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Digital Engineering: a Case Study in an Irish Consultancy Practice

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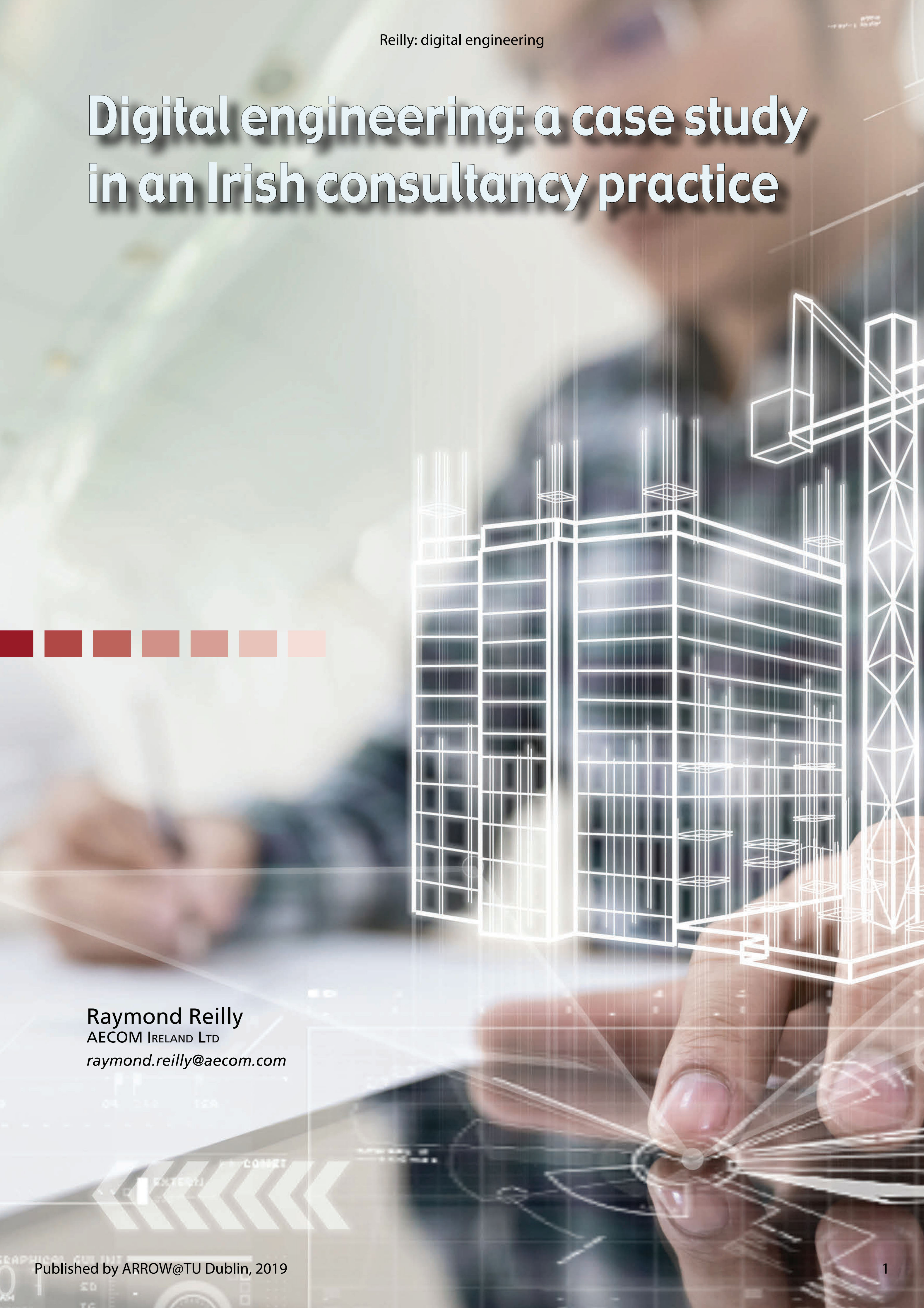

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Abstract

The building services engineering (BSE) industry has wrestled with its productivity gap for many years and the time has come to embrace innovation. Its practitioners now have the key to unlock the future by the smart use of technology, which has the power to transform how we design. Embracing digital technology provides smarter, faster, better and safer solutions. Scholarship in BSE consultancy practice is limited, and although this inquiry is a means of advancing knowledge, it also serves as a disciplined and systematic procedure by shedding a new light on design effectiveness in practice, thus improving the design process through digital engineering.

