublin is poorly spatially distributed in the city, and derived from a numerical format (footfall per hour, week, etc), this involves firstly geographically locating gate count locations of other researchers, and then deriving clusters by visual analysis at different scales of resolution. This technique is the least reliable for getting an overall spatial impression of the system, but it is likely that developments in recording and visualising footfall in Dublin will evolve rapidly for Dublin in the near future, so a more precise, and less exploratory of the spatial complexity map could be derived in the near future.

**Step 6**

In each of the three criterion maps, each of the three issues is assigned a separate layer, in order that three criterion maps, when overlaid, convey the level of complexity of the relevant issue of complexity. When all three maps are complete, combine layers of all three maps to derive a single spatial complexity map. Due to time limitations in the
maing of these complexity maps, only highest and lowest detected clusters of complexity are mapped, but this method could be developed to map all five quintiles of complexity, in each of the three issues, and all nine criteria, separately and joined, and be analysed at multiple scales, including the 1km and 0.5 cell size, but also at much larger sizes, including Norton’s 20 x 20 m grid, and finally, into three (and four) dimensions, by mapping onto two (sections) and three dimensional views, pixels of complexity divided into building storey heights, plot widths, and other urban and spatial unit demarcation conventions.
5.0 Note on visibility cluster analysis

Data mining for urban analysis has been defined as ‘the inspection of a large data set with the aim of knowledge discovery’. Behnisch & Ultsch (2009:521) In data processing, as part of data preprocessing and reduction, clustering techniques are defined as follows:

‘Clustering techniques consider data tuples as objects. They partition the objects into groups or clusters, so that objects within a cluster are “similar” to one another and “dissimilar” to objects in other clusters. Similarity is commonly defined in terms of how “close” the objects are in space, based on a distance function. The “quality” of a cluster may be represented by its diameter, the maximum distance between any two objects in the cluster’.

(Han, Kamber & Pei, 2011:83)

(Gal, Doytscher, 2014:526) employ a spatial visibility clustering (SVC) analysis method to study urban environments, which, by mining real pedestrians’ mobility datasets, enables by a visibility measure, to set a number of clusters. (Gal, Doytscher, 2014:526). However, although this has interesting graphical outputs related to temporal clustering of pedestrians in urban environments, the emphasis is on mathematical underpinnings of developing the method, algorithms, and numerical discoveries. More usefully for urban analysis and design, in quantitative classification of neighbourhoods Song, Knapp (2008) use an empirical cluster analysis technique to identify neighbourhood types. This is defined as a method of combining observations into groups based on their similarity, within a set of predetermined characteristics (Song, Knapp, 2008:11). O’Dea employs
K-means clustering technique to study socio-economic and age data in Dublin in exploratory research about spatial values related to property price, location and data visualisation, at the scale of the street network (O’Dea, 2014:40). Norton’s (2016:37) study of plot frontage width clusters in Dublin city centre investigated small plot dimensions, finding clear bands, including a cluster of frontage widths between 4m and 7m, and a clear step in frontage dimensions above 10m, as well as close association between frontage dimensions and plot area (Norton, 2016:37). Behnisch & Ultsch (2009) generate ‘emergent self organisation maps’ as part of a clustering and classification technique in ‘urban data-mining’, defined as a methodological approach to reveal logical or mathematical and partly complex descriptions of patterns and regularities inside a set of geospatial data. Clusters are considered in this analysis to be defined by ‘distances or densities’ (Behnisch & Ultsch 2009:522). Gil, Beirão, Montenegro, et al. (2012) employ data mining techniques to uncover various ‘dimensions’ of urban form, using k-means statistical clustering technique to produce objective classifications from the large complex data sets typical of urban environments (Gil, et al., 2012:27). However, as the aim in this study is to derive exploratory mapping only, at two large scale so the city (whole –city scale and case context scale) it is decided that statistical clustering methods are not necessary, and that a simple means of spatial visibility clustering analysis can reveal concentrations of complexity at these scales, by observing and recording differences in spatial data at selected scalar resolutions, primarily from other mapped secondary sources.
Appendix C  Glossary of Terms

Urban Analysis and Design Evaluation

(PhD Appendix)

For

Evaluation of spatial complexity of urban sites
Glossary of Terms

Commonly accepted terms and generally understood units of analysis are used in this study. However, some technical terms related to exploration, evaluation and visualisation methods need precise definition, and certain important theoretical concepts of the research are also described in this Appendix. Words which appear here within other definitions in the Glossary are indicated in italics.

Abductive research

Abduction, in philosophical terms, is defined as: ‘the formation or adoption of a plausible but unproven explanation for an observed phenomenon; a working hypothesis derived from limited evidence and informed conjecture’ (OED). Suitability of abductive methods to urban design research is evidenced by numerous previous studies, including (Gregorowicz-Kipszak, 2010) and (Väyrynen, 2010:1288). Abduction is described by Kitchin as ‘a mode of logical inference and reasoning forwarded by C.S. Pierce (1839-1914). It seeks a conclusion that makes reasonable and logical sense, but it is not definitive in its claim’ (Kitchin, 2014:6). A hybrid combination of abductive, inductive and deductive approaches are argued to advance the understanding of a phenomenon, and are recommended in response to increasing generation and availability of big data and new data analytics (Kitchin 2014:5) particularly related to geography (Kitchin, 2014), design (Cross, 2011) urbanism and urban design (Çalışkan, 2012).

Assemblage

The concept of ‘assemblage’ derives principally from the work of Deleuze and Guattari (1987), and is defined, in one interpretation, (and related to social sciences and critical urban theory) as follows: ‘Assemblage—whether as an idea, an analytic, a descriptive lens or an orientation—is increasingly used in social science research, generally to connote indeterminacy, emergence, becoming, processuality, turbulence and the
sociomateriality of phenomena.’ (McFarlane, 2011:205). DeLanda’s philosophical concept of ‘social complexity’ combines complexity theory with an assemblage theory approach, drawing philosophical support from non-linear mathematics and physics, seeing social life as a complex set of components, virtualities and potentials, whereby the social is both non-material and real (DeLanda, 2006:877).

**Axial Map** (space syntax term)

‘The longest and least set of lines that cover all continuous space in the urban environment’ (Hillier and Hanson, 1984:90). This is the base ‘fewest line’ map (Griffiths, 2014:163) prepared by the space syntax researcher. Hillier argues that the axial map ‘maximises local simplicity as a means to picturing global complexity’. (Hillier, 2002:177).

**Choice** (space syntax term)

As a syntactical measure of configurational complexity, choice as a local between-ness or ‘choice’ measure reflects ‘through’ movement potentials for areas and spaces. A space has a strong choice value when ‘many of the shortest paths, connecting all spaces to all (other) spaces of a system, passes through it.’ (Klarqvist, 1993:12). Choice is ‘intimately bound up with structuring the geographical scale at which urban-like space emerges’ (Griffiths, 2014:164). Urban centres will usually be high choice places.

**Compositional complexity**

While ‘composition’ here means the combination of elements constituting an urban site, compositional complexity, in relation to this study can be defined as complexity of compositional aspects of urban form. The complexity of urban form is extensively researched for urban design (Marshall, 2005)(Batty, 2007, 2008)(Clifton et al,

---

34 While the Oxford English Dictionary contains numerous definitions for ‘composition’, two are especially relevant to urban form and environments. While the first, used here, is of ‘the forming (of anything) by combination of various elements, arts, or ingredients; formation, constitution, construction, making up’ (OED, noun, 2), another definition, ‘the action or art of disposing or arranging in due order the parts of a work of art, esp. of a drawing or painting, so as to form a harmonious whole’ (OED, noun, 8), relates to the later discussion in this study of urban design as art. (See Chapter 4, Section 4.5.2, and Chapter 8, Section 8.1.3.4, in relation to outputs of this study, and how they relate to urban analysis and design practice.)

‘Complexity Map’

The concept of a ‘complexity map’ of the city is discussed by Krafta in relation to defining and measuring urban configurational complexity (Krafta, 1997:11) but not developed or illustrated. Krafta proposes in the concluding part of his paper that this type of map should be an algorithmic possibility, but does not graphically illustrate the concept. (Ch 5, Section 5.1 Introduction)

**Configurational complexity**

Configurational complexity of urban sites here means complexity of topological relations between elements. This can be distinguished from the primarily geometric relations of compositional complexity. (Chapter Two, 2.2.5 Definition of spatial complexity adopted for this study).

**Deformed Grid**

In repeated studies, settlements appear to be composed of urban blocks which, though irregular, are surrounded by space which forms intersecting rings, and therefore take the form which is at least a topological resemblance to an urban grid. The presence of this ‘deformed grid’ was suggested by Hillier (1989:334) as a feature of the great majority of towns constructed throughout history.

**Depth (space syntax term)**

‘Depth between two spaces is defined as the least number of syntactic steps in a graph that are needed to reach from one to the other’ (Glossary of Space Syntax, Klarquist, 1993)

**DepthmapX (space syntax term)**
‘depthmapX is a single software platform to perform a set of spatial network analyses designed to understand social processes within the built environment. It works at a variety of scales from building through small urban to whole cities or regions. At each scale, the aim of the software is to produce a map of open space elements, connect them via some relationship (for example, intervisibility or overlap) and then perform graph analysis of the resulting network. The objective of the analysis is to derive variables which may have social or experiential significance.\textsuperscript{35} See also Varoudis T. (2012) 'DepthmapX Multi-Platform Spatial Network Analysis Software’. Version 0.30 OpenSource ed.

**Evaluation** (for urban design)

It is considered that in the design of the urban built environment generally: ‘evaluation is an integral, if informal, element of an abductive design process, which we are just beginning to understand (Coyne et al., 1990)’ (Alexander, 2009:4).

**Hierarchy** (of complex systems)

Simon (1962) discusses ‘hierarchy’ in connection with complex systems, related to a smallest unit, but also as regards relations between clusters and aggregates, and suggests that systems in which there is no relation of subordination of subsystems are also important to hold in mind. He suggests that groupings in the structure of a social system might be defined operationally by ‘some measure of the frequency of interaction in (a) sociometric matrix’ (eg. Numbers of social contacts between groups) (Simon, 1962:469). He claims that in biological and physical systems, by contrast, the hierarchical structure is ‘a physical fact’, but that some physical substances have a ‘flat hierarchy’, whereby ‘the number of first-order subsystems belonging to the (object) can be infinitely large’. He concludes by suggesting that ‘in ordinary usage, we tend to

\textsuperscript{35} Source: https://www.bartlett.ucl.ac.uk/space-syntax/research/projects/ucl-depthmap, accessed 261116.
reserve the word ‘hierarchy’ for a system that is divided into a small or moderate number of subsystems, each of which may be further subdivided’ (Simon, 1962:469).

**Integration** (space syntax term)

‘Integration is a measure that describes relativized asymmetry in the graph network. It is a measure of mean depth that is specifically adapted for architectural layouts. The global measure shows how deep or shallow a space is in relation to all other spaces. Using integration, spaces are ranked from the most integrated to the most segregated. Integration is usually indicative to how many people are likely to be in a space, and is thought to correspond to rates of social encounter and retail activities (Hillier, 1996a).’ (Al-Sayed, 2014:14) Integration measures the extent to which one space is ‘close’ to another space within all spaces in a specified network radius. One would expect the relatively closest space to all others in the system to constitute some kind of centre and be a source of natural movement (Griffiths, 2014:164).

**Integration core** (space syntax term)

‘It is sometimes helpful to illuminate higher values in a system (i.e. the highest 10% values) in order to illuminate the integration core in a city. The integration core might take different shapes (a spine, a deformed wheel, diffused, and concentrated).’ (Al-Sayed, 2014:14)

**Intelligibility**

Intelligibility has been defined as ‘an axial graph measure that represents the relationship between streets that have high connections to other streets (connectivity) and streets that are more integrated in the axial system’ (Al-Sayed, 2013:285). As a second order measure, intelligibility is the correlation between connectivity (a static local measure) and integration (a static global measure) (El-Khouly, 2012:287). DepthmapX represents values for intelligibility on a Scattergram, showing a Regression line to indicate the best fitting straight line through a group of points on the scatter plot. An $R^2$ value is generated in the Scattergram, and the value ranges from 0 to 1, where
low values would be closer to 0, and highest closer to 1, with 0.40 representing moderate correlation, and 0.65 and upwards indicating a high correlation (Al-Sayed, 2014:65) and therefore high intelligibility. If the two values were in perfect correlation, the regression line would appear as a 45 degree line ($r^2 = 1$), indicating high levels of intelligibility.

**Optimality (in spatial complexity)**

Although (Batty, 2005) discusses size, scale and shape of cities, and considers the question of ‘optimal’ city size still unresolved, optimisation theory seeks top down solution to city design, something complexity theory suggests is unachievable, as optimality is constantly changing.

**Metric Reach**

Metric reach can be defined as ‘the network length that can be covered walking in all possible directions from a point of origin for a specified distance threshold, and is essentially a means of measuring the density of available footpaths’ (Ellis et al, 2016:141).

**Morphology (urban)**

The International Seminar on Urban Form (ISUF) ‘working’ definition of urban morphology is ‘the study of the physical (or built) fabric of urban form, and the people and processes shaping it’. The ISUF definition considers that the term is principally used for ‘a method of analysis which is basic to finding out principles or rules of urban design’ (Gebauer & Samuels, 1981), although they also note ‘that the term can be understood as the study of the physical and spatial characteristics of the whole urban structure: this is closer to the geographer’s usage’ (http://www.urbanform.org/glossary.html).
Morphological Period

A morphological period is defined as any cultural period that exerts a distinctive morphological influence upon the whole or any part of a town\(^36\).

Nested hierarchies

The concept of nested hierarchies is defined ‘a commonly accepted notion of scale’, and as ‘a set of areal extents in which it is assumed that the sum of all components at one level, such as counties or consumers, produces one component at a larger scale, such as states or households (Haggett, 1965)’ (Manson, 2001:408).

Plan-unit

According to Conzen, ‘plans’ are any large-scale maps showing essential detail of (town) layout in recognizable and measurable form (Conzen, 1968:115). The term ‘town plan’ means ‘the cartographic representation of a town’s physical layout reduced to a predetermined scale, but in the literature it has also come to denote the physical layout itself’ (Conzen, 1968:116). In defining town plan analysis, Conzen states: ‘streets, plots and buildings integrate in space and time to form individualized combinations of a dynamic rather than an static nature, recognizable in the town plan as distinct plan-units. These again combine to form the major plan divisions of a town. Recognition and comprehension of the whole plan structure in these terms form the subject of town-plan analysis’ (Conzen, 1968:117).

Plot

Norton defines the plot as ‘the extent of a discreet unit of ownership within the urban block’ (Norton, 2016:249) but does not define the urban block. (See Porta, 2011 definition)

Regression line

A regression line is the best fitting straight line through a group of points on a scatter plot of x and y axes. In space syntax, the groups of elements plotted in a scatter plot (or ‘scattergram’) having the highest correspondence occur along, around and close to a regression line (al Sayed, 2014:59).

**Scattergram**

A ‘scattergram’ defined by OED as a compound word of ‘scatter diagram’, is ‘a diagram having two variates plotted along its two axes, (used in statistics) and in which points are placed to show the values of these variates for each of a number of subjects, so that the form of the association between the variates can be seen’ (OED, accessed 041116). In space syntax, scattergrams are primarily used to visually judge the relationship between two continuous variables, and are useful to find out how recognized clusters might have spatial distribution. (Al Sayed, 2014:58).

**Segment Analysis** (space syntax term)

Segment analysis can be performed on the axial map, by examining segments of axial lines between junctions, which has the advantages of finer resolution analysis than the overall axial map, and also different ways of analyzing and defining the distance between one segment and another. Metric distance measures how far one point is from another, fewest turns distance (topological) measures how many turns a route requires (or how complex it seems) while least angle distance (angular or geometric) measures how much turning a route requires in terms of total deflection from a straight line. The three different analyses are argued to capture different ways of representing urban complexity (Hillier, Stutz, 2005:33). Marcus et al (2015) found that evaluating choice (using segment analysis) at metric radii gave a more robust measure of pedestrian activity than integration, but that the radii tested should vary depending on the type of neighbourhood tested (Marcus et al, 2015:14). Also, research has also shown that ‘there
is a stronger correlation between human movement and the spatial configuration of the street grid in the angular analyses (fewest angular deviations) than in the topological analyses (fewest turns)’ (Van Nes, 2012:361)(Hillier, 2007:360).

**Spatial complexity (definition, components of)**

See Chapter One, Section 1.3.7.1

**Spatial sciences**

Spatial sciences disciplines are considered to include regional, spatial and urban planning, landscape, and architecture. The term is used in connecting complexity and planning (O’Sullivan et al, 2006),(Rasouli, 2012), also in architecture (ETH, NSL research group) and mapping (Journal of Spatial Science).

**Space Syntax**

Space syntax is a set of theories and techniques which applies graph measures to study the configuration of spatial networks in architecture, urban design and transport planning (Varoudis et al, 2013). It is based on research of Bill Hillier, Julienne Hanson and colleagues at UCL, developed since the 1970’s. Space syntax analysis is not restricted to any particular scale of analysis, which, for urban designers is ‘a quality of the highest importance’ (Griffiths, 2014:165). Importantly for this study, Hilliers has connected spatial complexity and space syntax, for example as follows: ‘Space syntax....sees itself as in the service of the art of design, and to this end it sees one of its fundamental roles is expressing spatial complexity in ways which access it to design intuition, for example by the simple procedure of using colours to represent patterns of numbers’ (Hillier, 2005 #786@105).
Street

‘An enclosed, three-dimensional space between two lines of adjacent buildings.’ (Moughtin, 2003:129). Here, narrow lanes (eg. 1m wide) and very wide streets with few or no current buildings (35m) are included, as both these types are features of certain urban sites in Ireland.

Syntax (space syntax term)

‘Syntaxes are combinatorial structures which, starting from ideas that may be mathematical, unfold into families of pattern types that provide the artificial world of the discrete system with its internal order as knowables, and the brain with its means of retrieving description of them. Syntax is the imperfect mathematics of the artificial. Any set of artificial entities which uses syntax in this way can be called a morphic language. A morphic language is any set of entities that are ordered into different arrangements by a syntax so as to constitute social knowables. For example, space is a morphic language. Each society constructs and ‘ethnic domain’ by arranging space according to certain principles’.

Source: The Social Logic of Space, Hillier / Hanson, 1984, Pg 48

Synergy (space syntax term)

Synergy as a configurational measure in space syntax is defined as ‘the relationship between smaller radii of integration (local) and larger radii (global)’ (Al-Sayed, 2014:15). It is claimed to be illustrative of the relation between the parts and the whole in the urban system. Hillier claims that the synergy correlation represents ‘how local movement potentials in the area relate to movement potentials through the area’ (Hillier, 2004:42) so an indicator of medium connectivity is added by this measurement of the area.
**System complexity**

In describing system complexity, Marshall states that this type of organised complexity: ‘is different from artefactual complexity in that the parts are not necessarily assembled with respect to the whole, and the whole is in practice unknown by any agency’ (Marshall, 2012a). Alexander’s understanding of systems in relation to urbanism begins with his description of a ‘set’ as ‘a collection of elements which for some reason we think of as belonging together’, before defines a system as follows: ‘When the elements of a set belong together because they cooperate or work together somehow, we call the set of elements a system’ (Alexander, 1965:58). According to this definition, the complexity of a system could be related to the ‘kinds of entities and relationships’ which are ‘more common, important, and necessary than others’ (Manson & O’Sullivan, 2006:681). Therefore, here system complexity of urban sites means a measure of the numbers, size and relations between entities of the evaluated systems. This definition is developed further in Chapter Four (Section 4.3.1.3).

