Conference papers   School of Multidisciplinary Technologies

Digital Construction and BIM Research in Ireland 2016-2020

Barry McAuley
Technological University Dublin, barry.mcauley@tudublin.ie

Roger P. West
University of Dublin, Trinity College, rwest@tcd.ie

Alan V. Hore
Technological University Dublin, alan.hore@tudublin.ie

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[1]Roger P. West, [2]Alan V. Hore and [3]Barry McAuley

[1]Department of Civil, Structural and Environmental Engineering, Trinity College, University of Dublin, Dublin 2

[2]School of Surveying and Construction Management, Technological University Dublin, City Campus, Dublin

[3]School of Multidisciplinary technologies, Technological University Dublin, City Campus Dublin 1, Ireland.

E-mail: [1]rwestt@tcd.ie   [2]alan.hore@tudublin.ie   [3]barry.mcauley@tudublin.ie

As the construction industry opens up post pandemic, new and significant challenges will demand considerable expertise, not least in financial viability, solving the housing crisis and facing the very significant climate change pressures to make the industry less wasteful and less carbon intensive. This presents an excellent opportunity to further inculcate aspects of lean construction, particularly BIM into many aspects of construction not traditionally associated with digital construction, provided the necessary expertise is available and known to exist. Following a well-received recent conference paper summarising BIM-related research published by academics in Ireland's higher education institutions in 2020, this paper will review and identify noteworthy publications in digital technologies, including BIM, by academics of this island's third level institutions in the last five years. Areas of expertise of individuals will be identified to act as a useful directory for both industry and fellow researchers as well as providing a valuable national resource to identify research gaps which need funding if the ambitions of the national plan for the digitisation of the industry are to be realised. Using an already proven methodology, a survey of the 16 academic institutions in Ireland will be conducted through identified representatives in each institution, seeking all conference and journal papers published in the 2016-2020 period. The assembled database will be categorised, sorted and analysed to identify academic individuals in the workforce with extant research strengths in the various themes to establish the available expertise and areas for growth in the next five years.

keywords– Academic publications, BIM, Digital construction

I INTRODUCTION

In 2017 there were three important general BIM publications in Ireland, all undertaken under the auspices of the Construction Information Technology Alliance (CitA), namely, a global BIM review, an Irish BIM review, and the proceedings of the third BIM Gathering [1-3], the latter two as part of the government sponsored BIM Capability Programme [4]. This was followed in 2019 by updates on Ireland's BIM maturity [5] and the fourth BIM Gathering [6] and in 2020 by a review of the BIM publications of academics on the island of Ireland in the five-year period from 2015-to 2019 [7]. This latter has served as a useful guide and national repository identifying who has published what and where in the wide range of areas that BIM now covers.

Subsequently, in the last two years, CitA has added the broad topic of Digital Construction to its interests' themes and has organized a well-attended series of seminars on related topics. It is thus considered timely to conduct a similar review of the publications of Irish academics in digital construction in the broader sense while also updating the previous BIM publications list as a subset of digital construction research.

Digital construction could be described as the application of digital tools to improve the delivery and operation of the built environment. It encompasses many facets of digital technology, including, non-exhaustively, electronic devices and software such as tablets, lasers, drones, visualisation

tools, robotics, 3-D printing, BIM, e-commerce, etc. It is primarily data driven and involves a cultural shift towards technological collaborative tools.

Through a survey of learned publications of Irish academics, the aim of this paper is to both act as a repository of knowledge and, hopefully, to provide a stimulus for future research topics and funding.

II METHODOLOGY

In total, sixteen academic institutions (Table 1) which teach/research in the construction arena were contacted and asked to submit a list of peer-reviewed conference and journal papers on the topic of digital construction by them and their colleagues in the period 2016-2020 only. While four contacts had none that they knew of, the rest produced 277 titles which were reviewed by the authors. A filter system was used to eliminate papers outside the specified time period and those outside the paper theme (digital construction), taking as broad a perspective as possible. What resulted was a list of some 167 papers that are referenced in this paper. The paper titles were each considered in turn to categorise them in subsequent sub-themes, and from this, the structure of the remainder of this paper was derived. Furthermore, using the 'Find' facility in Excel, an index of the more prolific authors was assembled for inclusion in this paper, as given in the Appendix.