This paper outlines how digitalisation encapsulates people, processes and technology to improve the design process in Irish BSE practice, thus providing the basis for promoting a sustainable design process during and after design.

(This paper includes content submitted by the author as part of his Professional Doctorate in the Built Environment at the University of Salford).

Keywords

Digital Engineering, Building Information Modelling.

1. Introduction

What was once deemed the province of a craftsman, building services engineering (BSE) now demands the services of a body of highly-educated and specialist-trained professional engineers (Portman, 2014). Building services engineers are responsible for the design of the mechanical, electrical and public health (MEP) systems required for the safe, comfortable and environmentally-friendly operation of buildings (Miller, Vandome, & McBrewster, 2009). This multidisciplinary field of engineering essentially brings buildings and places to life. The increasing complexity of modern Irish buildings has significantly increased the pressure to improve the performance of the design process.

Thus far, research has identified that a large percentage of defects at construction stage arise through decisions or actions at the design stage; any unresolved design issues must be resolved at construction stage. Poor communication, lack of adequate documentation, deficient or missing input information, unbalanced resource allocation, lack of coordination between disciplines, and erratic decision-making have been identified as the main problems at design stage. This inherent productivity gap leads to inferior quality of systems' installation, increased costs and extended time delays at construction stage (Yongping, Chunyan, Pengfei, & Weiping, 2014). Such deficiencies initiate dysfunction in terms of redesign and associated financial burden in consultancy practice. The small relative cost of the design process when compared to construction costs disguises its true importance for overall performance (Austin, Baldwin, & Newton, 1994).

BSE is a dynamic and complex design process due to its multi-disciplinary nature. It requires a high degree of technical competence to ensure that MEP systems are safely designed, legislatively compliant, and more importantly, technically coordinated with other team disciplines (Trevelyan, 2014). Success in BSE practice relies on the ultimate design deliverable being performed correctly. Moreover, BSE practices are expected to invest heavily in adopting new technology and in training their practitioners to operate that technology efficiently. Sustaining the implementation of digital technologies requires extra

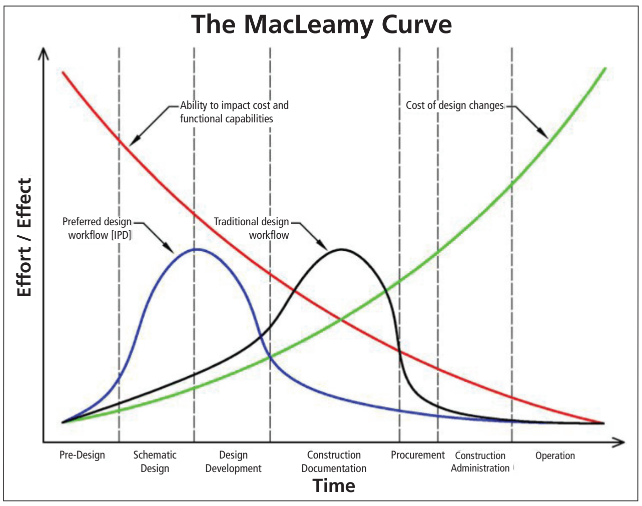

Figure 1: Design Workflow – The MacLeamy Curve (Walaseka & Barszczb, 2017).