**Urban design**

The definition of urban design is contested (Cuthbert, etc). It could be argued that the emergence of the discipline concurred with the emergence of complexity theory, around the middle of the twentieth century, and reflects the developing requirements of city design to acknowledge multidisciplinarity and interdisciplinarity, and thus complexity and urban design have characteristics in common.

**Urban Block**

An urban block has been defined as ‘the land defined by the grid of streets’, in the Urban Design Compendium, (English Partnerships and the Housing Corporation, 2000:67).
Topology

Topology is concerned with those properties of figures and surfaces which are independent of size and shape. Topological characteristics are distinct from geometric characteristics in that this branch of mathematics. (OED, mathematical definition of topology, accessed 27022014).

Urban complexity

Batty describes urban complexity as having ‘its basis in the regular ordering of size and shape across many spatial scales’ (Batty, 2008:769).

Urban Morphometrics

Urban Morphometrics can be described as a science which concentrates on systematic and quantitative aspects of urban morphological research (Dibble et al, 2015:2) (See also Porta, 2011, and Dibble, Porta et al 2015 definition).

Urban site

Urban site in this study means an urban area roughly equating to neighbourhood size. The concept of ‘neighbourhood’ is highly contested across the spatial, social and political realms, so ‘neighbourhood’ as spatial unit of delineation is not adopted. Jencks & Dempsey, (2007) in their study of varying spatial, social, functional, and community understandings of the concept of neighbourhood, contrast the concept of ‘spatial delineation’ with that of ‘social delineation’, and propose 400m and 800 m ‘buffer zones’ around official mapped (spatial) definitions of neighbourhood (Jencks & Dempsey, 2007:165).
Appendix D

Pedestrian Movement Fieldwork

Urban Analysis and Design Evaluation

(PhD Appendix)

For

Evaluation of spatial complexity of urban sites
Introduction

The description of pedestrian gate count and timelapse video fieldwork for the three cases, as well as a brief introduction to concepts of measurement of pedestrian movement complexity, form the basis of this Appendix.

Pedestrian Movement Complexity Fieldwork

Direct observation of public life can be regarded as the most detailed scale of urban analysis for urban design, dealing as it does with pedestrian movement activity itself, and the individual pedestrian. As described in Chapter Four, Ewing and Handy argue that in discussing complexity as an urban design quality, ‘human activity may contribute as much to the perception of complexity as do physical elements’ (Ewing et al, 2009:81). The concept of pedestrian movement network complexity has established measurement methods, involving collection of observation data about people moving in urban sites. This data can function as a support for other evidence (like compositional and configurational readings). McArdle et al (2014) suggests that pedestrian movement behaviour can be classified using visualisation and clustering, and that movement data can identify spatiotemporal patterns (McArdle et al, 2014). In this study of spatial complexity of urban sites, as regards the context of the case site, public or official data availability is mixed, with highly commercial parts of the city and cordon ‘gateways’ having high levels of coverage, but little data availability in the less commercial parts of the city (as described in Chapter Five). The Liberties can be regarded in this sense as a less commercial part of the city, as evidenced by the lack of available measured footfall data. Although it is claimed there is streaming information, and live readings from a set of footfall sensors in Dublin city, as well as over 700 ‘video cameras for public safety’
(Tallevi-Diotallevi et al, 2013:181), little of this information is available publicly in Dublin. The approach of Melbourne city, where live pedestrian data is available online and graphically illustrated\(^\text{37}\), would be the type of data of benefit to this analysis of pedestrian movement in urban sites. The fieldwork approach in this study involves timelapse observation, which records movement of pedestrians in one central location using stop-motion digital video, with a camera positioned to maximise viewing of expected busy centres of urban sites. However, for the case sites, the objects of this Appendix Chapter, and in the context of a lack of available data, additional gate tally counts of pedestrian movement are also carried out, to inform an overall picture of pedestrian movement in the case sites. Additionally, while gate counts are a purely quantitative dataset, timelapse data contains visual detail and richness of a qualitative method.

In order to classify pedestrian movement complexity for this study of urban sites, a review of separate complexity, urban design, pedestrian observation and movement ecology theories was undertaken, and the Table of Indicators was prepared in advance of data collection. Size, clusters and diversity of pedestrian populations featured in the review, and therefore these characteristics were sought in analysis of the data collected.

---

<table>
<thead>
<tr>
<th>Complexity theories</th>
<th>Size</th>
<th>Clusters</th>
<th>Diversity</th>
</tr>
</thead>
<tbody>
<tr>
<td>‘Urban complexity has its basis in the regular ordering of size and shape across many spatial scales’ (Batty, 2008:769)</td>
<td>‘clusters of dense interaction...will identify a hierarchic structure’ (a feature of complex systems)(Simon, 1962:469)</td>
<td>‘Four properties of complex adaptive systems: aggregation, non-linearity, flows, diversity’ (Holland, 1995:42)</td>
<td></td>
</tr>
<tr>
<td><em>Urban design theories</em></td>
<td>’the complexity of a coherent system is proportional to its size’ (Salingaros, 2000)</td>
<td>‘the presence of other pedestrians increases the number of temporary nodes by clustering groups of people, and generally forming complex interactions between human beings. Pedestrian flow turns out on closer examination to consist of many rather short paths between temporary pedestrian nodes (Whyte, 1980)’ (Salingaros, 1999:42)</td>
<td>‘A physically simple system in general contains a small number of component types and all components of one type are identical’ (Salingaros, 2005:177)</td>
</tr>
<tr>
<td><em>Pedestrian Observation Theories (Movement ecology)</em> (Pedestrian flow theory)</td>
<td>group size associated with movement preferences, complex relation between walking speeds and companions (Willis et al, 2004)</td>
<td>The formation of increasingly complex patterns in pedestrian flow includes the development of clusters (Hoogendoorn et al, 2005) Cluster analysis to classify pedestrian movement behaviour (McArdle, 2014)</td>
<td>‘movement diversity among different groups, indicating complexity (Wei, 2015)’</td>
</tr>
</tbody>
</table>

Table DD-1 Indicators of Pedestrian Movement Network Complexity
1.0 Liberties character area Fieldwork

![Figure DD-1 Pedestrian footfall and local choice](image)

Sample Image of pedestrian footfall (red dots), and local choice (metric, 400m), city centre area, Source: Author

**Timelapse results**

According to this protocol (No 9), a series of filmed (timelapse photography) records of the urban site ‘centres’ is made. The camera locations are identified after on-the-ground assessment of the perceived ‘centre’ of the ‘places’ (Cornmarket, Ballymun, Sandyford) from a fixed point at eye level, (facing a market ‘centrepont’ in the small public space’). In the case of the Liberties, the historic public space at Cornmarket is selected, and the camera faces the focal point of public activity at this junction of High Street and Thomas Street.
Fieldwork description

Eight separate fieldwork timelapse videos of 3 minutes duration are recorded on the hour, every three hours over one 24 hour period, to capture the flow of pedestrian activity in one day in July 2014. Three separate shorter duration confirmation videos are made in the same location at 9am, midday and 3pm in December 2015, to reinforce data reliability, and compare seasonal changes of flows.

Results

At Cornmarket, 78 pedestrians in total pass through the space in the 8 video recorded times. The highest volume time is 6pm, with 23 pedestrians in 3 minutes. The lowest volume times are 3am and 6am, with 1 pedestrian in 3 minutes in both cases. Some patterns of occupation are as expected: for example people leaving the city centre on foot tend to dominate at 6pm (18 persons), and the busiest time otherwise in the 24 hour period is around midday, when this focal point of the neighbourhood has shoppers and other pedestrians passing through Cornmarket.

Conclusion

In overall terms, the highest single volume time ‘snapshot’ recorded at Cornmarket (23 pedestrians in 3 minutes, at 6pm) compares with Dublin City Council data on nearby count locations, where extrapolated figures are higher but comparable (45 in 5 minutes, at two separate gates). High numbers of pedestrians are recorded passing through this prominent public space at varying times during the day, and are captured across daily and seasonal intervals. This evidence suggests high pedestrian network and therefore system complexity of a key public space in the character area of the Liberties, which in turn suggests high spatial complexity in the local system.
In this urban site, relative complexity of the pedestrian movement network is also revealed through timelapse fieldwork by evidence of size (total number of pedestrians observed), which is relatively high for this historic public space in a partly high-density residential environment, clusters (spatial concentrations of pedestrian activity) which are apparent at busy times, and type diversity (adults, kids and tourists). While the generational mix across the timelapse footage indicates a good mix of adults and children, tourists also appear in some footage, although this is not an easy distinction to qualify, as it relies on the impression of the observer who evaluates the timelapse data.

**Gate counts results**
Pedestrian movement was observed in a selected number of gates at the edges or ‘entry points’ of the urban site of the Liberties Character area, around the historic public space at Cornmarket. The Liberties case is a data ‘gap site’, where information on publicly or officially recorded pedestrian movement flows are not available. In this context, assumed flows are extrapolated from nearby city centre locations to form an overview picture of pedestrian movement complexity of the urban site, in conjunction with five gate counts onsite, as described in Chapter Five. In this urban site, the collected data on pedestrian movement reveals a complex shifting pattern over time, of movement peaks and troughs, high local spatial densities of pedestrians, and unexpected flows at different times. Categorising complexity of a pedestrian movement network is not a feature of the urban design literature, so here three generally understood indicators of presence of a complex system are used, as discussed in Chapter Four: size, clusters and diversity. Simon’s definition of a complex system as ‘one made up of a large number of parts that interact in a non-simple way’ (Simon, 1962:468) is also relevant.
Gate counts results indicate that in overall terms, high levels of pedestrian activity characterize the urban environment of the character area of the Liberties. Complexity is revealed by evidence of size (total number of pedestrians observed), clusters (high and spatial concentrations of activity), and type diversity (adults, kids and tourists). 1,678 pedestrian movements were observed, at 5 gate locations, over two separate days, with four 5 minute counts on each gate on a weekday, and again on a weekend day. Weather was sunny and rainy on alternate days, and the counts were carried out in April, thus capturing a mid-point between high points of Summer and Winter (Gehl, 2004:51). Pedestrian movement flow categories are classified as ‘high’, ‘active’ and ‘low’, and one gate (High St.) shows especially high levels on a certain day (Saturday), while the same gate has consistently ‘active’ counts on a weekday. The highest gate count value was 114 pedestrians passing Gate 5 (Thomas St.) in 5 minutes, at 5.55pm on a weekday. In overall terms, the urban site of the Liberties compares favourably with pedestrian network complexity of the commercial heart of Dublin, having high relative numbers, clusters and diversity (described in Chapter Four). For the overall city, diversity of pedestrian type cannot be compared, as the city centre data is aggregated without sub-categories, but the high numbers of tourists in the Liberties counts confirms diversity of pedestrian type. Another feature of the gate count data is the low number of children counted, suggesting a generally child unfriendly street environment in the city centre, a finding suggested by Bourke (2015) and others (O’Connor et al, 2015).

39 However, in a separate study, comparing different parts of the city overall, Fitzsimons D’arcy et al (2013) found that inner city neighbourhoods were relatively walkable.
2.0 Urban Ballymun Fieldwork

Timelapse results

According to this protocol, a series of filmed (timelapse photography) records of the urban site ‘centres’ is made. The camera locations are identified after on-the-ground assessment of the perceived ‘centre’ of the ‘places’ (Cornmarket, Ballymun, Sandyford) from a fixed point at eye level, (facing a market ‘centrepoint’ in the small public space’). In the case of Ballymun, the main Plaza is selected, and the camera faces the centre of this primary public space of the regenerated town.

Fieldwork description
Eight separate fieldwork timelapse videos of 3 minutes duration are recorded on the hour in Ballymun Civic Plaza, every three hours over one 24 hour period, to capture the flow of pedestrian activity in one day in July 2014. Three separate shorter duration confirmation videos are made in the same location at 9am, midday and 3pm in December 2015, to reinforce data reliability, and compare seasonal changes of flows.

**Results**

At Ballymun Civic Plaza, 40 pedestrians in total pass through the space in the 8 video recorded times. The highest volume time is midday, with 26 pedestrians moving through (in two directions) in 3 minutes. The lowest volume times are 3am and 6am, with no pedestrian in 3 minutes in both cases. Some patterns of occupation are as expected: for example people using this civic centre on foot tend to be most numerous between midday and 6pm when this focal point of the neighbourhood has shoppers and other pedestrians passing through.

**Conclusion**

In overall terms, the highest single volume time ‘snapshot’ recorded at Ballymun Civic Plaza (26 pedestrians in 3 minutes at midday) compares with Dublin City Council data on city centre count locations, where extrapolated figures are a lot higher (average of 107 pedestrians moving in 5 minutes, over 28 locations). However, pedestrian footfall counts are not generally available for suburban civic centre locations in Dublin, so direct comparison is not possible. From the figures, low numbers of pedestrians are recorded passing through this prominent public space at varying times during the day, and are captured across daily and seasonal intervals. This evidence suggests low pedestrian network and therefore low system complexity of a key public space in the
regenerated town centre of Ballymun, which in turn suggests low spatial complexity in the local system.

In this urban site, relative complexity of the pedestrian movement network is also revealed through timelapse fieldwork by evidence of size (total number of pedestrians observed), which is low for a suburban civic centre in a partly high-density residential environment, clusters (spatial concentrations of pedestrian activity) are relatively absent, and type diversity (adults, kids and tourists). While the generational mix across the timelapse footage indicates a good mix of adults and children, a surprising ethnic mix is also captured, and tourists do not appear in any footage.

**Gate counts results**

Gate counts results indicate that in overall terms, low levels of pedestrian activity characterize the urban environment of Ballymun. In this urban site, relative complexity of the pedestrian movement network is revealed by evidence of size (total number of pedestrians observed), clusters (high and low spatial concentrations of activity/non-activity), and type diversity (adults, kids and tourists). In urban Ballymun 83 (more to add) pedestrian movements were observed, at four gate locations, over one separate days, with four 5 minute counts on each gate on a weekday, and four 5 minute counts taken again on a weekend day. Weather was sunny and rainy on alternate days, and the counts were carried out in April and mid-June, thus capturing a mid-point between high points of Summer and Winter (Gehl, 2004:51) as well as a Summer high point.

243 pedestrian movements were observed, at 4 gate locations around the Civic Plaza, over three separate days, with four 5 minute counts on each gate on weekdays, and
again on a weekend day. Weather was sunny and rainy on alternate days, and the counts were carried out in April and June, thus partly capturing a mid-point between high points of Summer and Winter (Gehl, 2004:51).

Pedestrian movement flow categories are classified as ‘high’, ‘active’ and ‘low’\textsuperscript{40}, and according to this measure, no single gate shows high levels. The highest reading, of 46 pedestrians in 5 minutes, at 1.30pm on a Friday, is recorded at the gate on Shangan Road, east of the Civic Plaza and close to the centre. Extrapolated to an hourly rate, at 552 persons, this figure comes close to an ‘active’ categorisation, but this is an isolated spike in otherwise very low figures. In overall terms, the suburban site of Ballymun compares poorly with pedestrian network complexity of the commercial heart of Dublin, having low relative numbers, few clusters of activity and low diversity of pedestrian type (described in Chapter Four).

For the overall city, diversity of pedestrian type cannot be compared, as the city centre data is aggregated without sub-categories, but the complete absence of tourists in Ballymun, as well as low numbers of children counted confirms low diversity of pedestrian type. In conclusion, the pedestrian network complexity Ballymun evaluated through gate counts and illustrated here suggests a low level of system complexity, which in turn suggests low spatial complexity in the local system.

\textsuperscript{40} The ‘Pedestrian Comfort Guidance for London’ (2010) document defines these three pedestrian flow categories. ‘High’ has 1,200 pedestrian movements per hour (pph), ‘active’ has 600-1,200 pph, and ‘low’ is below 600 pph. This guide is recommended for use in Irish urban conditions by the ‘Design Manual for Urban Roads and Streets’, (2013:87).
3.0 Carmanhall Fieldwork

Figure DD-3  Gate count location Carmanhall: view (l), and plan (r)

Timelapse results
According to this protocol, a series of filmed (timelapse photography) records of the urban site ‘centres’ is made at Beacon South, a mixed residential and commercial development at Carmanhall Road.

Fieldwork description
Eight separate fieldwork timelapse videos of 3 minutes duration are recorded on the hour, every three hours over one 24 hour period, to capture the flow of pedestrian activity in one day in July 2014. Three separate shorter duration confirmation videos are made in the same location at 9am, midday and 3pm in December 2015, to reinforce data reliability, and compare seasonal changes of flows. In the case of Beacon South, a shopping destination which opened during an economic downturn, the additional
timelapse footage also investigates whether pedestrian flow levels have changed in the 18 months between the two fieldwork tasks.

**Results**

At Beacon South, 54 pedestrians in total pass through the space in the 8 video recorded times. The highest volume time is 6pm, with 22 pedestrians moving through (in two directions) in 3 minutes. The lowest volume time is 9am, with only one pedestrian in 3 minutes captured in timelapse. Some patterns of occupation are as expected for a shopping destination which is car-dependant: for example people using this commercial centre on foot tend to be most numerous between midday and 6pm when this focal point of the area has shoppers and other pedestrians passing through.

**Conclusion**

In overall terms, the highest single volume time ‘snapshot’ recorded at Beacon South (22 pedestrians in 3 minutes at 6pm) compares with Dublin City Council data on city centre count locations, where extrapolated figures are a lot higher (average of 107 pedestrians moving in 5 minutes, over 28 locations). However, pedestrian footfall counts are not generally available for suburban civic centre locations in Dublin, so direct comparison is not possible. From the timelapse figures, low numbers of pedestrians are recorded passing through the commercial centre of Beacon South at varying times during the day, and are captured across daily and seasonal intervals. This evidence suggests low pedestrian network and therefore low system complexity of an important public space for the future neighbourhood of Carmanhall, which in turn suggests low spatial complexity in the local system.
In this urban site, relative complexity of the pedestrian movement network is also revealed through timelapse fieldwork by evidence of size (total number of pedestrians observed), which is low for a suburban shopping destination in a partly high-density residential environment, clusters (spatial concentrations of pedestrian activity) which are completely absent, and type diversity (adults, kids and tourists). While the generational mix across the timelapse footage indicates a good mix of adults and children, a surprising ethnic mix is also captured, and tourists do not appear in any footage.