Institution	Contact name	Institution	Contact name
Athlone IT	Finola Deavey	Sligo IT	Trevor McSharry
Carlow IT	Eoin Homan	Technological University of Dublin	Barry McAuley
Munster Technological University	Ted McKenna	Trinity College Dublin	Roger P. West
Dundalk IT	Eamon Cushnahan	University College Cork	Paraic Ryan
Galway-Mayo IT	Mark Kelly	University College Dublin	James O'Donnell
Letterkenny IT	Anne Bonner	University of Limerick	Javier Buran
Limerick IT	Paul Vesey	University of Ulster	David Comiskey
Queens University Belfast	Tara Brooks	Waterford IT	Gordon Chisholm

Table 1: Key contact list for the third level institutions

A cursory analysis of the selected 167 papers reveals that 60% and 32% were conference and journal papers, respectively, the balance being other publications. Of the conference papers, 18% and 23% were published in the 3rd and 4th BIM Gathering proceedings, respectively, the balance of 59% being published in other national and international conferences. This indicates the importance of the BIM Gatherings as a forum nationally for sharing information.

Of the 167 papers submitted on the theme of digital construction, some 50% were on the BIM sub-theme and the next biggest themes were remote sensing (12%) and the digital age (8%). This shows both the disparate nature of digital construction and its universal applicability in many facets of construction.

III DIGITAL CONSTRUCTION

a) Digital age

Throughout the design and construction process, digital construction continues to have an enormous impact. For example, from design [8,9] to quantity surveying [10-12] to site practices [13] to regulations [14] and education [15], digital engineering is making a difference, as is information technology, through the internet of things [16], e-business [17] and ICT [18]. This transformation has also been identified in the roadmap for incorporating digital transition to the construction industry [19], notably through a Centre for Excellence for digital construction [20, 21].

b) Remote sensing

In the areas of photogrammetry, the digitisation of the earth's infrastructure on a macro scale [22], to a more local scale for asset management [23] and building energy performance [24] has come to prominence. Even specific small-scale recording, such as in, say, litter detection [25], building patch repairs [26], and time-lapse videos [27] have received attention. With the advent of unmanned aerial vehicles, such as drones [28], inspection of buildings has become much easier, albeit with data protection issues [29]. Similarly, digital construction has introduced virtual and augmented reality, where architectural [30] and engineering [31,32] features can be visualized and used creatively [33].

Even in a more specialized area, such as in bridge engineering, digitization has become an essential tool for monitoring bridges using computer vision [34] and drive-by monitoring [35] to allow image processing [36] and analysis [37] so that knowledge repositories of Ireland's bridges can be generated for review [38].

In manufacturing in civil engineering, computer vision is also used for assessing pre-stressed concrete elements [39] and micro-computed tomography for characterizing architectural cementitious materials [40]. Furthermore, digitally logged data with mapping can be used to troubleshoot and analyze factory floor data [41,42].

c) Data transfer

An essential element of digitization is the storage and transfer of information. Data sharing platforms have been investigated for practice and education [43,44]. Using dynamic information servers in an attempt to unify construction data has also been investigated [45,46], as has the use of industry foundation classes (IFCs) in design [47].

d) Project and facility management

The development of project management software tools has continued apace and one recent application in the area of trade/contractor performance has been published [48,49]. In the management of public sector procurement and implementing big data to achieve smarter buildings, the facility manager's role has come under the spotlight in two publications [50-52].

e) Building energy performance

Digital technologies are pervasive in evaluating the energy performance of buildings [53], which includes advanced modelling of building energy performance simulation [54-56]. The use of machine learning to minimize uncertainty [57] and optimize performance [58] have been explored. In specific applications, the important emerging needs to model occupant behaviour and to utilize renewable energy systems have been noted [59, 60].

f) Recycling

The role of the life-cycle engineer [61] continues to develop in significance, where whole life cycle costing [62], including recycling of construction waste and demolition waste management [63, 64], have become an essential part of any design.

g) Education

Many of the advances in technology and the use of digitization in the construction industry are taught in the third level institutes and have impacted student learning [65] and collaborative education [66]. Equally importantly, life-long learning provides many opportunities for retraining, for example, as a tool for developing a knowledge of the essence of smart cities [67, 68]. On campus, self-organised laboratories and synergistic partnerships between the academic and administrative functions have both borne fruit [69, 70].

h) General

There were 13 papers on aspects of digital construction that did not fit into one of the themes listed above and so will be dealt with here, briefly and individually:

Leadership in lean construction is complex as it has many facets which have been explained in [71].