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effort from practitioners with their openness in delivering quality design in the format of transferable digital information (Walaseka & Barszczb, 2017). Consequently, and according to the MacLeamy Curve (see Figure 1, p46), most of the practice workload and effort is encouragingly shifted towards the design stage.

The UK has led this adoption in response to its Government mandate, and is readily transferrable to the Irish construction industry (GCCC, 2017). The Irish government has recently committed to increasing the use of digital technology, and its statement of intent defines a Building Information Technology (BIM) Adoption Strategy to support the implementation of Government policy objectives in the procurement of public works projects, in their construction and in their maintenance upon completion (GCCC, 2017). BIM is gaining traction in Ireland at present, and it is essential that it receives the investment, focus and time initiated from a Government-led strategic framework to ensure it is successfully implemented (Engineers Ireland, 2019).

There is a real need to design buildings faster and cheaper in Ireland. This requires multidisciplinary practitioners to work together in a more concerted manner. A collaborative approach with BIM is proven to be more effective for successful projects, and can be further encouraged in the industry by redrafting the GCCC suite of contracts to include use of BIM processes and technologies (McAuley, Hore, & West, 2012). BIM implementation success lies in both cultural and technological change. It requires BSE practitioners to change outdated design practices, adversarial approaches, and to adopt new technologies and methodologies. Practitioners do not like change and without strong leadership and management, they are more likely to maintain the status quo of poor design practices (Montague, 2015).

This paper sets out the theoretical issues relating to the design process during the design and construction stages which required a well-disciplined literature review in order to synthesis its adaptability to BSE design practice. The theoretical components were then examined and tested from the findings on a practice-based case study on a modern grandstand building at the Curragh Racecourse, County Kildare (see Image 1), completed in May 2019 and with a construction value of €87 milion.

It is intended that this research will draw upon critical perspectives, linking the theoretical and work experiences to understand and suggestively improve practice, removing avoidable risks during the construction stage, thus creating a new knowledge base (Rigg & Trehan, 2008). It is also recognised that lessons drawn from one case study are limited, and therefore practitioners can extrapolate design process improvements from their own experience. Notwithstanding this, the researcher has established strong parameters and set clear research objectives which is critical in case study design (Yin, 1994).

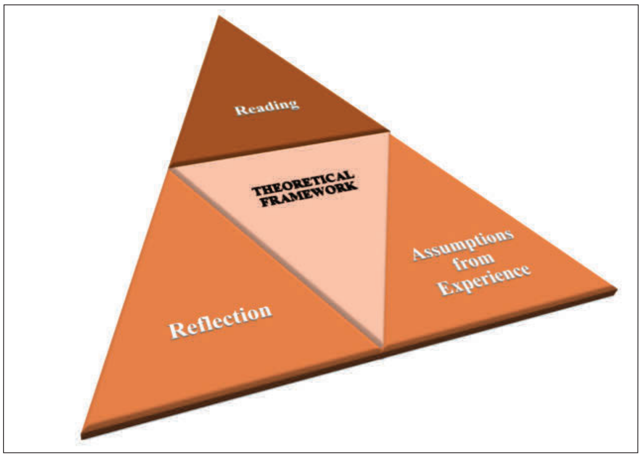

Figure 2: Sources of Theoretical and Conceptual Frameworks (Trafford & Leshem, 2012).

1.1 Theory and Practice Test

Linking theory and empirical research through interactions from reading, reflection and assumptions has enabled the researcher to develop new theory (see Figure 2).

This empirical research of engineering design practice at both design and construction stages is set in the context of *people, processes* and *technology* (PPT) in order to synthesise its theoretical adaptability to BSE practice (see Figure 3, next page). The reason for this triangulated focus is that successful project implementation requires an approach that optimises the relationship between PPT. Ensuring that the BSE team consists of people with relevant education, skills and experience who are committed to conducting staged processes throughout the project life and supported by suitable digital technologies is imperative for effective engineering practice. BSE is not simply a design-based process but a complex integration of explicit and tacit knowledge of both technical and managerial practitioners nearing a successful installation at construction stage (Sheppard, Colby, Macatangay, & Sullivan, 2006).