**Gate counts results**

264 pedestrian movements were observed in Carmanhall, at four gate locations, with two 5 minute counts on each gate on a weekday, and two 5 minute counts taken again on a weekend day. Weather was sunny and rainy on alternate days, and the counts were carried out in April and mid-June, thus capturing a mid-point between high points of Summer and Winter (Gehl, 2004:51) as well as a Summer high point. Pedestrian movement flow categories are classified as ‘high’, ‘active’ and ‘low’, and according to this measure, a single gate, on one coun, shows very high levels. This highest reading, of 109 pedestrians in 5 minutes, at 12.55pm on a Friday, at Gate 4 (Carmanhall Rd. East) is recorded at the gate on Carmanhall Road, east of Beacon South and close to a pop-up food market in an otherwise disused light industrial site. Extrapolated to an hourly rate, at 1308 persons, this figure would be a ‘high’ pedestrian flow categorisation, but this is an isolated spike in otherwise very low figures. The next highest reading in Carmanhall, of 22 pedestrians in 5 minutes, at 4.15pm on a Friday,

41 The ‘Pedestrian Comfort Guidance for London’ (2010) document defines these three pedestrian flow categories. ‘High’ has 1,200 pedestrian movements per hour (pph), ‘active’ has 600-1,200 pph, and ‘low’ is below 600 pph. This guide is recommended for use in Irish urban conditions by the ‘Design Manual for Urban Roads and Streets’, (2013:87).
also at Gate 4 (Carmanhall Rd. East) is more representative of typical footfall in the area. Gate counts results for the edge-city site of Carmanhall in Sandyford indicate that in overall terms, low levels of pedestrian activity characterize the urban environment of Sandyford. Carmanhall compares poorly with pedestrian network complexity of the commercial heart of Dublin. In this urban site, relative complexity of the pedestrian movement network is revealed through gate counts by evidence of small size (low total number of pedestrians observed), clusters (low spatial concentrations of activity), and type diversity (mostly adults, few kids and no tourists). Pedestrian movement flow categories are classified as ‘high’, ‘active’ and ‘low’\(^{42}\), and one gate (Gate No. 2, Beacon South) shows typical active levels for the urban site on a certain day (weekday, midday), while the same gate has consistently ‘active’ counts on a weekend (needs to be confirmed Sat, 250616).

\(^{42}\) The ‘Pedestrian Comfort Guidance for London’ (2010:25) document defines these three flow categories of pedestrians. Up to 1,200 persons per hour (PPH) is classified as ‘high’, 600 – 1,200 PPH is classified as ‘active’, and less than 600 PPH is classified as ‘low’. This guide is recommended for use in Irish urban conditions by the ‘Design Manual for Urban Roads and Streets’, (2013:87).
Appendix E

Syntactic Analysis of Dublin

Urban Analysis and Design Evaluation

(PhD Appendix)

For

Evaluation of spatial complexity of urban sites
Introduction

This Appendix describes the approach to syntactical analysis of urban sites taken in this study, including conceptual background, data collection, analysis, limitations, and relevance. The ‘Dublin Axial Map 2012’ dataset is described in detail, compared to other cities, and used to derive evaluation sof configurational complexity of the three urban sites of the study, and each is described in detail.

Syntactic Analysis of Dublin

Configurational (syntactical) analysis techniques for cities measure, in an empirical way, the extent to which street networks and areas are intelligible and connected to other parts of the urban system, that is ‘relations taking into account other relations’ (Hillier, 1984 #134), and between the parts (of a city, for example) and the whole entity.

This study applies syntactic analysis to the case of Dublin city, based on a dataset referred to throughout this study as the ‘Dublin Axial Map 2012’\(^43\), supplied to the researcher in May 2014 by Space Syntax Ltd. London.

Simulation research methods are used in this thesis in the sense that configurational analysis of urban sites, as represented by axial line maps within the space syntax methodology and DepthmapX software, are used to examine the urban and spatial environment of the case unit sites. While these representations can also be drawn by hand (Bentley, 2004) the availability of an axial map and dataset for Dublin\(^44\) makes

\(^43\) The supplied dataset is known to Space Syntax Ltd. as the Dublin Spatial Network Model.

\(^44\) It is supplemented with subunit site data from fieldwork, using open source software, called ‘DepthmapX Multi-Platform Spatial Network Analysis Software’ is used to interpret and visualize the data. Version 0.30 OpenSource ed. (Varoudis, T, 2012) is used throughout.
computer software more efficient for this thesis, especially for global analysis. Other data, seen here as ‘compositional facts’ (demographic, census, density and diversity data) are also overlaid at global and local scales on the syntactical analysis output maps, using visual representational methods, to generate new understandings of levels of spatial complexity in urban sites. Two key measures in space syntax recommended for urban scale analysis are ‘integration’ and ‘choice’ (Griffiths, 2014:164). Integration measures the extent to which one space is ‘close’ to all other spaces in a specified network radius. ‘Choice’ measures the extent to which one space occurs on a path between two other spaces, relative to all other spaces in the system, and is associated with ‘through movement’. Both of these measures are used in this thesis as they have to do with properties of urban form that make cities intelligible, and intelligibility is seen as part of physical and configurational complexity, one indicator of spatial complexity (Hillier, 1988, 1989). The relation of simulation research to logical argumentation is that simulation research can be used to empirically test a theoretical position in a way that a logical system (theory) cannot demonstrate. The simulation approach framework ‘is able to demonstrate dynamic interactions and to yield empirical outputs’ (Groat & Wang, 2002:7). In this thesis the simulation system is designed to enact a particular set of cases of the general theory. It is considered that ‘the strategy of logical argumentation becomes more enmeshed with simulation research. This is because ‘any computer program is necessarily a formal-mathematical system, that is, a domain of logical argumentation’ (Groat & Wang, 2002:7).

In relation to techniques (or tactics) of simulation and modeling research, this research employs simulation as a quantitative research strategy/tactic, in the sense that configurational analysis of space and places, as contained for example within the
syntactical analysis techniques of Space Syntax methodology and DepthmapX software, can be used to examine the urban and spatial aspects and characteristics of sites.

**Other configurational analysis techniques**

Other configurational analysis techniques for urban design include methods for analysing street patterns in relation to complexity, defining this quality as a route structural property, and a heterogeneous feature, and relating numbers of distinct types of routes present in an area, with a finding that often complex, characteristic structures are found in traditional street layouts (Marshall, 2005: 148-9). This combination of scales and temporal analysis, while not incorporating space syntax methods, contributes to the diversity of configurational analysis methods. This method is employed later in this study, but categorised as a system criterion (See Note on Nomenclature, Chapter Four, Section 4.3.1.4) A separate approach, based on a network analysis of streets in a complexity frame, examines centrality from a ‘primal’ analysis approach (describing space syntax approach as a dual approach), arguing that this leads to expanded comprehension of the ‘hidden orders’ (or complex orders) that underlie the structures of real, geographic spatial systems. The network analysis research finds that the distribution of this centrality feature of some urban sites is different in so called ‘self-organised’ cities than in ‘planned’ cities (Porta, 2006). However, this method was ruled out as it concentrates on geographic network analysis (Porta, 2006:705), at scales larger than the urban site scale as understood in this study. A third approach to configurational analysis of urban sites, related to raster analysis of urban form, involves digital elevation models (DEM) which reflect different storey heights of buildings through pixel shadings. This method is argued to enable configurational analysis of urban form, and especially assist in urban design decision making at design stage. It is claimed to be
a method of connecting urban texture to urban quality (Ratti, 2004:297). However, this method was ruled out as it was part of emergent digital technologies related to urban measurement which have since advanced into highly-scientific and abstract digital representations of urban form (Morello & Ratti, 2009), thus unlikely to be used in conventional urban design practice.

**Configurational Data Generation for this study**

Although the base dataset of the Dublin Axial Map 2012 was generated by Space Syntax Ltd., numerous other data generation tasks were undertaken to further investigate the configurational aspects of Dublin, including:

- Generation of global, local and integration core mapping
- Generation of global 1km and 400m metric radius ‘Choice’ mapping
- Generation of intelligibility scattergram graphics and mapping
- Generation of visibility graph analysis of urban site centres mapping

**Configurational Data Analysis for this study**

The research ‘tactics’ employed here for syntactical analysis include:

- Text report/appraisal of the ‘Dublin Axial Map 2012’ (which was prepared by Space Syntax Ltd.)
- Use of DepthmapX software to analyse Dublin dataset.
- Desktop comparison of other research outputs for ‘whole’ city units
These methods can be useful for urban designers who are evolving methods of analysing and exploring similar sites and situations. These methods can be employed as improvements to current urban analysis and design processes in practice.

**Configurational Data limitations for this study**

**Relevance**

Space syntax methods are argued to have less relevance in certain types of locations (Marshall, 2005:111) such as low density or peripheral locations, multi-level locations (eg. bridges are not captured). However, in this research these methods have been calibrated to suit the low urban density and character where appropriate, by varying radii and number of steps chosen, as demonstrated in other recent relevant research, whereby ‘each neighbourhood type asks for a tailored spatial analysis’ (Berghauser Pont & Marcus, 2015:14)

**Boundary effects and the ‘paradox of centrality’**

When analysing the Dublin System, the limitations of selecting only a certain geographical area, which in turn is not within a county or local authority boundary, limits the relation between findings and local authority level understandings. Also, as Hillier points out in relation to systems, having first considered one of three settlements on its own, and then combining analysis with others, ‘if we consider each settlement on its own, then the internal pattern of integration will approximate the internal movement structure, while if we consider them as a system of settlements the edge pattern will reflect movement in the overall system’. (Hillier, 2001:176). He describes this concept as the ‘paradox of centrality’. The edge settlements of Dublin are excluded from influencing the analysis in this study because they are not included in the axial map.
The dataset records road or street centre lines, and in accordance with the most recent
digital Ordnance Survey public mapping which was available at the time of generation
of the Axial map (2012), and the most recently published OS map for Dublin available
at that time was dated 2010. So for example the Coombe Bypass in Dublin 8, (the south
ege of one of the case sites, Liberties) completed in the mid-2000’s, has been added
manually to the dataset. Other recent roads added to the Axial map include Benildus Avenue, Sandyford, Dublin 14, completed in 2009, which connects the Drumartin Link Road to Blackthorn Avenue, (at the west of the Carmanhall case site). Incomplete road layouts are a feature of Ballymun, the third case site, so some representations of this site are not reflective of site conditions in 2015.

It is possible that the limitations of OS map updating in 2010 is the reason that three significant new bridge crossings of the river Liffey, (the primary configurational barrier between north and south sides of the city), are not represented in the Dublin Axial Map 2012. These three bridges are indicated in Fig EE-1, as well as one which opened in 2014 (Rosie Hackett Bridge), and which also understandably does not appear in the Dublin Axial Map 2012.
Another limitation of the dataset of the Dublin Axial Map 2012 is the representation of the Dublin Port access Tunnel, a twin bore tunnel of 4.5km in length with a height clearance of 4.65m, described as ‘the longest urban tunnel in Europe’, and which opened in 2006\(^45\). The tunnel appears in axial line form as though it were constructed above ground. The implication of this is that potential ground levels spatial and configurational relationships which could not exist in reality are measured for in the map.

\(^{45}\) Source: http://www.dublintunnel.ie/about/ description accessed 011216.
Some notes taken on axial map after fieldwork visits to Ballymun, indicating ‘on the ground’ differences to the axial mapping.

**Figure EE-2  Sample of configurational data limitations (2)**

Configurational Data Presentation for this study

- DepthmapX modeling of global and local integration values for three case urban sites within Dublin
- Generation of graphical and visual indicators of integration, intelligibility, scattergram outputs for three urban sites
1.0 Dublin Axial Map 2012

**Configurational Analysis**

**CITY comparisons** (Axial Map Analysis)

Dublin Axial Map
From Space Syntax Ltd. (2012)
14,818 axial lines
Average Connectivity 2.8

London Axial Map
('between North and South Circular Roads'
adapted from 'Space is the Machine', Fig 4.4, Pg 121 (Hillier, 1996)
17,321 axial lines
Average Connectivity 4.2
(Read, 1999)

Amsterdam Axial Map
adapted from (Fig 3, Read, 1999)
8,591 axial lines
Average Connectivity 4.5
(Read, 1999)

NOTE: images are approximate indicative impressions of size only, not scalar comparisons

**Figure EE-3  Dublin City configuration compared**

Configurational analysis: Dublin (left), London (centre) and Amsterdam (right) compared. Source: Author

Space syntax applies methods from graph theory to study configurations in the built environment, using a single software platform to perform a set of spatial network analyses (DepthmapX). Here, syntactical relations can reveal topological characteristics. Topological characteristics are distinct from geometric characteristics in that this branch of mathematics is concerned with those properties of figures and surfaces which are independent of size and shape.\(^{46}\). DepthmapX (Varoudis T., 2012) software has been

\(^{46}\) (OED, mathematical definition of topology, accessed 27022014)
used throughout here, and the Dublin dataset and DepthmapX file which was made available by Space Syntax Ltd. has been only minimally updated for this research to reflect certain changes since the file was originally prepared. The dataset records road or street centre lines, and in accordance with the most recent digital Ordnance Survey public mapping which was available at the time, dated 2010. So for example the Coombe Bypass in Dublin 8, (the south edge of one of the case sites, Liberties) completed in the mid-2000’s, has been added manually to the dataset. Other recent roads added to the Axial map include Benildus Avenue, Sandyford, Dublin 14, completed in 2009, which connects the Drumartin Link Road to Blackthorn Avenue, (at the west of the Carmanhall case site). Incomplete road layouts are a feature of Ballymun, the third case site, so some representations of this site are not reflective of site conditions in 2015.

![Figure EE-4 Dublin Axial Map 2012](image)

Global Integration Rn (l) and Local Integration R3 (r). Source: Author

**Dublin City as Spatial System**

The Dublin map, as discussed above, covers a land area of 240km sq approx., from Dublin airport in the north, 17 km south to the base of the Dublin Mountains, and from Dublin Port in the east, to Lucan, a suburban town 13km from the city centre to the
west. According to the 2012 CSO Census, 39% of Ireland’s urban population lives in the environs of the capital city of Dublin.

Dublin City configurational analysis

![Figure EE-5 Dublin Axial Map 2012 Attributes Summary](image1)

![Figure EE-6 Dublin Axial Map 2012 Overall Integration](image2)
As outlined in Table EE-1 above, Dublin is compared in this study to some syntactical averages of 58 cities from four parts of the world (Hillier, 2002:153). The syntactic characteristics of Dublin, which can be derived from the DepthmapX file, include: number of axial lines, connectivity, integration (global, local, integration core), syntactic choice (overall and local) and intelligibility. Each of these aspects of the syntactical signature of Dublin, as revealed through analysis of the dataset, are described in more detail below. However, it is clear that the overall comparison shows a city of very low configurational complexity, as Dublin has the lowest rating of all 48
cities in all six of the indicators. While it is apparent that many more axial lines are tested in Dublin, than for example in Arab cities, and that Dublin is the single representative city of Ireland in this analysis, some of the indicators are in stark contrast to, and well below, international norms. In discussing comparisons between cities, Hillier states: ‘European cities have a degree of geometric organization somewhere between UK and American cities’, and also that: ‘Arab cities (seem to be) less intelligible than European cities’ (Hillier, 2002:157) suggesting that these differences could be ‘possible expressions of a spatial culture’. He then says: ‘For example, in cities in the Arab world, the spectrum between public and private spaces is often quite different from that in European cities’ (Hillier, 2002:157). He then discusses the differences in geometries of axial maps:

The differences in the geometry of the axial maps seem to be a natural expression of these differences. Even in the case of American cities, where one of the main factors in creating the more uniform American grid is thought to be the need to parcel up land as quickly and easily as possible to facilitate economic development, we note that the grid was prior to economic development and should therefore be seen as a ‘spatial cultural’ decision to create and use space in a certain way’ (Hillier, 2002:157).

---

47 Hillier also makes an interesting point about ‘complex’ layouts in this passage: ‘In historic European cities, we find that local areas are for the most part easily permeable to strangers, with public spaces in locally central areas easily accessible by strong lines from the edge of the area. At the same time, fronts of dwellings are strongly developed as facades and interface directly with the street both in terms of visibility and movement. In many Arab cities, strangers tend to be guided much more to certain public areas in the town, and access to local areas is rendered much more forbidding by the more complex axial structure. At the same time, dwelling facades are much less developed, and the interface with the street tends to be much less direct both for visibility and for movement. The differences in the geometry of the axial maps seem to be a natural expression of these differences’ (Hillier, 2002:157).
2.0 Numbers of axial lines

When the Dublin Axial Map is compared with other cities (Rui Carvalho, 2004), at 14,818 lines, Dublin has a relatively high number of axial lines, between for example, the levels of Baltimore, 11,363 (USA) and Inner London 15,969 (UK). This implies that Inner London and Dublin have similar numbers of convex spaces. Further, in Axial Map terms, Dublin is probably closest to Manchester, the third of four city examples quoted in research in relation to ‘more geometric’ or ‘less geometric’: the cities are Atlanta (USA), the Hague (Holland), Manchester (UK) and Hamedan (Iran) (Hillier, 2002). This is subject of course to the original authors caveats, about different numbers and lengths of axial lines, etc in each city. In other words, Dublin is seen as not ‘very’ geometric by this measure.
Connectivity measures how many streets are directly connected to other streets in the overall system, in topological terms. In general, streets with higher connectivity value are expected to attract more traffic, and be more active. In terms of mean connectivity value, for Dublin, this is 2.819, well below the average for a European city, possibly reflecting a specifically local ‘spatial culture’. (Europe, 4.609, UK, 3.713) (Hillier, 2002). This syntactic characteristic implies that connectivity between convex spaces in Dublin is poorer than in other comparable European and UK cities.

In analysis the whole city map of Dublin, certain axial lines (mostly adjoining streets which together form a straight axial line in DepthmapX) stand out in the axial map as more connected. The six most connected axial lines/streets are, in descending order:

1. Dorset St. (comprising Bolton St/Dorset St. Lower/ Dorset St. Upper/Drumcondra Rd. Lower)(N1)
2. Georges St. (comprising Georges St. Lower/Upper, Dun Laoghaire, Do. Dublin) (R119)
3. Kimmage Rd West, Terenure Road West, Dublin (R818)
4. Morehampton Road, Dublin 4 (N11)
5. New Cabra Road, Dublin 7 (N3)
6. Mount Merrion Avenue, Dun Laoghaire, Do. Dublin (N31)

Two of these locations are urban sites: Dorset St., in the city centre, and Georges St. in the suburban centre of Dun Laoghaire. All are primary traffic routes in the city, and the most connected is in the highest category of road, the N1. One difference between integration and connectivity is that, while relatively longer and therefore better connected lines will be randomly distributed through the system, integration will be concentrated in the centre (Hillier, 2002:164).
4.0 Integration (global, local, integration core)

**global**

In global integration terms, Dublin appears as a ‘deformed grid’ or wheel structure with interstitial areas in overall configurational terms, more the product of organic development than any large, single urban grid imposition for example. This is important, as it has been argued that: ‘The configuration of the urban grid itself is the main generator of patterns of movement’. (Hillier et al., 1993) Concentrations of globally integrated areas occur in Dublin postal code areas 1, 2, and 8, as well as around the inner part-ring road (NCR and SCR), and outer part-ring motorway (M50). Other research has shown that highest to-movement potential in cities tends towards motorways (van Nes, 2012). The data indicates that few areas in Dublin city centre are easy to get to from each other, and that the ring access routes, while somewhat easy to access from outside and inside the rings, have poor connections from these integration cores both to the city centre and to outside of these rings.