Monitoring the displacement of real structures using optical flow methods and vision-based sensors has been described in [72, 73].

In a similar vein, aspects of structural health monitoring and dynamic risk assessment in roads have been published [74, 75].

In the environmental engineering discipline, the use of technology in oil and gas construction projects, environmental modelling and water distribution systems have all been discussed in [76-78].

On the construction materials side, diverse papers have been published on machine learning predictions of geopolymer concrete compressive strength, the use of additive manufacturing of cementitious products and the employment of technology to establish the location of cavity barriers in walls [79-81].

Finally, on a more detailed level, 3D-printing in construction has become a research topic in its own right and its use in printing full-scale concrete structures is gaining momentum [82, 83].

IV BIM

BIM topics are strictly a subset of digital construction, but as it is a well-developed research topic with many authors and papers (50% of this cohort), it was deemed to merit its own section in this paper, recognising that the 2015-2019 BIM papers list has already been published at the Civil Engineering Research in Ireland conference in 2020 [7]. This list updates its predecessor.

a) Lean construction

The relationship between lean construction and BIM has been explored [84], and the introduction of BIM at an early stage in the design process has been recognized as a contribution to lean construction [85]. An analysis of the BIM contribution to lean construction in small to medium enterprises (SME) has also been conducted [86]. More specifically, the

application of lean and BIM principles to office fit-outs has also been studied [87].

b) BIM maturity

As already mentioned in the introduction to this paper, the state of BIM maturity in Ireland has been comprehensively evaluated twice in the last four years [2, 5]. Progression and deficiencies in BIM maturity in Ireland can be observed [88-90] and arising from this, as part of the roadmap for BIM adoption in Ireland, an assessment was carried out in 2020 on the state of readiness of Irish construction for the potential imposition of a BIM mandate, as extant elsewhere [91]. A further paper [92] extended the concept of BIM readiness to the SME sector in 2017.

c) Knowledge management

Explorations of the nature of a BIM design model and the demystifying of what BIM data comprises were described previously [93, 94]. BIM-based knowledge management and building information management in construction were reviewed [95-98], as was the transfer of information between parties in construction projects [99-100].

d) Management approaches

The introduction of BIM processes into the industry is a significant challenge in change management. Incorporating existing construction knowledge into a BIM environment is part of that challenge [101, 102], where there is a culture of natural resistance to this change when introducing transformative new technologies and processes [103]. Much can be learnt from international academic collaboration in the process of training a new cohort of construction professionals [104, 105].

e) Public sector

When a mandate is imposed in Ireland, as it will likely be, it is expected that it will impact the public sector initially. Again, by studying trends abroad [1, 106], there are lessons for Ireland which can lead to a strategy for BIM adoption in the public sector [107], based on government policy objectives [108].

f) Facility management

Using a knowledge of the construction and facility management (FM) processes, one can design an approach for incorporating BIM while planning for the maintenance and operation of buildings [109, 110]. BIM can be supplemented by expert systems and FM-designed software to assist in this role [111, 112]. Recently, it has particularly been the focus to establish the benefits of early FM and contractor involvement using the BIM environment to promote more efficient design and construction [113].

g) 5D BIM

Some disparate research work has been undertaken in Irish academic institutions on 5D BIM specifically: The interoperability of costs codes between BIM models [114]; the embedding of life cycle costs in a 5D BIM model [115]; and a review of the Quantity Surveyor's model view definition (MVD) for collaborative engagement [116].

h) Block chain and big data

Two of the key issues in the adoption of blockchain technology, namely how to incentivize its use in procurement and the matter of trust when collaborating, have been addressed in two papers [117, 118]. On the matter of big data, again, two BIM papers address current issues – disaster resilience and spoken dialogue systems [119, 120].