Image 1: Practice-based Case Study Project – Grandstand at the Curragh Racecourse (Reilly, 2019).

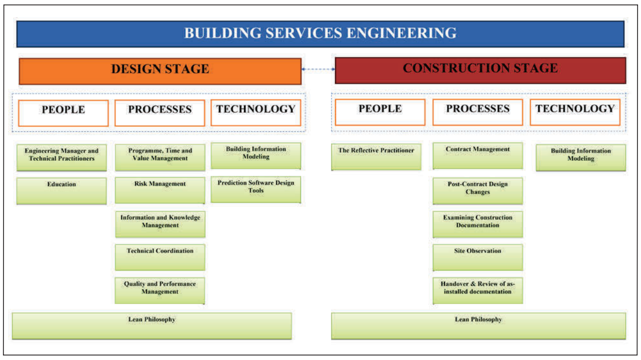

Figure 3: Primary Scope of Literature Review.

The adoption process of digital technology is never instantaneous in practice. Instead, it is dependent on management and practitioners who are more apt to embracing new innovates. The theory of diffusion of innovation not only validates this fact, but also demonstrates that practitioners who are more willing to adopt new innovations have different characteristics when compared to those who adopt innovation later (Walaseka & Barszczb, 2017). The chasm occurs at the transition between the early adopters and the early majority. It is suggested that once 16% adoption of any innovation is reached, media strategy is changed from one based on scarcity, to one based on social proof in order to accelerate through the chasm to the tipping point. The tipping point is the point at which the mainstream begins to adopt the innovation (Maloney, 2010) (see Figure 4).

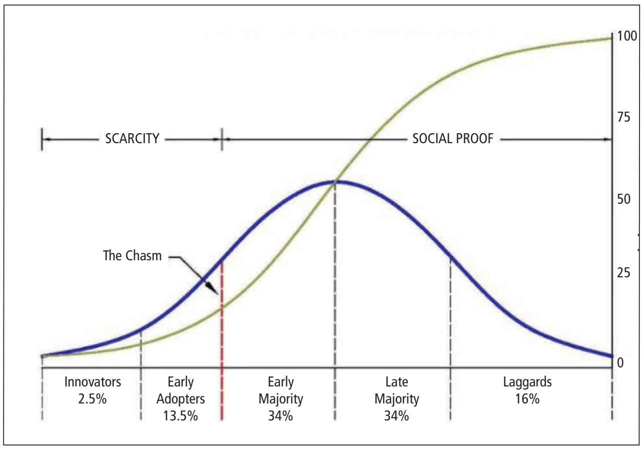

Figure 4: Rogers' Law of Diffusion of Innovation (Maloney, 2010).

2. Digital Technology

Engineering design practices' key resources are related to their core competences, including integrating multiple streams of technologies. By allowing market trends and new technologies to be disregarded leads to professional obsolescence (Engineers Ireland, 2016). The BSE design process and, by extension, the construction process is somewhat aided by the use of computer models which create virtual buildings and simulate the performance of mechanical and electrical systems (Portman, 2014). Undoubtedly, BIM is transforming the construction industry by changing the way multidisciplinary project teams collaborate at every stage of the project cycle to deliver significant efficiency and cost-saving benefits. As familiarity and maturity increase across the globe, BIM is set to influence a new generation of practitioners (British Standards Institute, 2019). Thus far, the overall and practical effectiveness of BIM utilisation in practice is difficult to quantify (Li, *et al*, 2014).

BSE-related technology changes faster than that in any other part of a building or place. The development of BSE software design packages is intended to improve the efficiencies of MEP systems, but new digital demands are arising from the technological change taking place in the activities of building occupants. While the BSE design process is also aided by the use of computer models which simulate the performance of thermal behaviour, energy usage, electrical distribution, artificial lighting, vertical transportation, ventilation and renewable energy resources, the best modelling programs cannot account for the unpredictable nature of occupants (Portman, 2014).