**4.1 Local integration**

According the r3 Local Integration Map [HH], Dublin appears to have only a small number of local or neighbourhood level integrated cores, meaning places of particular importance for local users of the city, (or ‘centres’) and which connect to other places well in configurational terms. This is defined by the ‘to’ movement potential which exist in surrounding public spaces, within the nearest three syntactical steps. Research indicates that these places should have high numbers of people passing through, as well as high possibility to generate public activities and retail (Hillier et al., 1993).
Three different local integration cores are apparent in the city (and one in a historic suburban centre, Dun Laoghaire), in contrast to its single global integration core, which is in a different location. In the Dublin case, we also find that the most segregated locations are located on the end of routes, which do not in turn connect beyond the city limits (e.g. at the sea coast) due to boundary effects.

### 4.2 Integration core

According to Al-Sayed: ‘It is sometimes helpful to illuminate higher values in a system (i.e. the highest 10% values) in order to illuminate the integration core in a city. The integration core might take different shapes (a spine, a deformed wheel, diffused, and concentrated)’. Though Dublin is integrated well in global radii, it has a low global integration value as a unit, and the integration core is a weakly integrated deformed wheel. There are also non-typical integration values between core and edge, as global and local integration cores do not coincide, so the integration values do not fall away from the centre to the edge in a gradual way, in the way that for example the London axial map does (see Space is the Machine, Hillier, 1994).
5.0 Choice (overall and local)

Given that in space syntax, choice: ‘constitutes a measure for the potential for passing through spaces or simply through- movement’ (Hillier, Vaughan, 2007), this attribute of cities can be measured at different scales. Syntactic choice (overall and local) is not discussed in the original Hillier paper on concepts of spatial complexity (Hillier, 1998)\(^\text{48}\), and global choice levels for whole cities are not commonly reported, as this analysis method is recent (Griffiths, 2014:164) and not yet tested widely. Therefore the Table 1 used to compare Dublin with other cities above (Hillier, 2002) does not have a choice value for comparison internationally. A further limitation is that it is necessary to normalise choice in order to be able to compare different urban systems (Hillier et al, 2012) and global cities tend to be concentrated on in studying NACH (Normalised Angular Choice). Choice is calculated for trips up to a certain length, so for example an all city choice attribute for vehicles could be derived. However, this scale of focus is beyond the scope of this study of urban sites, and therefore local choice levels (radius r400 metric) are concentrated on.

\(^{48}\) See Volume One, Chapter Two, Section 2.2.4 ‘Two distinct spatial complexity definitions’.
6.0 Intelligibility.

According to Al-Sayad et al: ‘Intelligibility is an axial graph measure that represents the relationship between streets that have high connections to other streets (connectivity) and streets that are more integrated in the axial system.’ (Al-Sayed, 2013) As a second order measure, intelligibility is the correlation between connectivity (a static local measure) and integration (a static global measure) (El-Khouly, 2012). From the two observations on global and local integration above, including the lack of overlap between global and local integration cores, and from the scattergram reading, it can be deduced that Dublin has a relatively low intelligibility overall. Lower intelligibility is associated with loss of the expected relationship between spatial integration and movement (Penn, 2003), so analysis of the Dublin axial is a less useful predictor of movement patterns than in the case of a more intelligible city. Penn also discusses ‘highly complex and unintelligible urban areas’ at very local level (specifically ‘modern housing estates’) but this is a different condition to the Dublin whole city-case, where the unit is of low complexity, as well as low intelligibility.
7.0 Case context configuration: Liberties

Figure EE-7 Dublin Axial Map 2012 Liberties highlighted

8.0 Case context configuration: Ballymun

Figure EE-8 Dublin Axial Map 2012 Ballymun highlighted
9.0 Case context configuration: Sandyford
Configurational complexity is hard to be exact about, because levels of resolution ranging from single streets to entire city scales all give different readings of configurational complexity levels, so while M50 is the most globally integrated (and possibly complex) location in Dublin, a street in Temple Bar, East Essex Street, Dublin 2, is the most configurationally complex single street location (highest local choice, 400m metric radius measure of 14,818 axial lines). Assessing how this type of variation affects evaluation at the scale of an urban site is assisted through abductive visualization.
Conclusions

In conclusion, as regards an axial map analysis of the whole city ‘unit’ of Dublin city, it appears that there are poor global and local integration features, and therefore that intelligibility of the city unit is low. In international terms, there is poor connectivity, in general. These features in turn suggest low levels of spatial complexity, and in spatial terms of ‘orders of complexity’, it could be said to rank in a lower order of syntactical topologies.
Appendix F

Visualising Spatial Complexity

Urban Analysis and Design Evaluation

(PhD Appendix)

For

Evaluation of spatial complexity of urban sites
Introduction

Visualisation, one of the three primary objectives of this study of spatial complexity of urban sites, involves significant primary generation of graphical and representational material, related to the exploratory impressions and evaluation results of the study. These are collected in Appendix F.

Recent related visualisation of Dublin

Patterns of development of the Dublin Region and their impacts on urban form at regional scale for spatial planning have been investigated employing visualisation in pixel sizes of 200m x 200m, (MOLAND) (Williams et al, 2011) (Walsh, 2010) (Shahumyan, Walsh, 2010:xx), and O’Dea has undertaken exploratory research into spatial values related to property price, location and data visualisation, at the scale of the street network (O’Dea, 2014:40). Nedovic-Budic (2016) favours overlaying postal addresses on a 1km x 1km grid to census data at this level of resolution in measuring the density aspect of urban form at community scale. It is considered by the authors that ‘the mismatch between the census boundaries and 1 km x1 km grids prevent the use of census data’ (Nedovic-Budic et al, 2016:154). Norton has applied a grid-based approach for the first time to research on urban grain of Dublin for spatial planning and urban design, assigning values to grids of ‘rasterised pixels’ (20 x 20 m) (Norton, 2016:35) partly using GIS to visualise results. These three varying scales are each visualised as part of the research outputs in each study, and could be seen in hierarchical terms as large (region), medium (neighbourhood), and urban block (streets) scales respectively.

However, so far these and other studies of urban spatial characteristics and features of Dublin have been conducted at single scales. So, while Williams found for example that
applying the concept of a functional urban region is appropriate as a tool of analysis of urban systems, and especially in the case of Dublin, the implications of this proposition have not been investigated at the scale of resolution of urban sites. And while O’Dea concluded that a street network matrix for Dublin would be an appropriate way of defining spatial location and value of property, (a finding argued to have resonance with space syntax research findings related to social value) (O’Dea, 2014:40) this finding has not been exploited for larger neighbourhood levels. Also, whereas Norton looked at urban grain at coarse and fine degrees in relation to blocks in the urban centre of Dublin, these findings were not extrapolated or explored across higher (eg. city, neighbourhood) or lower (eg. street, individual building) scales.

**Art practice and urban design visualisation**

One of the conclusions of this study is that interpretative analysis contributes to urban design practice (Chapter Eight, Section 8.2.3, ‘Visualisation conclusions’). This section briefly addresses art practice and urban design visualisation, by setting out the artistic methods employed in this study. The expression of the discipline of urban design as art discourse has not been a feature of this study, but the artistic aspects do have an importance for this Section in relation to visualisation of evaluation results of urban design analysis. Numerous researchers have recently linked urban design and artistic practice (Boyko et al, 2014) (Marshall, 2013), with one related proposal that urban design could become refocused if conceived of as an integrative art of place (Marshall, 2015). As quoted in the opening chapter of this study, Tufte sees the world as ‘complex, dynamic, multidimensional; the paper is static, flat. How are we to represent the rich visual world of experience and measurement on mere flatland?’ (Tufte, 1990:5). In his book, ‘Envisioning Information’, Tufte emphasises the importance of including multiple
types of evidence in research: ‘Evidence that bears on questions of any complexity typically involves multiple forms of discourse. Evidence is evidence, whether words, numbers, images, diagrams, still or moving’ (Tufte, 2006). Onwuegbuzie et al’s presentation of a broad taxonomy of visual representation of mixed methods research includes connections made to mixed methods research outputs generally, suggesting that graphical methods have particular strengths in this regard (Onwuegbuzie, 2008). Creative practice research methods are considered appropriate to this study in this regard, even though the recent urban design research methods literature is silent on this topic (Carmona, 2014). As regards the relevance of the art of urban design, (or of ‘art’ to the practice of urban design) as introduced in Chapter Two, and further explored in Chapter Four, (Section 4.5.2) it has been demonstrated, especially in the exploratory stages of this study, that the interpretative, artistic interpretation of the infographics employed has enabled ‘abductive’ knowledge to emerge, and that this knowledge contributes to later, more hard-scientific, evaluation results. Hence, it can be concluded that the interpretative, creative or iterative and ‘designerly’ aspects of urban analysis do have a place in urban evaluation and therefore do contribute to urban design practice.

1.0 Complexity, resolution, pixels, and visualization

This section of the Appendix relates especially to the conceptual framework of the study, (Chapter Four, Section 4.5.3, ‘Urban evaluation visualization methods’) and is in essence the preamble to the proposal of concepts of a ‘Toolbox’ and a ‘Databox’ of spatial complexity.
Two primary representation methods are employed to represent spatial-related information related to the urban environment: vector and raster format. Vector representation uses unions or overlays of basic geometric constructs, such as points, lines, polygons, and the partitions and networks formed by these components (Hahn et al, 2011:17) to represent streets, road-centre lines etc, and normally contain attribute information such as length and position. The other primary format, raster representation, consists of ‘n-dimensional bit maps or pixel maps’ (Hahn et al, 2011:17). A pixel, or ‘picture element’, defined as: ‘each of the individual elements in a digital image’ (OED) and it is the smallest indivisible unit in a raster image. Rasterisation is the process of transforming vector-based information into raster information, so points, lines, polygon shapes are transformed into pixels or dots, at various resolutions, primarily for output on a visual display or printer, or for digital storage in a bitmap file format. The resulting rasterized image is normally represented in a grid structure where each grid cell has a single value.

Batty makes two key distinctions in discussing geographical information systems (GIS) and mapping at fine spatial scales, as regards possible decision support tools for urban design: firstly between geographic and geometric data, and secondly between vector and raster data (Batty, 1998:8). In distinguishing between geographic and geometric data, Batty argues that GIS treats all map data as geometric, although most of the large scales dealt with by GIS are geographic. Batty’s distinction of geographic mapping in GIS is that it ‘produces thematic rather than real representations’ (Batty, 1998:8). He uses the example of census data being averaged out over different resolutions of electoral districts or wards, arguing that while this was traditionally useful for urban designers, contemporary availability of much finer data resolution (‘to the lowest level-
50 metre resolution or less -’) is providing enormous spatial variability in data. Batty separately defines geometric data as being associated with ‘the physical configuration of the environment itself’ (Batty, 1998:9) suggesting that geometric data is often classified into points, lines and polygons. While he argues that ‘many GIS problems are defined in terms of one type or the other- either geographically or geometrically- not both, urban design cuts across both types of representation, requiring ways in which geographic and geometric can be handled simultaneously (Batty, 1998:9). Batty goes on to say:

‘In short, a rarely discussed limitation of GIS involving the ways different types of representation might be reconciled in conceptual terms, is directly confronted in urban design. This might explain in part why the application of GIS to urban design has been so slow in coming, and why more formal theories of urban design have hardly been developed to date.’

This commentary on limited usefulness of GIS to urban design arguably highlights limits to GIS as well as limits on urban design disciplinary definition and theory. Batty’s second distinction is between vector and raster data, and he states that: ‘as data becomes finer, the distinction between vector and raster data becomes more difficult to resolve’ (Batty, 1998:9). He cites as an example reconciling the distinction between aerial photographic data which is raster with vector-data based on-street and site outline information, suggesting that a level of precision not usually required at coarser scales becomes necessary at smaller scales (like urban design and architectural scales).

So while raster images have distinct advantages\(^4\) including geographical and ‘thematic’ visual representation capabilities, a mutli-scalar approach to analyzing spatial complexity of urban sites for urban design requires a combination of raster and vector

\(^4\) Norton’s (2016) grid-based (raster) analysis of urban grain cites particular advantages of raster stored data, including that they can be applied across larger areas, can allow for layering of other datasets on the same grid, and that the raster data model is recognized as the most appropriate approach to the analysis of land use and development of land use models, as it is area-oriented rather than boundary oriented (Norton, 2016:35)
data, as both larger geographic scales, and finer geometric scales are closely connected to the scalar focus of the research question, the urban site. As outlined in Chapter One (Section 1.3.4) the research question asks ‘how can a combination of complexity theory and urban design theory contribute to an increased exploration and understanding of spatial complexity (composition, configuration and system properties) for urban analysis and design, as well as to development of practical urban design evaluation tools for urban sites?’ In focusing on exploration as well as evaluation, a multi-scalar approach is made clear, as exploration in this study means analysis at larger geographic scales, and evaluation means closer measurement at finer scales associated with urban design at neighbourhood or urban site scale. As complexity theory also suggests a multi-scalar approach to exploration and evaluation, vector data, raster information, rasterisation are all linked to generating data and visualising spatial complexity. So while large scale representations of spatial-related information such as those facilitated by Geographical Information Systems (GIS) are more suited to infrastructure planning, design and construction, some urban design researchers argue that these tools enable better understanding of spatial complexity of urban sites, particularly for participatory planning (Talen, 2000). Other urban design researchers tend towards raster based imagery (Ratti, 2004),(O’Dea, 2014),(Norton, 2016) as cell size, the basic unit of analysis can be varied in size to suit the object of analysis. Space syntax (Hillier &Hanson, 1984) originally proposed two complimentary approaches to spatial definition: convexity, which represents two-dimensional features of the system, and axiality, which emphasises the one-dimensional (Batty, 2002:4). The second of these, involving generation of axial lines, involves vector representations of space, and has come to predominate in space syntax research. In this study of spatial complexity, while compositional evaluation including urban morphological analysis represents
spatial-related information in raster-based format, the configurational analysis represents spatial-related information in vector-based format. In summary, this study adopts a combination of raster and vector representations, and integrates both at multiple scalar resolutions, without losing advantages of either format.

1.1 Pixels and visualisation

System and other analysis also uses a grid of raster cells (or pixels) to represent data. A graphical review of pixel size in recent urban analysis literature (Fig. 4-9) shows a large range of sizes in use, related to specific research aims and questions, across landscape, geography, spatial planning and urban design. Norton has applied a grid-based approach for the first time to research on urban grain of Dublin for spatial planning and urban design, assigning values to grids of ‘rasterised pixels’ (20 x 20 m) (Norton, 2016:35). O’Dea has undertaken exploratory research into spatial values related to property price, location and data visualisation, at the scale of the street network (O’Dea, 2014:40). In particular, Nedovic-Budic (2016) favours overlaying postal addresses on a 1km x 1km grid to census data at this level of resolution in measuring the density aspect of urban form at community scale, representing all data in quintiles of colour. It is considered by the authors that ‘the mismatch between the census boundaries and 1 km x1 km grids prevent the use of census data’ (Nedovic-Budic et al, 2016:154). This last grid unit size, 1km x 1km, equates to many urban designers\(^50\) suggested optimal size for a typical urban neighbourhood or character area, and so it is adopted as the core pixel size through which to visualise urban sites of Dublin for urban design.

\(^{50}\) Although associated with a certain physical determinism, New Urbanists suggest an ‘ideal neighbourhood’ would have an ‘optimal size’ of 400 m from centre to edge (Madanipour, 2001), which coincides with the Urban Design Compendium guidance (Pg 40), although Dempsey et al suggest buffer zones of both 400m and 800m should be considered in defining the neighbourhood (Dempsey et al, 2007).
Figure FF-1  Graphical review of pixel size in urban analysis
1.2 Spider plots
As regards visualization tools in the decision-making process related to evaluation, in particular for complex issues, so-called ‘spider analysis’ is recommended for comparative and scenario studies (Baycan-Levent, 2005:236). Defined as ‘an analytical tool, which can be used to visualize the relative strengths and weaknesses of the selected case studies or different scenarios for various chosen factors’ (Rienstra, 1998), it functions, not as a mathematical tool, but as a visual analysis instrument. The ‘spider’ refers to the appearance of a spider’s web, and the scores of each factor are plotted on an axis which has lowest scores at the centre, working outwards towards higher values. The resulting image is called a spider plot. According to Baycan-Levent, the scores may be qualitative (ie. ordinal rankings) or quantitative (eg. standardized on a 10 point scale). In recent urban design evaluation, Serra, Gil, & Pinho (Serra, et al, 2013:10) have used this model to illustrate and apply a ‘taxonomic nomenclature’ evolving street patterns, and Mehta has used this format to visualize indices of evaluation of public space. Mehta argues that the value of the index she develops is ‘not in absolute values or scores but by the graphic representation of the spaces’ (Mehta, 2014:83). In this study, a spider plot format (Fig. 4-11) is the concluding part of the proposed Toolbox aspect of evaluation, as it can visually summarise both the quantitative and qualitative aspects of the urban site evaluations, and in simple form can be based on either lines alone, or lines and colour. Quick summary impressions of relative levels of evaluated spatial complexity can be achieved with spider plots, and visual comparisons within, between and across urban sites are improved by spider plot preparation.
Figure FF-2  Spider plot format for visualisation of spatial complexity
1.3 Colour and visualization

Selected prior theory, research and practices of employing colour to enhance graphic representation of urban evaluation are now described by reference to the three issues of spatial complexity which this study considers important to explore and evaluate. The reason to foreground use of colour in visualization here is related to the development of practical urban design evaluation tools for urban sites, (one of the aims of this study). Bringing together various visualisation techniques and standards of colour representation to synthesise evaluation results could enable a clear portrayal of evaluated spatial complexity of urban sites. This visualization tool could relate back, in an interactional way, to some accepted and previously used constituent colour ranges in urban analysis (See Figure 4-12). These already occur across selected compositional, configurational and system analysis methods, for use in urban design analysis and design, in description, prescription and design. So for example, a space syntax researcher could extract useful information about syntactical as well as spatial complexity aspects of urban sites by attending to the spatial complexity evaluation colour key developed in this study, and relating it to the colour range selected for use in that researcher’s primary ‘domain’, of space syntax.

Firstly, for compositional studies, selected relevant recent urban form, land-use mix, and density evaluation colour indicators are shown in Fig. 4-10. Stoner (2011) has used a colour key for relative size of urban blocks, to facilitate ease of visual comparison between clusters of larger and smaller blocks. As regards ABCD street pattern analysis, although Marshall (2005), indicated analysis of streets and patterns in black and white, he had earlier developed a ‘Periodic Table of street pattern (2004), including 4 colours.
As regards urban analysis of land-use mix, although Radberg (1996), and later Von den Hoek (2007), for example, indicated in graphical triangle indicator images of black and white, more recently other researchers have combined this method of analyzing land-use mix through the development of colour visualization techniques, and combined these indicators with other methods. Berghauser Pont & Haupt introduce nine colour bands of ‘archetypical samples’ of Dutch density in their measurement tool (Spacemate) (Berghauser Pont, Haupt, 2009:118).