i) Thermal performance and digital twins

The adoption of an MVD can also be applied in thermal comfort analysis [121-123] and building energy performance simulation [124, 125]. Similarly, dynamic building performance evaluation can be conducted post-occupancy using a dynamic digital twin for commercial buildings [126-128]. Given the prevalence of popular dialogue on digital twins, it is surprising there are not more papers published in this emerging topic.

j) GEOBIM and Historic BIM

Subsets of the BIM heading exist, two of which are GEOBIM and Historic BIM (HBIM). A valuable summary of the status of GEOBIM in Europe is given in [129]. Linking geospatial data into BIM is described in [130] while the same data for retrofit projects in discussed in [131]. The role of green BIM is presented in [132].

In HBIM, the current state of the art is described in [133] and useful guidelines for its use in Ireland are given in [134]. Papers on sustainable historic building maintenance and conservation of the Armagh observatory can be found in references [135,136] respectively.

k) Education

This category had the largest number of contributions, perhaps not surprisingly considering how well BIM education in Ireland ranks internationally [2,5]. A summary strategy for BIM education is a good place to start [137]. The importance of pedagogy in

teaching is reflected in [138, 139], for example in 6D BIM curricula as presented in [140, 141].

Much can be learned from international studies [1, 142, 143], with specific examples published in [144, 145]. Indeed, international collaborations in Europe have led to a sustainability-based energy BIM-Cert as an example of what can be achieved [146-148].

Academia working more closely with industry has benefits for both through collaborative and knowledge transfer partnerships [149-151]. Furthermore, a BIM toolkit has been developed to assist in training academics involved in BIM-related education [152].

Infusion of BIM into specific programmes has been described for Structural Engineering [153], Quantity Surveying [154] at undergraduate level and a Masters programme at postgraduate level [155].

Finally, an interesting reflection on lessons learned from observing the use of BIM on a campus construction project can be found in [156].

l) Use cases

In the review of the papers on BIM, a number of diverse examples of digital construction in practice emerged, and these shall be mentioned individually here.

A case study highlighting the steep learning curve when introducing BIM in practice is given in [157] and is further extended by reference to BIM being engaged in construction [158], including recording construction details on site [159].

Intelligence assisted design [160] and the automation of compliance checking using BIM [161] have been investigated, including for fire-safe design [162].

Instrumenting new and existing buildings to monitor building performance using BIM has been described in [163] and, by way of interesting examples, the application of structural health monitoring on a historic lighthouse has been described in [164] and using BIM to record information on a listed viaduct in [165].

Many BIM case studies have been conducted by CitA, for example the use of BIM on the National Children's Hospital [166].

Cases are not just restricted to construction, as a study on the impact assessment of green infrastructure using BIM shows [167].

V CONCLUSIONS

The last five years has seen much new activity in research in digitization of the construction industry, building on the work on BIM in the last decade. The authors aim was to create a paper which could be widely used to inform students, academics, and all facets of industry as to who has published what and where, so that the rich vein of expertise might become better known. To that end, the names of the many authors mentioned in the list of references below were examined to create an index (Table 2) which it is hoped will also prove helpful when using this focused repository of knowledge. The most prolific academics in publishing in digital construction appear to be Comiskey and McKane in the area of technology, data sharing and education; Motawa in big data and building peeformance; and Hore, McAuley and West in BIM. Areas for significant potential growth include remote and building performance sensing, lean sustainable construction and dynamic digital twins using BIM models.

It is a limitation of this paper that it may be the case that not all academics had the opportunity to submit their publications lists to the authors and so the references here, while manifold, may not be exhaustive. Furthermore, it is recognized that this paper, while lengthy, offers little opportunity for in-depth analysis of the list peer-reviewed papers, as published by academics based in or in collaboration with Irish third level institutions. It is a further limitation of this paper that its original scope was also to compile all MSc and PhD theses titles on relevant topics in the review but the pandemic restrictions ensured that academics did not have ready access to campus to assemble the relevant lists. It is thus recommended that this rich source of knowledge be explored and analysed in future research on digital construction.

ACKNOWLEDGMENT

APPENDIX

An index of the publications of the top 50 most prolific authors is given in Table 2.

Table 2: Index of the publications of the top 50 most prolific authors

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