2.1 Digitalisation

Digitalisation is the adoption of digital technology by a practice, and the introduction of BIM represents the BSE industry's moment of digitalisation. Undoubtedly, the wider use of technology, digital processes, automation and higher-skilled practitioners contribute greatly to the economic, social and environmental future (EUBIM, 2017). The use of digital technology has, until recently, largely been confined to the pre-construction stage. Indeed, the construction and operational phases are still somewhat reliant on paper outputs from the digital platforms used at the design stage. This is because, until relatively recently, the technology had not developed sufficiently to facilitate the complex supply chain that contributes to a construction project. BIM is now evolving to provide a means of extending the digital reach into the construction and operation stages (GCCC, 2017).

It is no secret that the Irish construction industry is changing. The impact of technological advancements in recent years has been nothing short of transformative. Clients are demanding higher quality, greater reliability, faster delivery and the higher safety standards. Recent advances in technology have brought new ways to optimise project delivery, increase productivity and create efficiencies throughout the design and construction stages (AECOM, 2018). By rethinking the way digital technology plays a role in the BSE practice, it is imperative to establish radical new solutions, thus transforming project delivery and unlocking the full power of the BSE consultancy offer to clients. By connecting with market-leading digital expertise, practitioners can leverage the scale to deliver innovative, differentiated solutions to clients, boost performance and ultimately grow business.

The National BIM Council (NBC) of Ireland's recent endeavour to roadmap digitalisation of the Irish construction industry advocates more productive ways of working that improve competitiveness. This roadmap is divided into four key pillars – leadership, standards, education and training, and procurement. Remarkably, the Irish government has not yet afforded adequate leadership in diffusing BIM, and has failed to provide online supports or reviews of the suitability or provisions made for developing public construction contracts. However, the National Standards Authority of Ireland (NSAI) has developed a BIM certification program aligned with the publication of IS EN 19650: Part 2, providing an internationally-recognised standard for BIM. Moreover, third-level and professional institutes are perceived as entities for upskilling prospective and

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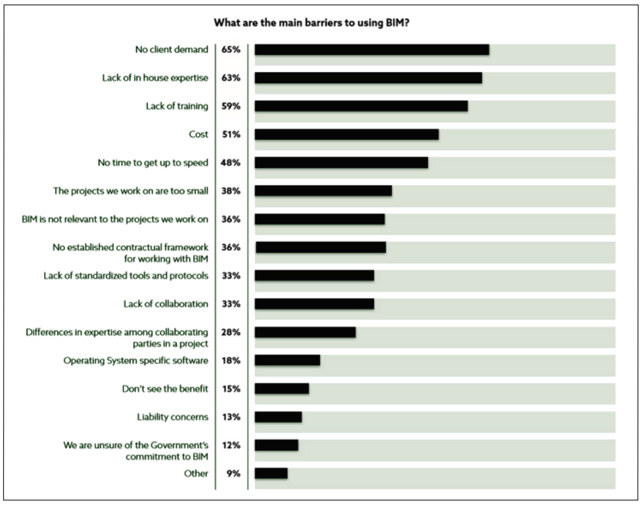

Figure 5: Main barriers to BIM implementation (NBS, 2019).

current practitioners, respectively (McAuley, Hore, & West, 2019).

While Ireland has recently shown a steady increase in some aspects of its BIM maturity, barriers to its implementation are inherent (Figure 5). BIM necessitates significant change to workflows, practices and procedures. It requires investment of knowledge in BIM standards and protocols, training in new software platforms, and financial investment to access these digital tools (NBS, 2019).

2.1.1 Digital Engineering

Using existing technologies, as well as developing new digital solutions through the use of artificial intelligence, facilitates BSE practitioners in designing systems that better meet clients' needs during all stages of the project lifecycle. This research suggests that practitioners who adopt digital tools to develop an innovative new approach to BSE design will dramatically improve the efficiency and quality of the design process.