Secondly, as regards the selected configurational analysis method, Hillier has connected spatial complexity, colour, and the usefulness of space syntax to express this characteristic for design:

Space syntax….sees itself as in the service of the art of design, and to this end it sees one of its fundamental roles is expressing spatial complexity in ways which access it to design intuition, for example by the simple procedure of using colours to represent patterns of numbers. (Hillier, 2005 #786@105)

However, space syntax software (DepthmapX) allows for the setting of six ‘colour scale’ options, in relation to representing axial line maps, the primary analysis tool used in this study. Additionally, there are sixteen ‘Attributes List’ items, each of which could be illustrated according to any of the six ‘colour scale’ options. Therefore 96 colour options are available for visually representing each axial line, and this assessment does not include possibilities to vary line thickness, and additional colour variation possibilities within a colour wheel (eg. from black to white). While the result of these software colour options facilitate a large diverse community of space syntax researchers examining objects as different in scale as a room in a building, and a large geographical
region, these communities are not facilitated in communicating visually across what are arguably sub-disciplines of what could be termed ‘space syntax disciplinarity’, and even less likely to easily communicate visually outside the space syntax community of research. Thirdly, for system evaluation, while Gudmundsson et al (2013) have used only single colours to represent entropy and order in street network complexity, many visualisations of dynamic system measurement and mapping rely on colour-coded representation (Mc Ardle, 2014)(Kveladze, 2015).
However, limitations on peer reviewed journal colour reproduction capacity sometimes mean complex data is represented in monotone (Batty, 2004). Intensities and
complexities of pedestrian movement networks are generally represented through pedestrian flow charts with colour key, sometimes even alongside space syntax integration measures (Zhang, 2012).

The many established distinct colour representations of degrees of compositional, configuration and system complexity do not facilitate the core task of this study, which could be stated as: ‘a clear portrayal of complexity, that is, the revelation of the complex’ (Tufte, 2002). Integrative methods are discussed earlier as relevant to explorations of spatial complexity of urban sites (See Section 4.3.1.5) and visualization of separate measures of urban sites is represented in numerous papers, including Van Nes et al (2012), Ye, (2013) and Marcus, (2015) but visual clarity can sometimes be compromised.

So while Van Nes et al (2012) combines Spacemate (to measure density) space syntax (to measure configuration) and a Mixed-Use Index (MXI) (related to Van Hoek’s method) to measure land-use mix, alternative colour keys are used for each of the measures. While the data from the separate frames are then combined using GIS, and correlations shown to occur between higher densities, mixed land-use and integrated areas, it is the next step in data analysis which misses an opportunity for colour and graphical synthesis. While four types of density and four types of integration are combined in a matrix, global integration and segment angular analysis is shown in five degrees of colour (Fig. 7). The combination of integration analyses of different radii are shown in eight degrees of colour (Fig. 9), environmental types (different density types) and function mix is each shown in nine degrees of (different) colours, and the final
synthesizing matrix consists of six different colours and categories (Fig. 15. 16). Later this colour key is reduced again, in combining social data, to four indicators (Fig. 18).

Ye & Van Nes (2013) used multiple analytic tools to investigate spatial ‘flaws’ of new towns as compared with old towns, visualizing and quantifying spatial properties of the built environment including integration, land-use mix and density through cell based colour pixel analysis (Ye, Van Nes, 2013:17). While nine degrees of colour of street network configuration are indicated (Fig. 3), and nine degrees of colour of comparison of density and building type (Fig. 5), only eight degrees of colour of land-use mix are indicated (Fig. 6). Finally, the three different urban morphological measures (Space Syntax, SpaceMatrix and MXI) characteristics are combined in one map, indicated seven different ‘degrees’ of ‘general urban morphological differences’. While this analysis is useful in visualizing and quantifying spatial properties of the built environment, a certain lack of visual synthesis of colour coding of degrees of the measures leads to low applicability of the visualization techniques for urban design practice.

Berghauser Pont & Marcus (2015) mixed methods approach to an analysis of urban typology and configuration in Stockholm, which includes Marshall’s (2005) method of analysis of ABCD street typology and morphologies, a Spacemat approach to density, and space syntax methods. While integration is represented in seven degrees of colour (Fig. 4), and pedestrian flow rates are superimposed on the ABCD grid in three different colours (Fig. 9), arguably the opportunity to graphically synthesise the results in one graphical indicator of degrees of movement behavior, street pattern type and configuration is missed.
As regards degrees of colour to represent data in this study, the level of spread or breaks between measures will depend on the resolution of the data and the size of the object to be described. Quintiles are common in representing Irish spatial data at the macro scales, such as the Dublin region (MOLAND) (Williams et al., 2011) (Walsh, 2010) (Shahumyan, Walsh, 2010:xx), meso scales such as the neighbourhood (Nedovic-Budic, 2016) and micro scales of urban design, such as a few urban blocks and streets (Norton, 2016:35). In order to provide for maximum comparability with these and other prior Ireland related publications across these multiple scales, a spatial complexity colour key for urban sites is proposed in quintiles, as indicated in Figure FF-4.

<table>
<thead>
<tr>
<th>Spatial Complexity Colour Key</th>
<th>R</th>
<th>G</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red - High</td>
<td>255</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Orange - High/Medium</td>
<td>255</td>
<td>170</td>
<td>0</td>
</tr>
<tr>
<td>Yellow - Medium</td>
<td>255</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td>Green - Medium/Low</td>
<td>0</td>
<td>255</td>
<td>0</td>
</tr>
<tr>
<td>Blue - Low</td>
<td>0</td>
<td>0</td>
<td>255</td>
</tr>
</tbody>
</table>

**Figure FF-4 Proposed spatial complexity ‘degrees’ colour key**

In this image, five colour bands are connected to their allocated RGB numbers, according to the RGB colour Model. In this way, exact colour ‘signatures’ of evaluations can be compared visually and mathematically across space and time. This proposal is described in Section 6.6, Volume One, Pg 393, ‘Data transformation’. Furthermore, where for example, three layer of exploration information is overlapped, one third transparency (33%) is assigned to each in mapping the results. Samples are produced for overall Dublin complexity maps of composition, configuration and system, as well as the integrated result, in Volume One, Figs 5-16, and 5-17, Pgs 272-3.

1.4 Spatial data cubes

The concept of a ‘spatial data cube’ is defined as a unit of organisation of spatial data which facilitates data mining and ‘organization of data into multidimensional structures and hierarchies’ (Hahn et al., 2011:18). Hong’s conceptualization of the ‘voxel’ or
‘volumetric pixel’ was developed in order to facilitate a theory of ‘interdependant urbanism’, which involves, in the authors terms, ‘simulating interdependent complexity, beyond prescriptive zoning’ (Hong, 2012:140). Hong suggests that this innovation can improve on land use and development zoning in cities. Hong also argues that computation can play a major role in urban design, ‘by leveraging performance based zoning standards instead of prescriptive rules’. His innovation is in representing performance of the urban environment through ‘simultaneous evaluation’ of variables (‘daylighting, building cores, proximity to parks, programming and other factors’) in order to give immediate feedback to designers, planners and stakeholders about the existing urban environment as well as potential urban design scenarios. He employs Rhinoceros and its Grasshopper plug-in software in conjunction with the programming language Python. After describing a number of novel tools which pertain to ‘the generation of maximum envelopes’ (for example seek optimal design forms related to sunlight and sky exposure) the author goes on to discuss the idea of ‘the voxel (short for volumetric pixel) as a way to subdivide this overall mass and imbue it with qualitative data in the form of both inputs and outputs’. Hong then describes the advantages of the voxel as follows;

‘Designers have the freedom to assign any number of parameters to the voxels, limited only by computation power. For our test case we included such factors as minimum daylight factor, views, circulation, and proximity to open space. From these inputs, qualitative outputs, or ‘readings’, of data are produced. The voxels thereby become an interconnected mesh, as data output from one voxel can be fed into the input of another, allowing interdependencies to ripple through the entire model.’
In another innovative approach to visualization of spatial data, Hahn et al define a ‘spatiotemporal database’ as a ‘spatial database that stores spatial objects that change with time’ (Hahn et al, 2011:18). These trends in urban data visualization are reflected in other enquiries, including investigations from architecture like ‘information urbanism’, (Tang et al, 2011), and ‘parametric urbanism’ (Schumacher, 2009), and geographical research into ‘data-driven, networked urbanism’ (Kitchin et al, 2015) though the latter is still primarily represented in two dimensional plan.

![Spacetime cube concept.](source)

**Figure FF-5 Spacetime cube concept.**

Source: Illustration of ‘Pedestrian movement in Delft city centre’, (Kveladze, 2015:62), (Fig. 3.12.) (See also Chapter Four, Volume One, Figure 4-11)
2.0 Visualising Case Contexts

Figure FF-6  Sample neighbourhood visualisations

Case Context images of Liberties character area (l), and exploratory overlap boundary mapping of Liberties character area

Case context image of urban Ballymun, and exploratory overlap boundary mapping of urban Ballymun

Case Context images of Carmanhall, and exploratory overlap boundary mapping of Carmanhall

Figure FF-7  Exploratory case context and neighbourhood visualisations

Source:  Author
4.0 Databox representations of Liberties character area

This section presents and describes some Databox representations of spatial complexity of Liberties character area, which result from the Toolbox evaluations (Chapter Six) and the ‘whole city’ and case context explorations (Chapter Five) carried out for the three relevant scalar levels of this study of urban sites. (See also, Appendix B, Evaluation Protocols, Section 4.0, ‘Note on deriving exploratory complexity maps’).

Figure FF-8  Exploratory sketch of link between Irish Grid and Databox

Source: Author
Figure FF-9  Exploratory sketches of Dublin spatial complexity map

Source: Author
Figure FF-10 Exploratory sketch of link between Irish Grid and Cornmarket site

In this image, the smallest grid unit considered useful for evaluating spatial complexity of an urban site, of 20m x 20m, is linked to the standard Irish Grid, which is a 1km x 1km geolocated mesh covering the plan (but not spatial) dimension of the landmass. Source: Author

Figure FF-11 Exploratory sketch of spatial complexity in section

This exploratory sketch extends the Irish Grid to a sectional image, and combines this with established sources of undesground spatial complexity (archaeological finds) Source: Author.
6.0 Toolbox representations of urban Ballymun

![Image of Toolbox representations]

Figure FF-12 Sample representation Toolbox evaluation (coloured) of Ballymun

This image returns to the Conceptual Framework Chart (Figure 4-1, Pg 158, Chapter Four, Vol. 1) for one sample evaluated location, to test this visualisation method. However, the images in the Addendum to Volume Two are considered to achieve the evaluation visualisation requirement more clearly, and therefore each of the three urban sites is presented there.

7.0 Databox representations of urban Ballymun

![Image of Databox representations]

Figure FF-13 Databox representation sketch of Ballymun

Infographic sample of ‘zoom-in-out’ facility the digitally developed Databox could have, in further development of the concept, whereby energy ratings of a kitchen appliance (fridge, for example) could be the lowest level of detail evaluation, linking over 22 zoom stages to an entire city configurational map.
11.0 Visualisations of highest compositional complexity

Figure FF-13 Compositional complexity overall map sketch
Address points overlaid on Dublin map at 2km resolution, and interpretative mapping of neighbourhoods. Source: www.Myplan.ie

Figure FF-14 Three urban sites compositional complexity
Address points for three urban sites in central Dublin at 500m resolution, and outline mapping of neighbourhoods: Liberties character area left, Temple Bar, top, and Norton (2016) (‘Grafton Street Area’) right. Source: www.Myplan.ie
Figure FF-15 Land use mix at Ballymun
Address points for Ballymun urban site at 500m resolution. Source: www.Myplan.ie. The clustering of low density residential development around a spatially dispersed mixed-use ‘centre’ is evident. Source: www.Myplan.ie, Author.

Figure FF-16 Land use mix at Sandyford
Address points for Sandyford urban site at 500m resolution. In this image, the primarily mixed-use cluster of the Industrial Estate becomes visually clear, and the concentration of high density residential development in one part is also visible. Source: www.Myplan.ie, Author.
12.0 Visualisations of highest system complexity

This section describes the conversion of secondary ‘point’ data on walkability, as well as primary derivation of Walkscores, combined on a 1km x 1km grid on the city overall. While this data could be also examined at lower resolutions (up to the maximum grid resolution of this study, of 3m, a storey height) the aim here is to begin derivation of an overview for the case contexts in relation to system complexity of the city.

![Figure FF-17 Visualising system complexity](image)

**Figure FF-17 Visualising system complexity**

Map transferring Walkscores and walkability indices, (D’Arcy, 2013:213) (Table 5-5, ‘Objective GIS results for method 4’) to 1km sq grid (see text Chapter Four, Volume One, Section 4.4.4, ‘System criteria of spatial complexity’).
13.0 Visualising architectural complexity

This section describes one interpretation of architectural complexity as it may relate to spatial complexity. As illustrated below, clusters visually identified as part of this study, of protected structures, did not necessarily coincide with urban sites of high evaluated spatial complexity, sometimes due to single use status (being mainly residential), extreme low density of structures, or non-complex geometrical characteristics of blocks or plots. According to this limited analysis, architectural complexity does not necessarily positively affect evaluated spatial complexity of urban sites.

Figure FF-18 Visualising architectural complexity
Sample of NIAH sites clusters, Dublin north inner city at 500m resolution. Source: www.Mylan.ie
Appendix G

Applications Reports

Urban Analysis and Design Evaluation

(PhD Appendix)

For

Evaluation of spatial complexity of urban sites
Introduction

Applications of the Method Reports

These three reports are the detail versions of the (edited and shortened) accounts of applying the evaluation methodology of spatial complexity, as contained in Chapter Eight, Section, 8.3 ‘Applications: Prescriptive, descriptive and design’. Including these reports is intended to demonstrate application examples, which could enhance urban site exploration, evaluation and visualization methods for urban description, prescription and design (See Section 3.2.5.3, ‘Audience for this study’).
1.0 Cornmarket Description Report

Spatial Complexity Evaluation Report Cornmarket

Figure GG-1  Embedded case site at Cornmarket, Liberties character area
Source: Author

Introduction

This Spatial Complexity Evaluation Report document focuses on a historic urban site within the Liberties, at Cornmarket, Dublin 8. The current Liberties Local Area Plan document (2009) for the Liberties quarter in central Dublin is the primary policy and planning document related to urban analysis for the area, and as such, guides all urban analysis, design and future change in the area. In defining spatial complexity as the spatial component of urban complexity, and claiming that evaluation and measurement of this characteristic of urban sites is important to understand in urban analysis for
design, it is argued in spatial complexity research\textsuperscript{51} that previous attempts to quantify complexity for urban design have failed to sufficiently account for the spatial aspects at multiple scales simultaneously, and also to include multiple variables related to composition, configuration and systems issues related to urban sites, and that therefore comprehensive urban analysis and design evaluation is enhanced by focusing on spatial complexity of urban sites.

In defining the concept of spatial complexity, this characteristic of urban sites is argued to be constituted from an integration of three criteria of evaluation: compositional, configurational and system aspects. While these can be weighted differently depending on the hierarchical status of an urban site, in an overall official planning/policy spatial hierarchy for an urban agglomeration, it is argued in spatial complexity research, for example, that urban compositional aspects are more important to consider in historic urban sites. Such is the case in the urban site evaluated in this Report. Three steps can be distinguished in this Spatial Complexity Evaluation Report. Firstly, a desktop analysis, secondly, an exploration/fieldwork stage of analysis, and thirdly, a Spatial Complexity Evaluation Report is prepared.

\textbf{The Liberties Local Area Plan, 2009}

The Liberties Local Area Plan (LAP) was prepared by a private consultant urban design firm, with many sub consultants, working for the local authority for the area, Dublin City Council. The making of Local Area Plans (LAP) in Ireland is a primary planning tool for the development of local area planning schemes, defined as ‘the principal statutory instrument for setting out a balanced understanding, vision and

\textsuperscript{51} ‘Spatial complexity research’ in this Report is the term used to refer to research on exploration and evaluation of spatial complexity of urban sites for urban design, by Alan Mee.
spatial strategies at local level’ (LAP Manual, 2012:2). The official planning/policy Manual which guides preparation of the LAP does suggest that different analysis techniques should reflect the nature and complexity of the study area, but among the eight quantitative analysis techniques suggested ‘urban and landscape structure’ appears second to last, and without detail explanation of the components of this important analysis tool (SPACE Queens University Belfast, 2012: 24). The Manual seeks to cover all spatial conditions on the island within one document, from green field development of the countryside, to inner-city historic urban landscapes, which is an ambitious aim. The ‘case examples’ in this Manual, together with the ‘case studies’ in a later ‘Adaptation and Reuse’ Manual, (dealing with historic urban environments), comprises the entire current official urban analysis and evaluation guidance for urban sites in Ireland. Other aspects of best practice evaluation for urban design in Ireland include the Urban Design Manual, and DMURS, important contributions to spatial organization and design of urban sites in Ireland. The first deals with housing in a general sense, in low-density locations. The second deals with urban streets. Two types of evaluation of the urban site environment happen in the realm of urban roads and streets in Ireland. Auditing processes related to street environments in Ireland are generally of the first type, Road Safety Audits, but Quality Audits are also undertaken, but less frequently.

The aim of the LAP is described in the introductory parts of the document:

‘The key role of the LAP is to strike a balance between protecting what is cherished within this historic city quarter and promoting the type and quantum of development that will enable the Liberties to become an exciting, attractive and liveable city quarter as well as contributing to the economic prosperity and social success of the city and the nation.’ (Liberties Local Area Plan (LAP), Dublin City Council, Section 1.1, Pg 3)
The focus on development is in line with the general climate of economic growth which prevailed at the time of the preparation of the plan, just in advance of the end of the last Irish economic boom, which lasted from 1988-2008.

**Step One: Desktop**

Firstly, a desktop study of the LAP is undertaken to ascertain the prominence of Cornmarket in the document. Numerous shortcomings of the LAP are evident, as an urban design description document. Some of the limitations of the LAP relate to boundary definition of the LAP area, which fails for example to account for major road widenings in the area, which have led to loss of historic urban fabric in the recent past. Also, multiple contested or differing previous neighbourhood boundary definitions of the Liberties are not recorded, even though the area has many historical accounts related to the difficulty of exactly spatially defining the area.

Following desktop analysis of the published document, shortcomings in particular aspects can be highlighted. Firstly, a mismatch between analysed morphological units and boundary definition of the LAP area is evident. Although it is accepted in the literature that character areas as defined by residents and planners might differ (Birkhamshaw et al, 2012), in this case no spatial consideration of options is available in relation to criteria for selection of Electoral District boundaries, which were used to define the geographical limits of the LAP area.

Secondly, an under-emphasis on significant urban spaces which are of primary importance to the city as a whole is evident. These would include High Street, Cornmarket, Patrick Street, Nicholas Street, Bridge Street. For example, a
supplementary report feeding into the LAP, the ‘Thomas Street and Environs Proposed Architectural Conservation Area Report’, published in 2008, mentions Cornmarket, a historic origin site of Irish urbanity, only five times, and then often to describe architectural features, as opposed to urban historic aspects of this space.

**Step Two Exploration / Fieldwork**

Secondly, a historic research methods approach is adopted to one of these shortcomings, the lack of attention in the planning document to the urban importance of the public space at Cornmarket, asking why this was the case. A descriptive historical account of the spatial development of the location is prepared, and it supports historical accounts of the primacy in national urban history terms, of the public space located at Cornmarket. A literature review of primary and secondary sources was prepared, which revealed a rich urban history of the site at Cornmarket, including numerous claims of the primacy of this place in relation to the history and urban development of the city as a whole. It is concluded that at an urban scale, this location has historically been one of the most important public spaces in the Liberties.

**Step Three Evaluation**

The third step in this Spatial Complexity Evaluation Report is a spatial complexity evaluation of the site at Cornmarket, following the steps suggested by the Toolbox and Databox in the spatial complexity research document, including an emphasis on morphological development over time, as the site is located in the historic inner city. The evaluation highlights three issues (composition, configuration and system) and nine criteria, three related to each issue.
Composition

In relation to evaluation and composition, once clusters of ‘public curtilage’ were established, high evaluated compositional and therefore spatial complexity of the public space is described for the location.

Figure GG-2  Public curtilages of ACA’s and NIAH structures at Cornmarket

Figure GG-3  Land-use mix (address points) at Cornmarket

Source: Author
**Configuration**

Depthmap analysis of the Cornmarket area reveals a reduction in local integration in this site, as compared with the two adjoining neighbourhoods, Liberties (to the west) and Temple Bar (to the northeast). Evaluated configurational and therefore spatial complexity is described for the location by local choice mapping at 200m and 800m metric radius, and both indicate that Cornmarket, though not a centre itself, is an important link public space in the city centre between neighbourhoods (which appear with red highlighted streets as centres of local choice).

![Choice mapping at 800m metric radius](image)

**Figure GG-4**  Choice mapping at 800m metric radius

*Source: Author*
System

As regards the system aspects of the urban site at Cornmarket, understanding the complex spatial networks of historic urban sites, and how they developed over time, including a study of historic patterns, paths and people (the steps used in this evaluation) strengthens the public interpretation of significant urban public spaces. This contributes to the unique spatial identity of cities. High evaluated system and therefore spatial complexity is described for the location.

Figure GG-5 Street network complexity analysis at Cornmarket

Top, Street network complexity sketch, bottom timelapse video location, Source: Author
### Evaluated Spatial Complexity Table Cornmarket (241016)

<table>
<thead>
<tr>
<th>Issue</th>
<th>Criteria</th>
<th>Method</th>
<th>Indicators</th>
<th>Spatial Complexity Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>Urban Form</td>
<td>Conzenian Analysis</td>
<td>low-medium-high</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Land Use Mix</td>
<td>Van Den Hoek</td>
<td>Mix triangle</td>
<td>Medium</td>
</tr>
<tr>
<td></td>
<td>Density</td>
<td>Plot Ratio/Site Coverage, Correlational Graph</td>
<td>Medium</td>
<td></td>
</tr>
<tr>
<td>Integration</td>
<td>Global</td>
<td>All types</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Choice</td>
<td>Local</td>
<td>All types</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Global and local</td>
<td>All types</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Intelligibility</td>
<td>n/a</td>
<td>All types</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Patterns</td>
<td>Street network complexity</td>
<td>Public space</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>Paths</td>
<td>Path network complexity</td>
<td>Urban site</td>
<td>High</td>
<td></td>
</tr>
<tr>
<td>People</td>
<td>Pedestrian network complexity</td>
<td>Urban site</td>
<td>High</td>
<td></td>
</tr>
</tbody>
</table>

**Spatial Complexity Colour Key**
- Red - High
- Orange - High/Medium
- Yellow - Medium
- Green - Medium/Low
- Blue - Low

**Spatial Complexity Databox**

**Figure GG-6  Visual indicators of spatial complexity at Cornmarket**

Coloured Toolbox and sketch of location in Databox
Source: Author
Figure GG-7 Cornmarket spatial complexity evaluation Report

Source: Author
Step Four  Visualisation, Recommendations and Conclusions

Visualisation

Finally, as a fourth step, an Evaluation Report document including visualization of results and recommendations is presented. This includes the application of indices in colour of evaluated levels of spatial complexity in relation to three issues and nine criteria.

Figure GG-8 Visualisations of spatial complexity at Cornmarket

Source: Author
Recommendations

The overarching recommendation of the Evaluation Report is for an evidenced approach to understanding of historic urban life at this location, including a geo-referencing of historic photographs, viewer locations and angles. In consequence, it is recommended that the record of this evaluated complexity mapping should be included in the LAP. This additional documentation should in turn be used to argue for a return to whole city-level public space landmark status and thus the significant enhancement of the contemporary public realm in the Cornmarket area. Other additional evidence in this regard could include extending gate counts, timelapse video and other fieldwork observation work of the spatial complexity research, in advance of strong evidence-based argument in the LAP for restoration of a pedestrian-centric environment to this primary and origin historic site of Irish urbanity. It is concluded from this application of the Toolbox and Databox of evaluation of spatial complexity that this characteristic of urban sites is an integrated ‘quantity/quality’, to be foregrounded even when appearing to be ‘latent’ within the archaeological or morphological setting of the city. In summary, this evaluation demonstrates that the descriptive aspects of a Local Area Plan could be improved through a focus on spatial complexity of urban sites, and three particular recommendations are made as part of this Report.

The addition of graphical analysis of ‘public’ curtilage of ACA’s and protected structure clusters in historic urban sites, in order to bring attention to more than the protected built ‘objects’, focuses attention on the spatially complex public environments historically created in the spatial ambit of historic structures, which can have multiplied effects through identification of cluster effect. The first recommendation of the Evaluation Report is an extension of the mapped plan outline of the adopted ACA area
to include the entire historic urban space at Cornmarket, as well as all property plots which have frontages facing onto the space (see image of extension of hatched green area, denoting ACA boundary).

Configurational mapping of historic urban form (graphically, using Depthmap) shows configurational benefits of the historic urban fabric and grain of medieval town plans, even if more recent development has partially removed the coherence of the streetscapes. The second recommendation of the Evaluation Report is for a study of the historic lanes of the area, which are shown in the report to have formed a significant contribution to the configurational coherence of the urban site in the past.

Understanding the complex spatial networks of historic urban sites, and how they developed over time, including a study of historic patterns, paths and people (the steps used in this evaluation) strengthens the public interpretation of significant urban public spaces, which contributes to the unique spatial identity of cities. The third recommendation of the Evaluation Report is for an evidenced approach to enhancement of the public realm in the Cornmarket area, including gate counts, timelapse video and other fieldwork observation work, in advance of restoration of a pedestrian-centric environment to this primary and origin historic site of Irish urbanity.

As demonstration of best practice, current Irish policy documents around urban design evaluation do seek an architectural conservation report for LAP areas in historic urban centres, as in this case. However, the spatial scope of these documents tends to be limited to the evaluation at architectural scales, and to be confined within an LAP spatial boundary, which, as in this case, is often the result of a set of local authority
decisions. This planning boundary can fail to reflect historic urban morphological units and historic spatial patterns of urban sites. This evaluation improves on current practice of urban analysis and evaluation for urban design of urban sites in three ways:

Urban compositional complexity evaluation deepens current practices of researching historic urban sites for planning practice, by applying qualitative Conzenian, as well as more quantitative cross scalar ‘metrics’, to derive a single integrative result, which can be interpreted at multiple scales and levels.

Configurational analysis connects restrictive planning/policy urban site definition to whole city spatial data, measuring connections between all public spaces in the city, thus uncovering links between neighbourhoods, streets and place beyond bounded planning units, as well as the evaluating characteristics of single public spaces like convexity analysis within the site.

System complexity analysis improves on current urban site evaluation techniques by capturing dynamic and temporal aspects of urban sites, such as pedestrian footfall, and mapping these in a way that can be compared with other locations and temporal units. So while a typical temporal unit of analysis in monitoring pedestrians is a five minute gate count, in this analysis, this unit is compared with hourly, daily, weekly and annual counts throughout the city, thus positioning the relative evaluation of single locations within a global system of movement.
Conclusion

This Report emphasizes the ‘latent’ spatial complexity of the urban site at Cornmarket, and claims that the potential of this primary historic urban space was under-represented and under-valued by the site evaluation process of the Liberties Local Area Plan (2009), (LAP), a spatial planning policy document prepared to guide the development of the area in the future. The LAP, originally developed at the height of a construction boom, and in response to a large quantity of planning applications in this inner city neighbourhood\(^{52}\), has been followed by an official decision to extend the original time-frame for completion of the aims of the boom time plan, from an expected date in 2015, to at least the end of the timeframe of the current City Development Plan, in 2022. The decision, as part of the current Development Plan for the city, to extend the life of the LAP without modifications or improvements, deepens the serious negative effect of the under-evaluation of the historic status of Cornmarket. As a result, more recent official publications have also seemed to downgrade the protected status of Cornmarket\(^{53}\). This Report has highlighted some shortcomings of the current LAP. Over the development of the LAP document, the lack of appropriate evaluation of Cornmarket, (the most significant historic urban space in the area), became apparent. The evaluation of spatial complexity of a historic urban site at Cornmarket, in the Liberties quarter of inner city Dublin is undertaken. Three steps to evaluation are described: firstly, a desktop analysis, secondly, an exploration/fieldwork stage of analysis, and thirdly, a Spatial Complexity Evaluation Report\(^{54}\).

---

\(^{52}\) One significant planning application in the area involved a proposal in 2006 for a mixed use development of 38,400m\(^2\) of office space, a 360-bedroom hotel and 125 apartments, rising to a height of 171.9m, in 53 storeys in the historic city, at the Digital Hub, Thomas Street, Dublin 8. The development was proposed in the absence of urban site-specific building height policy and in a vacuum before preparation of the Liberties LAP, which came to act as a planning guidance document after 2009.

\(^{53}\) The Dublin City Council Public Realm Strategy considers Cornmarket to be located off the ‘civic spine’ of the city. (Dublin City Council, 2012, Map 2.6, Pg 22).

\(^{54}\) The purpose of the document is to supplement the current descriptions of the urban site provided in the primary planning and policy document applying to the site, the Liberties Local Area Plan (2009), prepared by Dublin City Council.
2.0 Ballymun Prescription Report

Spatial Complexity Evaluation Report Ballymun

The Report is carried out in response to a need generated by an urban design project, at Ballymun East, as an urban design practice commission. This design task was undertaken in 2010 by the researcher for a public client, Ballymun Regeneration Ltd., (BRL) the regeneration body of this urban site. BRL was the first designated, quasi-governmental agency established to regenerate a public housing estate in Ireland (Norris, 2001:2). The urban design task undertaken in 2010 by the researcher involved the preparation of an urban design framework plan for a key part of Ballymun, beside the Civic Centre of the regenerated town. The urban site at Ballymun East, which is partly located within the case site of this research, (the ‘urban Ballymun’ site, land area, 0.22 km², or 55 acres) is 0.36 km² or 9 acres, so approximately one fifth of the size of the case study site of this research.

Planning / Policy context

Ballymun (in overall terms) is designated by Dublin City Council as a district centre, and is officially considered to be one of the fastest growing and most dynamically changing locations in the city, although still subject in planning designation terms to the urban design intentions of the 1998 Masterplan. It is currently described as third highest single ‘area’ for ‘estimated capacity’ of housing, and is considered to have future capacity for 3,000 residential units. ‘Extensive new neighbourhoods’ are planned by the city authorities, and a Local Area Plan will be prepared by Dublin City Council in the near future. It is designated as as one of seventeen Strategic Development and Regeneration Areas (SDRA) and one of only eight Key District Centres (KDC), and is
one of the top (13) locations in the city selected by forward planning for high buildings in the future. As part of the future planning context of Ballymun, a number of recent events are relevant. In order to incentivise development in the area, Ballymun is identified (by DCC) as one of nine ‘mid-rise’ locations in the city, which allows future building heights of ‘up to 50 m’, which means “equivalent to 16 storeys residential or 12 storeys commercial”. Dublin City Council’s Draft City Development Plan 2016-22, due for adoption on 211016, forsees preparation of a Local Area Plan for Ballymun, and illustrates ‘Key Development Principles’ for the SDRA in Map 2-Ballymun, including increased connectivity and proposed land uses.
Figure GG-9 Urban Ballymun prescription analysis

Source: Author
The steps that can be distinguished in this second, prescriptive application of the developed evaluation method of spatial complexity of urban sites are now described. The first step involves a desktop analysis of the Ballymun Masterplan document (1998), to ascertain the level and extent of spatial evaluation of the urban site that happened prior to the preparation of the Masterplan in 1998.

**The Ballymun Masterplan 1998**

The regeneration project at Ballymun began in 1997 with the establishment of Ballymun Regeneration Ltd (BRL), a semi-state company owned jointly by the Department of Finance and Dublin City Council, the relevant Local Authority, to develop and manage the demolition of the existing tower blocks and the building of approximately 6,000 new homes, along with amenities. The 1998 Master Plan proposed by BRL was a 10-year regeneration plan encompassing physical, social, economic, environmental, cultural and process elements. The masterplan document was defined in the Introduction as follows: ‘The Masterplan establishes some broad, strategic principles which have to be generally agreed in order to submit the Integrated Area Plan’ to the Department of the Environment by March 31st 1998’ (BRL, 1998:2). As part of designation through the IAP process (as an urban renewal area), the original social housing project was to be developed partly through financing from urban renewal tax incentive status for the area. Little if any of the urban design related proposals of the Masterplan were considered statutory. The list of parts of the masterplan design proposal that the authors of the document considered had to be ‘fixed’ included ‘the size and location of open spaces’ and ‘the likely housing density’(BRL, 1998:2). However,

---

55 An ‘Integrated Area Plan’ is defined in the Urban Renewal Act, 1998. Part Two of the Act (paragraph 7.4) requires local authorities to draw up integrated area plans consisting of: “a written statement and a plan indicating the objectives for (a) the social and economic renewal, on a sustainable basis, of the area to which the plan relates, and (b) improvements in the physical environment of that area”. (Norris, 2001:20).
other important proposed urban design scale indicators were required to be left flexible, including ‘the actual size of new developments’, ‘the detailed design of the different public places’, and ‘the mix of new homes to be built’ (BRL, 1998:2). The Report sets out three steps to evaluation: Firstly, a desktop analysis, secondly, a Spatial Complexity Evaluation Report and thirdly, a visualisation of Prescriptions section.

**Step One: Desktop**

Urban design prescription in the Ballymun Masterplan was represented by aspirational rather than statutory requirements. Analysis revealed that spatial investigation of existing urban form, land use mix and density were not prominent in the published document. Further, configurational analysis of the site was not undertaken, at a time when international best practice in configurational analysis and research into failures of social housing estates was available (Hillier et al, 1987)(Hillier et al, 1989)(Hillier et al, 1993). Finally, in relation to the system aspects of the site which would be regenerated, desktop analysis reveals that no baseline analysis of street pattern network complexity, extent of paths, or onsite measurement of pedestrian movement had been undertaken in preparation of the Masterplan. From the desktop analysis of the Ballymun Masterplan document (1998) and fieldwork visits it was clear that by 2010, certain urban design intentions of the regeneration master-planners were not being carried out. As two urban design related examples, firstly the clear recommendation of the urban design masterplanners to avoid a single large new shopping centre as retail centrepiece of the regeneration was not followed\(^5\). Secondly, the urban design strategy to promote the

---

\(^5\) The ‘Masterplan for the New Ballymun’ document, dated March 1998, states that the proposal of a regional sized shopping centre, as opposed to incremental growth of retail uses, would be a ‘high-risk strategy’ dependant on commercial viability and planning approval, stating that there is ‘historically a conflict between lively main streets and very large shopping centres (BRL, 2008:67).
development of two-sided streets by single designers was not realized\textsuperscript{57}. Although the BRL Masterplan document was prepared before best practice guidelines were developed in Ireland for this type of document\textsuperscript{58}, the demonstration of adequate urban design evaluation in advance of the site of regeneration is not apparent in the Masterplan document.

**Step Two Evaluation**

The second step of this Report is a spatial complexity evaluation of the site at urban Ballymun (Key District Centre boundary) following the steps suggested by the Toolbox and Databox in the spatial complexity research document, including an emphasis on shortcomings of the urban site in relation to the official planning status of the location, as a Key District Centre. The evaluation highlights three issues (composition, configuration and system) and nine criteria, three related to each issue. Key evaluation indicators in each of the three issues categories were compared at both urban site scalar level (urban Ballymun) and a more general evaluation of the overall Ballymun development (‘overall Ballymun’) broadly including lands subject of regeneration from 1998 onwards. Single criteria evaluations of some historical characteristics of the overall Ballymun development were also undertaken, such as street network complexity of the original social housing estate in 1969, to contextualise the benefits to date of regeneration which took place between 1998 -2015.

**Step Three Visualisation of Prescription**

\textsuperscript{57} The masterplanners expressly stated: ‘An early mistake made in the UK New Towns was to divide up the development lands using the roads as boundaries- this results in the road engineers world of verges dividing and isolating hamlets of residential developments’(BRI, 1998:34). As a result, it was recommended that ‘housing development land parcels should straddle roads’ (BRI, 1998:34).

\textsuperscript{58} Irish urban design guidelines at national level were later introduced for Irish housing sites of a certain size (Urban Design Manual, 2009) Local Area Plans Guidelines (2012), and Design Manual for Urban Roads and Streets (DMURS, 2013).
Following evaluation, visualisation of which evaluated issues and criteria of spatial complexity would have to be prescribed for improvement, as part of any future urban design plan for the site. In summary, the prescriptive aspects of an urban design framework plan at urban Ballymun could be improved through a focus on evaluating the spatial complexity of urban sites, in particular the following aspects:

**Composition**

Urban morphological complexity at urban Ballymun is evaluated as low, with few plots and urban blocks per hectare, as well as very coarse urban grain. Low levels of land-use mix are related to low site coverage levels, as vacancy of sites reflects regeneration opportunities unrealised due to economic downturn. Constructed density levels of regenerated urban blocks are optimal for a Key District Centre, but few have been realised, so a patchwork juxtaposition of vacancy and high urban density is evident.

**Configuration**

Depthmap analysis of the urban site at urban Ballymun reveals that some local integration values for individual streets in the Ballymun Masterplan Area context are amongst the lowest local integration values in the city. Considering the global and local integration values for the context of the case study site suggests that the Main Street is well connected to the wider city for overall movement (such as by car) but not to the local area (e.g. for walking), or to the urban centre of Ballymun.\(^{59}\) Considering the official planning status of this location in the wider Dublin context, as one of only eight

\(^{59}\) Research suggests that urban areas with high levels of both global and local integration contain pleasant centres that support the overlap of various mobility flows (pedestrian, bicycle, car), and have urban spaces with qualities of mixed social and economic uses (Van Nes, Ye, 2013:7).
Key District Centres (KDC) in the city, a higher overall configurational complexity of the urban site would be necessary to ensure optimal spatial and urban complexity.

System

As regards the system aspects of the urban site at urban Ballymun, understanding the spatial system of New Towns, and how they developed over time, including impacts of regeneration includes a study of patterns, paths and people (the steps used in this evaluation) strengthens the public interpretation of future key urban centres. This contributes to the unique spatial identity of cities. Medium evaluated system and therefore spatial complexity is currently described for the location.

Visualisation

Here, visualization of results and prescription recommendations are presented. This includes the current evaluated levels of spatial complexity in relation to three issues and nine criteria, plotted in nine indicator Cartesian plots or triangles, and application of indices in colour for ‘optimal’ conditions to be achieved (in red) in the issues and criteria of spatial complexity. The visualisation shows how evaluation indices would need to improve in detail in order to achieve optimal spatial complexity conditions of a Key District Centre.
Recommendations and Conclusions

In concluding this section on possible prescriptive applications of spatial complexity evaluation of urban sites, it can be suggested that knowing evaluated levels of spatial complexity invites an urban design response, in that evaluated spatial complexity values of urban sites, in varying degrees, by implication confirm the requirement for a design approach to the complex issues discussed in the evaluation process. Graphically indicating required locations of future ground floor mixed use would help to direct prescription of uses along proposed mixed use streets. Mapping of densities of regenerated streets would help prescription of proposed densities in the light of unprecedented development pressure recently introduced for this type of site, setting an optimal and sustainable urban density appropriate to the hierarchical position of the urban site in evaluated spatial complexity terms.

Recommendations

The overarching recommendation of the Evaluation Report is for clear urban design prescription in an evidenced approach to guiding future urban development at this dynamically changing urban site. In consequence, it is recommended that the record of the evaluated complexity mapping of this Report should be included in the future LAP for Ballymun. This additional documentation should in turn be used to argue for a return to some original recommendations of the masterplanners of Ballymun regeneration in 1998, including proposal of appropriate quantum of development, and spatial controls of development of parcels in the area. Other additional evidence in this regard could include additional spatial complexity research, in advance of strong evidence-based argument in the future LAP for creation of a high quality urban
environment to this potentially key future urban site in overall Dublin terms. It is concluded from this application of the Toolbox and Databox of evaluation of spatial complexity that this characteristic of urban sites can be measured effectively, and improves on current measures of the urban built environment. In summary, this evaluation demonstrates that the descriptive aspects of a Local Area Plan could be improved through a focus on spatial complexity of urban sites, and three particular recommendations are made as part of this Report.

Compositional
In the case of urban Ballymun, for example, mapping of unsuccessfully regenerated streets (eg. one side complete only) could generate prescriptive requirements graphically of the original Ballymun Masterplan of 1999 to be reinstated (eg, Architects to do both sides of streets, to ensure coherent realization of whole streets rather than one side only). The first recommendation of the Evaluation Report is an extension of the graphical evidence base regarding existing spatial conditions of the urban site, to include this within the forthcoming LAP preparation.

Configurational
Configurational mapping of existing neighbourhood level units (graphically, using Depthmap) shows existing configurational shortcomings but could also be a base for seeking potential benefits by seeking iterative urban design options for change, even if recent regeneration has partially failed to enhance the connections. The second recommendation of the Evaluation Report is for a study of the existing configurational layout of the area, which is shown in the Report to have led to configurational incoherence of the urban site in the past.
System

Understanding the complex spatial networks of historic urban sites, and how they developed over time, including a study of historic patterns, paths and people (the steps used in this evaluation) strengthens the public interpretation of significant urban public spaces, which contributes to the unique spatial identity of cities. The third recommendation of the Evaluation Report is for an evidenced approach to enhancement of the public realm in the urban Ballymun site, including iterative evaluation of urban design options to increase street network complexity, improve metric reach measure and enhancement of spatial conditions for pedestrian activity and movement, all in order to finally deliver a pedestrian-centric environment to this Key District Centre.

As demonstration of best practice, current Irish policy documents around urban design evaluation do seek a prior systematic survey of spatial conditions of urban centres. However, the spatial scope of these documents tends to be limited to the evaluation at architectural scales, and to be confined within an LAP spatial boundary, which, as in this case, is often the result of a set of local authority decisions. This planning boundary can fail to reflect urban morphological, configurational, and spatial systems patterns of urban sites. This evaluation improves on current practice of urban analysis and evaluation for urban design of urban sites in three ways:

Urban compositional complexity evaluation deepens current practices of researching spatial conditions of regeneration sites for urban design practice, by applying qualitative as well as more quantitative cross scalar ‘metrics’, to derive a single integrative result, which can be interpreted at multiple scales and levels.
Configurational analysis connects restrictive planning/policy urban site definition to whole city spatial data, measuring connections between all public spaces in the city, thus uncovering links between neighbourhoods, streets and places beyond bounded planning units, like LAP boundaries.

System complexity analysis improves on current urban site evaluation techniques by capturing dynamic and temporal aspects of urban sites, such as pedestrian footfall, and mapping these in a way that can be compared with other urban locations and temporal units. Understanding current site conditions of pedestrian networks enables evidenced support for enhancement rather than wholesale change in public pedestrian environments.

**Conclusion**

In conclusion, this Report emphasizes the shortcomings of the content and implementation of the current urban design instrument for urban Ballymun, (the 1989 Masterplan) and claims that the potential of this Key District Centre, should be protected by including urban design prescription measures in the upcoming LAP, a spatial planning policy document prepared to guide the development of the area in the future. The Ballymun Masterplan document, originally developed partly to seek urban renewal tax incentive status for the area, has been followed by an official decision to extend the original Masterplan intentions of regeneration to a new Local Area Plan, as part of the current City Development Plan, before 2022. This Report has highlighted some shortcomings of the current Masterplan, the primary urban design policy and planning document related to the area. Over the development of the regeneration,
numerous intentions of the masterplanners were unfulfilled, partly due to a lack of precise urban design prescription. The purpose of this Report document is to supplement the current descriptions of the urban site provided in the current Masterplan and recent SRDA plan, prepared by Dublin City Council, by adding evaluations of spatial complexity of the site. The Report sets out three steps to evaluation: Firstly, a desktop analysis, secondly, a Spatial Complexity Evaluation Report and thirdly, a visualisation of Prescriptions section. In summary, this Report can deepen an evidence base for prescription as regards future development of a key urban site in the city.
3.0 Sandyford Design Report

Spatial Complexity Evaluation Report Carmanhall

Planning / Policy context
Currently, the official definition of the settlement as ‘town’ has status under certain public mappings (eg. myplan.ie zoning classifications) though not in others. It has been described by the Local Authority for the area as ‘a collection of disparate, poorly connected (industrial) estates’ in its 2011 Sandyford Urban Framework Plan, which has an aim to re-cast the area as a ‘business district’ (the Sandyford Business District).

The steps that can be distinguished in this third, design application of the developed evaluation method of spatial complexity of urban sites are now described. The first step involves a desktop analysis of the design proposals to ascertain how these would vary the current ‘static’ evaluation of the urban site. The second step was to analyse the ‘urban design proposals’ implied by both Urban Design Proposal A and B. The third step was to part-evaluate the two alternative urban design options for Carmanhall, in compositional complexity (density) and system complexity (‘patterns’, that is, street network complexity).

Urban Design Proposal A
The Draft Sandyford Urban Framework Plan, 2007 (Urban Initiatives/ Dún Laoghaire-Rathdown County Council, 2007) followed from a proposed Building Height Strategy for the County commissioned in 2007. The council commissioned specialist urban design consultants Urban Initiatives both the proposed Building Height Strategy and the
Draft Sandyford Urban Framework Plan around the same time, in 2007. Around this time, the Building Height Strategy identified Sandyford as the only place in the County suitable to develop a cluster of tall buildings. The urban design proposal sought to set out a clear vision and framework for the development of the area, providing specific recommendations on the form that new development should take, including land uses and density, the massing and heights of buildings, the location of landmarks, streetscape, public realm and public spaces. Proposals included three different centres, new boulevards, a green strip, clear expressed edges, pedestrian routes, and a hierarchy of public and green spaces. Proposed new structures included a ‘central regional and anchor landmark’ building of 32 storeys. However, the Draft Plan was rejected in October 2007 by the Local Authority, as it did ‘not deal adequately with the provision of infrastructure to support future development in the area’. Further, it was reported that the Local Authority considered that the change envisaged in the report was well above the quantum of development contemplated by the Council.

**Urban Design Proposal B**

The Sandyford Urban Framework Plan (SUFP) (Dún Laoghaire-Rathdown County Council, 2011) represented the start of urban design regulation over development in the area began with the adoption of the Sandyford Urban Framework Plan as Variation No 2 of the Dún Laoghaire-Rathdown County Council Development Plan, 2010-16 in September 2011. The primary objective of the Plan was stated as: ‘to transform

---


Sandyford Business Estates from a collection of disparate poorly connected estates to a co-ordinated, cohesive business district\textsuperscript{63}.

**Step One: Desktop**

Urban design in **Urban Design Proposal A**

This Draft document proposed major changes to private property as well as public lands, including moving tram stations, tall landmark structures, and a new network of pedestrian connections across the site. The proposal was represented by aspirational rather than statutory urban design proposals and requirements. Analysis revealed that

Urban design in **Urban Design Proposal B**

This adopted variation to the Development Plan makes few major proposals for urban design change, other than in proposed public space zonings, and controls on plot ratios and building heights. No new streets are proposed through private lands, although a number of suggested new road connections are indicated on edges of the site.

**Step Two Evaluation**

The second step of this Report is a spatial complexity evaluation of the site at Carmanhall following the steps suggested by the Toolbox and Databox in the spatial complexity research document, concentrate on compositional complexity (density) and system complexity ('patterns', that is, street network complexity). The evaluation highlights that current static evaluation shows low compositional and system complexity in the site in particular, and of the nine possible criteria, one related to each of two issues, density and density have the possibility to have explanatory value in

\textsuperscript{63} Section 1.6 ‘The Purpose of the Plan’, Pg 6, Sandyford Urban Framework Plan (SUFP) (Dún Laoghaire-Rathdown County Council, 2011).
seeking optimal levels of future spatial complexity on the site due to design. The two optional urban design proposals have the following results in relation to the criteria:

**Urban Design Proposal A**

Density in this proposal was projected to include tall buildings, including a plot ratio of 4.0, approximately 22 tall structures\(^6^4\), and a ‘central regional and anchor landmark’ building of 32 storeys. Street network complexity, though not calculated for this option, would only marginally improve on existing conditions, as only one new streets was proposed in the immediate vicinity of Carmanhall. However, significant improvements would have been evident in metric reach, as new pedestrian routes proposed throughout, including in private lands, would have significantly improved this measure.

**Urban Design Proposal B**

Highest proposed density in Urban Design Proposal B retains a plot ratio of 4.0, but tallest structures permitted are limited to seventeen storeys\(^6^5\), a significant reduction on the previous plan. As regards street network complexity, there are no expected gains in either complexity or connectivity, as no new streets or roads within the urban site are proposed.

**Step Three Visualisation of Evaluation of Design Options**

Following evaluation, visualisation of evaluated issues and criteria of spatial complexity, as part of any future urban design plan for the site concentrates on potential


\(^6^5\) Map No 3 ‘Building Height, indicates five locations earmarked for ‘Additional heights over building height limit’. No height is specified for these structures in the Map.
for improving urban design propositions through a focus on potential for optimizing future ‘designed’ spatial complexity of urban sites. This design application of the method derives specific design ‘targets’ for urban design options to meet. Iterative urban design options can be evaluated to ensure alignment at multiple scales (plot, urban block, and urban site, the focus of this study). Although all nine criteria of spatial complexity cannot be tested at design stage, (footfall measurement of the design options is not possible, but could be projectively modelled) eight criteria can be assessed. Therefore a value for ‘designed’ spatial complexity can be arrived at, and compared for different design options. Two issues are concentrated on, composition and system.

**Composition**

In deriving density metrics, the Protocol developed related to plot ratio and site coverage has best explanatory value, as it is directly related to plot, urban block and urban site scales in development control in Ireland. An optimal range is indicated in graph form, working from current city limits of these indicators. In site coverage terms, while urban morphological complexity at Carmanhall is evaluated as low, with few plots and urban blocks per hectare, as well as very coarse urban grain, low levels of land-use mix are related to low site coverage levels, as vacancy of sites reflects development opportunities unrealised due to the economic downturn from 2008. Constructed density levels of recently constructed urban blocks are very high, but few have been realised, so a patchwork juxtaposition of vacancy and high urban density is evident. The optimal range indicated for future design is well below current SUFP upper limits, but within district level recommended levels at city scale.

**System**
As regards the system aspects of the urban site at Carmanhall, low evaluated system and therefore spatial complexity is currently described for the location. In particular, low street network complexity is evaluated, and an optimal ‘characteristic structure’ band of optimality is indicated for the urban site, based on Marshall, (2005:152).

**Visualisation**

Here, visualization of optimal designed values for spatial complexity of the urban site are presented. This includes the current evaluated levels of spatial complexity in relation to two selected issues and two selected criteria, plotted in indicator Cartesian plots or triangles, and application of indices in colour for ‘optimal’ conditions to be achieved (in yellow). The visualisation shows how evaluation indices would need to improve in detail in order to achieve optimal spatial complexity conditions of a future neighbourhood at this location.
Figure GG-10  Optimal Design Density Carmanhall

Source: Author
‘Complexity versus Relative Connectivity’

- Carmanhall (x, 35, y, 25)
- Urban Ballymun (x, 29, y, 41)
- Liberties (x, 39, y, 43)

Figure GG-11 Optimal Street Network Complexity Carmanhall

Source: Author
Recommendations and Conclusions

In concluding this section on possible design applications of spatial complexity evaluation of urban sites, it can be concluded that indicating optimal future ranges of density and street network complexity, as examples, would help to direct urban design decision making. These design ranges help in setting an optimal and sustainable level of designed form appropriate to the hierarchical position of the urban site in evaluated spatial complexity terms. Importantly, this design application overcomes the gap in consistent application of density and other development control standards across the four separate local authority jurisdictions of Dublin.

Recommendations

The overarching recommendation of the Evaluation Report for Carmanhall is for clear ranges of optimal spatial complexity to be considered in urban design of urban sites, in an evidenced approach to guiding future urban development. In consequence, it is recommended that the Urban Design Proposal B, (The Sandyford Urban Framework Plan) (SUFP) should be supplemented by evidenced-based evaluations of the current proposed urban design changes in the area. This should include the full set of protocols of this study (three issue, nine criteria evaluation). This additional documentation should in turn be used to argue for a return to some original recommendations of the masterplanners of Urban Design Proposal A, (The Draft Sandyford Urban Framework Plan, 2007) including proposals for increasing pedestrian connectivity in the area. Other additional evidence in this regard could include additional spatial complexity research,
in advance of strong evidence-based argument in the future LAP for creation of a high quality urban environment to this important future urban site in overall Dublin terms. It is concluded from this application of the Toolbox and Databox of evaluation of spatial complexity that this characteristic of urban sites can be measured effectively, and improves on current measures of the urban built environment. In summary, this evaluation demonstrates that the design aspects of an urban design framework plan could be improved through a focus on spatial complexity of urban sites, and two particular recommendations are made as part of this Report.

**Compositional**

In the case of Carmanhall, mapping of current levels of urban morphological complexity, and metric reach, (as examples) could generate useful information about the current site, and indicate design goals to achieve in the future, by deriving optimal ranges of these measures appropriate to this urban site in the overall Dublin hierarchy of spatial planning. The first recommendation of the Evaluation Report is an extension of the graphical evidence base regarding existing spatial conditions of the urban site, to be added to the current Sandyford Urban Framework Plan.

**System**

The second recommendation of the Evaluation Report is for an evidenced approach to enhancement of the public realm in the Carmanhall site, including iterative evaluation of urban design options to increase street network complexity, improve metric reach measure and enhancement of spatial conditions for pedestrian activity and movement, all in order to deliver a pedestrian-friendly environment.
As demonstration of best practice, current Irish policy documents around urban design evaluation do seek a prior systematic survey of spatial conditions of urban centres. However, the spatial scope of these documents tends to be limited to the evaluation at architectural scales, and to be confined within an LAP spatial boundary, which, as in this case, is often the result of a set of local authority decisions. This planning boundary can fail to reflect urban morphological, configurational, and spatial systems patterns of urban sites. This evaluation improves on current practice of urban analysis and evaluation for urban design of urban sites in two ways:

Urban compositional complexity evaluation deepens current practices of researching spatial conditions of development sites for urban design practice, by applying qualitative as well as more quantitative cross scalar ‘metrics’, to derive a single integrative result, which can be interpreted at multiple scales and levels.

System complexity analysis improves on current urban site evaluation techniques by capturing dynamic and temporal aspects of urban sites, such as pedestrian footfall, and mapping these in a way that can be compared with other urban locations and temporal units. Understanding current site conditions of pedestrian networks enables evidenced support for enhancement rather than wholesale change in public pedestrian environments.

**Conclusion**

In conclusion, this Report emphasizes some shortcomings of the content of two urban design documents and implementation of the current urban design framework for Carmanhall and claims that the potential of this future neighbourhood should be protected by including urban design ‘optimal range’ measures in the Sandyford Urban
Framework Plan. The purpose of this Report document is to supplement the current descriptions of the urban site provided in the current urban design prescription for the site, by adding ‘optimal ranges’ of spatial complexity for urban design of the site. The Report sets out three steps to enabling design application. Of spatial complexity evaluation. The first step involves a desktop analysis of the design proposals to ascertain how these would vary the current ‘static’ evaluation of the urban site. The second step analyses the ‘urban design proposals’ implied by both Urban Design Proposal A and B. The third step part-evaluates the two alternative urban design options for Carmanhall, in compositional complexity (density) and system complexity (‘patterns’, that is, street network complexity). The Report finds that values for both can be improved, and ‘optimal ranges’ for each measure are indicated graphically. In summary, this Report can deepen an evidence base for prescription as regards future development of a key urban site in the city.
Appendix H

Case study research design options

(PhD Appendix)

For

Evaluation of spatial complexity of urban sites
Introduction

1.0 Five case study research design options

In this Appendix, related to Chapter Three, Section 3.3.4, ‘Number of cases’, this text outlines the options considered and the detail decisions taken in this study as regards number of cases in case study research design. In this study, while Dublin is considered as an appropriate background to an investigation of spatial complexity (See Chapter Five, Section 5.2) many potential units of study were examined within the background context for this exploratory case study approach. The literature on case study unit selection has no clear recommendations of numbers of cases which it is appropriate to select. For example, it is suggested that the ‘individuality or specificity of a single case can be either lost in the multiplicity of cases, or its significance overstated’ (Mc Farlane, 2010). In this thesis, the objects of study are multiple urban sites within the context of the spatially complex unit of the city of Dublin. Five types of ‘unit’ of case study are considered as options, as outlined below. As the selection of a multiple case study unit structure has impacts on the further selection of research strategies, tactics and techniques, a discussion of the advantages and disadvantages of each option is outlined here briefly, as well as reasons for selection of the chosen case study research design. This description is a demonstration of the exploratory nature of this study of spatial complexity for urban analysis and design. It is also hoped this textual account might assist other urban design researchers in the decision making process for considering selection of numbers and types of cases, in a complexity frame.
1.1.1 Single ‘holistic’ case (1)

Some of Yin’s five reasons for considering why a single case study unit (critical, extreme, typical, revelatory or longitudinal case) may apply or are partly met in the case of some objects of this research, (eg. spatial complexity, urban design and the case study background, Dublin). While there is no ‘well formulated theory with a clear set of propositions’ to justify a critical case in this study, and the conditions encountered in urban sites, (the objects of study) are not so rare as to justify an ‘extreme’ description, it could be argued that some of the spatial conditions observed in this research are ‘typical’, and the objective would be to ‘capture the circumstances and conditions of an everyday situation’ (Yin, 2003a:39). However, in the overall, and considering a number of urban sites, the conditions vary enough to as to be considered non-straightforward in this sense.

The core ‘target’ of this thesis is exploration and evaluation of spatial complexity for urban analysis and design. The last criterion for considering a single case unit research design, a ‘longitudinal’ aspect, is suggested by Yin as relevant when ‘the theory would specify how change happens over time’ (Yin, 2003:39). Although there are ‘retrospective study’ (ie. a longitudinal study that looks back in time) aspects to the research undertaken in this thesis, as the underlying theory of spatial complexity is defined by emergence (Holland, 1998)(Jencks, 1997:86)(DeLanda, 2013), prior theory suggests no clearly accepted delineations as regards how time is seen to have had causal effects on changes in spatial complexity levels in the urban site types studied. In conclusion, part of some of the five reasons suggested by Yin to select a single case apply, but not enough of any one, or a combination of enough parts to convincingly point in the direction of selecting a single case research design.
There are five other considerations of the option of pursuing a single ‘holistic’ case study research design based on the unit of ‘Dublin’ for five other reasons: Firstly, a ‘holistic’ study is associated with the ‘global’ nature of an organisation, program (Yin, 2003:45) or, as in this case, a city. However, it is considered important in this research to consider, alongside the of the ‘whole city’ background of Dublin, the local (or intermediate) context and micro (or atomic) urban site levels of evaluation detail in order to make research which is especially useful for urban analysis and design in practice.

Secondly, a ‘holistic’ study is considered appropriate when no logical subunits of study can be identified or when the relevant theory itself underlying the case study is of a ‘holistic’ nature (Yin, 2003:45). In this thesis, relevant case study units are identifiable, and though the underlying theories are emergent, and are founded on holistic aspects of complexity theories, it is important for this research in a complexity frame to acknowledge that the theory applies to all scales or levels: global, intermediate and detail scales. Importantly, the connections or ‘linkages’ (Yin, 2003b:11) between the different ‘levels’ of generality, or ‘holism’ on the one hand, and the detail or focused ‘levels’ on the other hand, are considered as important as the distinct units of study themselves in complexity theory. This important point is covered in more detail in other parts of this study (Chapter Two, Section 2.3.1 ‘Complexity, design and cities’ and Section 4.3.1.5, ‘Integrative urban design theory’), where integrative urban design is discussed.
Thirdly, a single ‘holistic’ study is considered open to accusation of being of a nature which is too abstract, lacking any clear measure or data (Yin, 2003a:45). In this thesis, as proposition and demonstration of evaluation methods and tools for evaluation of spatial complexity for urban analysis and design are important, including empirical data on individual buildings in some instances, a single ‘holistic’ case study unit would not be considered appropriate.

Fourthly, an embedded (as opposed to ‘holisti c’) case study research design is considered an important device for focusing a case study enquiry (Yin, 2003:45), as there is less danger that the entire nature of the case study may shift than in the single ‘holistic’ case study unit, with the implemented research design being no longer appropriate to the research questions being asked. Lastly, as regards scale of resolution, resolution, the data focus of this study is on the urban design scales, and not on the global ‘whole city unit’ of Dublin, thereby making the overall city the ‘context but not the target’ of the study (Yin, 2003:45). This thesis concentrates on urban design scales, and exploration of the theoretical concept of spatial complexity and therefore evaluation methods and tools for use in urban analysis and design are the primary ‘targets’ of this research.

In conclusion, a single ‘holistic’ case study unit is ruled out in this thesis research design, but a single case study unit with embedded subunits is next considered, as this could provide both a ‘holistic’ overview if one unit was considered to be the ‘whole city unit’ as well as embedded subunits in the form of single urban sites of smaller size/more detail. In summary, firstly because the research topic is studied at more than simply a global scale (and includes evaluation as well as exploration of spatial complexity),
secondly because clear subunits of study can be identified, also to avoid danger of the study remaining too abstract, avoid that the nature of the study shifts, and in order to preserve a scale of resolution below that of a global study, a single ‘holistic’ case study unit is not selected.

1.1.2 Single case study unit with multiple embedded subunits (4)

The second alternative in case study research design for this thesis is of the use of a single case study unit with embedded subunits (3). The advantages of this option include more indepth discussion and connection or linkage to the whole city unit of Dublin, which could involve engagement in the exploration of spatial definition and spatial complexity of whole cities, a topic of much complexity theories of cities research. One possible disadvantage is that attention on urban design aspects could become secondary, and the main object of the city of Dublin could be seen to dominate in the findings. This would deflect research focus from the specific scales of urban sites, defined as sites of a certain size (see later in this chapter) which are the primary focus of the research. However, it is concluded that studying the evaluated spatial complexity of Dublin, (a city of large geographical extent), as well as the requirements to link smaller units of study, in the absence of prior theory, would be beyond the capacity of one researcher.
1.1.3 Single case study unit with multiple embedded subunits (7)

A third option in case study research design for this thesis, is a single case study unit (of ‘Dublin’) with three embedded subunits, as well as three further embedded ‘smallest’ or ‘atomic’ units of study were considered, in order to demonstrate the ‘atomic’ (Batty, 1999) unit of study of spatial complexity for urban analysis and design, and show how this is linked to broader scales in a complexity frame (See Single Case, Many Embedded Units Option table). However, it was concluded that while studying the evaluated spatial complexity of Dublin, medium level urban design units (such as neighbourhoods), and smallest urban design units (such as individual streets) as well as the requirements to link smaller units of study, could be a useful and informative contribution to research for urban design, a team of researchers would need to be resourced for this type of large study. Similarly to the previous research design option, and in the absence of prior theory, this would be beyond the capacity of one researcher.

<table>
<thead>
<tr>
<th>Single Case Study ‘Unit’ name</th>
<th>‘Intermediate embedded units’</th>
<th>‘Smallest or ‘atomic’ embedded units’</th>
<th>‘Unit’ character</th>
<th>Kinds of Data</th>
<th>Smallest or ‘atomic’ unit of study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dublin Inner Tangent Ring</td>
<td>A ring road plan</td>
<td>Corommon</td>
<td>‘System’</td>
<td>Historical data, archive maps, changes in policy, reports</td>
<td>Historical data, archive maps, changes in policy, reports</td>
</tr>
<tr>
<td>Route</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dublin Ballymun</td>
<td>A collection of urban blocks</td>
<td>Ballymun Main Street/Town Centre</td>
<td>‘New Town’</td>
<td>Historical data, archive maps, changes in policy, reports</td>
<td>Historical data, archive maps, changes in policy, reports</td>
</tr>
<tr>
<td>Dublin Sandyford</td>
<td>A series of planning applications</td>
<td>Beacon Court</td>
<td>‘building’</td>
<td>Observation data</td>
<td>A plot/building</td>
</tr>
</tbody>
</table>

Table HH-1  Single Case, Many Embedded Units Option
1.1.4 Multiple-Case Research Design

A multiple-case study unit research design is now described. In relation to the advantages of a multiple-case research design over a single case, these include the fact that single case studies are considered to be ‘vulnerable’, in the sense that even two cases (or more if possible) increase the ‘substantial analytic benefits’ (Yin, 2003:53) of the research. Even a two case study has the possibility of a direct replication, which means that analytic conclusions independantly coming from two cases are more powerful than those coming from a single case. Secondly, as the contexts of both cases are likely to be different in these multiple-case situations, ‘if you can arrive at common conclusions from both cases, they will have immeasurably expanded the external generalizability of your findings, compared to those of a single case alone’ (Yin, 2003:53). Alternatively, if two or more case study cases have been chosen deliberately because they offer contrasting situations (as in this study) ‘and you were not seeking a direct replication, and the findings support the hypothesised contrast, the results represent a strong start toward theoretical replication – again vastly strengthening the external validity of the findings compared to a single case alone’ (Yin, 2003:54). In addition, ‘single case study units can be criticised for uniqueness or artifactual conditions surrounding the case (eg. special access to a key informant), which in turn can develop into skepticism about the ability of the researcher to do empirical work beyond the single case study’ (Yin, 2003:54). Having two or more cases blunts this effect.

Justifying a single case when dealing with complex phenomena also needs an extremely strong argument. It is further suggested that in cases where the researcher may frame a theoretical question that is narrower in scope and in which factors of importance may
vary from one case to another multiple case selection may be appropriate (Groat, Wang, 2002:356). While research design literature recommends that: ‘The evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as more robust’ (Yin, 2003:46), on the other hand, the conduct of a multiple-case study can require extensive resources and time, beyond the capacity of a single researcher.

In considering a multiple-case study unit research design the necessary number of cases to study arises, and two principles are suggested to consider (Groat, Wang, 2002:356), firstly, the nature of the research question (s) involved, and secondly, the role of replication in testing or confirming the study’s outcomes. Firstly, in relation to the research question, while, for example, Jacob’s study of New York sought to study ‘socio-physical phenomena involving multiple and highly complex factors’ (Groat, Wang, 2002) in a single-case study unit, New York, this thesis on spatial complexity seeks to study spatial phenomena at urban design scales, both for exploration of theory and evaluation of urban sites. It has been commented in relation to Jacobs single case selection (New York): ‘from a theoretical point of view, it made more sense ...to uncover the very complex dynamics of one setting of interest than to look less deeply at more settings (Groat, Wang, 2002:356). Whereas Jacobs studied dynamics of a whole city, this study seeks new knowledge to inform urban design practice in evaluating one specific aspect (spatial complexity) of urban sites, at a lower scale than the whole city.

Secondly, as regards the role of replication in testing or confirming the study’s outcomes, it is considered that ‘the power of generalizability comes from the concept of replication’ (Groat, Wang, 2002:356). Groat Wang define a literal replication as ‘a case
study (or studies) that tests precisely the same outcomes, principles, or predictions established by the initial case study. A *theoretical* replication in contrast, is defined as a case study that produces contrasting results but for predictable reasons (Groat, Wang, 2002:357). Therefore, in multiple-case studies, every case study should serve a specific purpose within the overall scope of the enquiry, and multiple cases should be considered as ‘one would consider multiple experiments- that is, to follow ‘a replication (ie. not sampling) logic’ (Yin, 2003:47). ‘Each case is chosen to either predict the same results across cases (*a literal replication*), or predict contrasting results but for predictable reasons (*a theoretical replication*)’ (Yin, 2003:47).

### 1.1.5 Multiple-Case Study units (6)

Having described the multiple-case study units research design option, in contrast to the single case study, the fourth alternative in considering case study research design for this thesis is outlined briefly. Having ruled out a single case for the reasons stated above and described the advantages of a multiple-case study type research design, the fourth option considered in this research design is now described. This involves multiple case study units (3) at large urban design scales, and further multiple embedded case study subunits (3) at small urban design scales, resulting in a total of six case study units of study (6). In this option, no overall case unit (of Dublin, for example) is selected as a case, because the global nature of the object of study is not the focus of the research question, which seeks knowledge at urban design scales only. So while spatial complexity of urban sites in exploratory terms is investigated, it is not conducted at the scale of a single whole city. In choosing three conventionally understood large units of urban design (a character area, an urban centre, a future neighbourhood) as well as three
small units of urban design (a public space, a street, an urban block) multiple scales could be investigated simultaneously, a suggested strength of a complexity approach to research (Chapura, 2009). However, having made extensive fieldwork investigations of candidate units at both scales it is considered that a focus on six locations as cases would be beyond the capacity of one researcher. Also, in the absence of prior theory on spatial complexity of urban sites, the potential for the study to lose focus on the need for usefulness of the study for urban design practice by attempting to cover many sites helped to rule out this option.

1.1.6 The selected option: Multiple Case Study units (3)

Lastly, this section describes the selected option, which involves three conventionally understood large units of urban design (a character area, an urban centre, a future neighbourhood). In this multiple-case research design, involving three geographically separate evaluation case study units within three exploratory contexts against the overall background of the city of Dublin emphasises a multi-scalar complexity frame as structure for the study, but also concentrates the focus into a small and manageable number, of three urban sites. As noted above, the number of case study units to select is undecided in the case study literature. Three case study units are chosen in this thesis and not two, or four, for two reasons. Firstly, in order to consider themes of temporal progression, and secondly, in order to clearly demonstrate contrasting results of high, medium and low evaluated levels of spatial complexity of urban sites. As regards the first reason for example, Liberties represents the past, Ballymun represents present, and Sandyford represents future ‘spatial complexity’ within an overall background of the
'whole city unit' of Dublin. The aim is to show, by chronological progression through the three units, from historical, present and future, how a *theoretical* replication approach (defined as a case study that produces contrasting results but for predictable reasons) to each case in turn, can show how evaluated levels or ‘results’ of analysis demonstrate contrasting results, but for predictable reasons in each case, which may relate to history in cases considered.

In complexity terms, the ‘linkages’ between the cases are considered to be as important as the individual cases, so these linkages also are a feature of the individual and multiple case study reports. In this study, which expands and develops theories of spatial complexity for urban analysis and design by demonstrating firstly that spatial complexity can be explored in contexts of precise units of study, and secondly by demonstrating that spatial complexity can be evaluated through an integrative process combining compositional (morphological) configurational (space syntactical) and system aspects of urban sites, it is not intended to predict the same results in the evaluation of spatial complexity for urban sites across cases (*a literal replication*), but it is of interest to predict contrasting results for predictable reasons (*a theoretical replication*) across different themes of scale, time geography, or policy. For example, comparing multiple cases could predict contrasting levels of spatial complexity in a between-case analysis because of different urban site size (*scale*), different historical path dependancies (*time*), different topography or urban densities (*geography*), or a lack of urban design frameworks in some cases but not others (*policy*). As regards the second reason to select three cases, in describing contrasting results, (and as described in Section 3.3.8, Weighting of findings) it is decided to confine the final quantification of evaluation to three evaluated levels of spatial complexity: high, medium and low.
In this study, exploration of spatial complexity is limited to the scales of urban design, and an important argument of this study is that criteria for evaluating spatial complexity may vary dependant on composition, configuration, and system properties of each urban site. For example, a factor of importance (in the consideration of spatial complexity for urban analysis and design) in the Liberties area of central Dublin is the historical urban prominence of compositional qualities at this site in overall Dublin terms. A factor of importance in Ballymun is the configurational properties of this New Town, especially as it relates to surrounding neighbourhoods. A factor of importance for Sandyford (in the consideration of spatial complexity for urban analysis and design) is the system nature of the site, particularly in relation to planning designation as a regional hub for future development. Deciding on three exploratory contexts and three evaluation cases also allows emphasis on the importance of ‘linkage’ between ‘agents’ or ‘units’ in complexity terms, as discussed later in this Chapter. In this regard, it is considered that ‘every case should serve a specific purpose within the overall scope of enquiry’ (Yin, 2003a) and this study complies with this requirement for a robust research design.
Addendum: Case results visuals

Appendix F illustrates a Sample representation of a Toolbox evaluation (coloured) of Ballymun (Figure FF-12, Pg 196, Volume Two), an image which returns to the Conceptual Framework Chart (Figure 4-1, Pg 158, Chapter Four, Vol. 1) for one sample evaluated location, urban Ballymun, to test this visualisation method. However, these images below are considered to achieve the evaluation visualisation requirement more clearly, and therefore each of the three urban sites is presented there. Therefore these additional graphical representations of evaluations of spatial complexity are added here post-completion of the overall study to enhance visual readings of overall results.
<table>
<thead>
<tr>
<th></th>
<th>urban form</th>
<th>land-use mix</th>
<th>density</th>
<th>compositional complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liberties</td>
<td>high</td>
<td>medium</td>
<td>medium</td>
<td>high/medium</td>
</tr>
</tbody>
</table>

+ 

<table>
<thead>
<tr>
<th></th>
<th>integration</th>
<th>choice</th>
<th>intelligibility</th>
<th>configurational complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liberties</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>high</td>
</tr>
</tbody>
</table>

+ 

<table>
<thead>
<tr>
<th></th>
<th>patterns</th>
<th>paths</th>
<th>people</th>
<th>system complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liberties</td>
<td>high</td>
<td>high</td>
<td>high</td>
<td>high</td>
</tr>
</tbody>
</table>

= 

<table>
<thead>
<tr>
<th></th>
<th>urban form</th>
<th>land-use mix</th>
<th>density</th>
<th>compositional complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Composition</td>
<td>high</td>
<td>medium</td>
<td>medium</td>
<td>high/medium</td>
</tr>
<tr>
<td>Configuration</td>
<td>integration</td>
<td>choice</td>
<td>intelligibility</td>
<td>configurational complexity</td>
</tr>
<tr>
<td>System</td>
<td>patterns</td>
<td>paths</td>
<td>people</td>
<td>system complexity</td>
</tr>
</tbody>
</table>

|                | high   | high  | high   | high              |

Spatial complexity Result | high |
### SUMMARY image urban Ballymun

<table>
<thead>
<tr>
<th>urban form</th>
<th>land-use mix</th>
<th>density</th>
<th>compositional complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>urban Ballymun</td>
<td>Medium/low</td>
<td>Medium/low</td>
<td>low</td>
</tr>
</tbody>
</table>

+ 

<table>
<thead>
<tr>
<th>integration</th>
<th>choice</th>
<th>intelligibility</th>
<th>configurational complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>urban Ballymun</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

+ 

<table>
<thead>
<tr>
<th>patterns</th>
<th>paths</th>
<th>people</th>
<th>system complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>urban Ballymun</td>
<td>High/medium</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>

= 

<table>
<thead>
<tr>
<th>Composition</th>
<th>urban form</th>
<th>land-use mix</th>
<th>density</th>
<th>compositional complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>urban Ballymun</td>
<td>Medium/low</td>
<td>Medium/low</td>
<td>Low</td>
<td>Medium/low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Configuration</th>
<th>integration</th>
<th>choice</th>
<th>intelligibility</th>
<th>configurational complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>urban Ballymun</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System</th>
<th>patterns</th>
<th>paths</th>
<th>people</th>
<th>system complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>urban Ballymun</td>
<td>High/medium</td>
<td>Medium</td>
<td>Low</td>
<td>Medium</td>
</tr>
</tbody>
</table>

Spatial complexity Result: Medium
## SUMMARY image Carmanhall

<table>
<thead>
<tr>
<th>Carmanhall</th>
<th>urban form</th>
<th>land-use mix</th>
<th>density</th>
<th>compositional complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>

+  

<table>
<thead>
<tr>
<th>Carmanhall</th>
<th>integration</th>
<th>choice</th>
<th>intelligibility</th>
<th>configurational complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

+  

<table>
<thead>
<tr>
<th>Carmanhall</th>
<th>patterns</th>
<th>paths</th>
<th>people</th>
<th>system complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

=``  

<table>
<thead>
<tr>
<th>Carmanhall</th>
<th>Composition</th>
<th>urban form</th>
<th>land-use mix</th>
<th>density</th>
<th>compositional complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
<td>Medium</td>
<td>Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carmanhall</th>
<th>Configuration</th>
<th>integration</th>
<th>choice</th>
<th>intelligibility</th>
<th>configurational complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Carmanhall</th>
<th>System</th>
<th>patterns</th>
<th>paths</th>
<th>people</th>
<th>system complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

V  

Spatial complexity Result: Low