The traditional design process, where detail is added to design components throughout, sees components designed from scratch for each project, creating re-work as more precision is built into the design. Digital libraries allow the creation, storage and reuse of proven and at-the-ready design components on multiple projects from the outset, dramatically reducing the time needed to design systems. The use of digital libraries continue to create efficiencies into the construction stage (GBC, 2019). Standardised components, specifications and tutorials stored within the model help speed up construction and procurement, potentially creating efficiency improvements of up to 20% on a typical project. This leads to reduced design and construction cost, improved design and construction quality, faster design and construction, and design practice efficiencies. By repeating the use of a standardised digital toolkit, design time is reduced, and the inherent prescriptive approach helps reduce design rework (BIM Today, 2019).

2.1.2 Digitally Transforming BSE Design

Digitally transforming the BSE design process has the potential to support practitioners and help clients make better-informed decisions by using automated knowledge-sharing and generative design techniques that provide multiple design options earlier in the design process. Providing detailed 3-d plantroom information with scheduling and cost data at scheme design stage, rather than at detailed design, means cost plans can be tested earlier and realistic financial models can be developed from the start, minimising risk and the program and cost impacts of design changes (Sacks, Eastman, Teicholz, & Lee, 2018).

Practitioners can then produce highly-detailed, construction-ready, designs that will improve technical co-ordination with the wider design team, reducing contractor design, requests for information schedules, change requests and shorten construction programme. Transforming the BSE design process permits better decision-making with more information, increases the productivity of the entire design team, improves cost certainty and reduces programme costs, thus reducing BSE contract times at construction stage (Schober, 2016).

Digital design tools have the potential to reap 20% savings in consultancy practices (Agarwal, Chandrasekaran, & Sridhar, 2016). *Automatic load calculations* help achieve significant time savings and create agility in responding to design changes by starting with the automation of standard rule-of-thumb calculations and leading to fully-automated dynamic simulations.

Automatic plantroom and riser-sizing tools facilitate the design of plantrooms and risers in 3-d. Creating a full set of plant and area schedules speedily allows for greater detail at earlier design stages, reducing costs and helping clients review options to choose the best solution for their building (AECOM, 2019). Standardisation of content and automated design detailing processes help produce more detailed and complete information without spending additional time on projects, improving design information and reducing issues during construction. Recent advances in digital technology have brought new ways to optimise project delivery, increase productivity and create efficiencies throughout the design and construction stages (Parsons, Mischke, & Barbosa, 2017). BSE practitioners must transform the way they use technology and data to deliver more efficient and valuable solutions to clients (Lawlor, 2017).

Adopting a digital workflow strategy, BSE teams supporting projects from inception to completion ensure that clients will benefit from digital best practice, workflow and governance throughout. Through a digital-healthy-start, practitioners can mobilise digital skills early on a project, ensuring the best available technologies are in place from the start. This strategy improves productivity in design between 2% and 10% by facilitating greater multidisciplinary coordination, reducing design-stage rework, reducing project costs due to reduced site clashes and issues, and improved stakeholder engagement (Byrne, 2018).

Implementing digital design reviews to improve coordination on large complex projects, and to facilitate collaboration between design teams and project stakeholders, is essential. Digital reviews bring together BIM from different design disciplines to facilitate clash detection and interdisciplinary coordination. The use of a combined model involving all stakeholders to conduct regular reviews helps identify issues early and increases program certainty.

The use of virtual and augmented reality technologies further enhances the design review process, immersing practitioners in full-scale simulations of the design. This facilitates early identification of issues, increases program surety, better management of risks, minimises rework and reduces issues during construction. It engages all project stakeholders in the design review/development process, and the visualisation of the design (Behzadi, 2016). Including visualisation and immersive technology is helping the project team to visualise projects like never before, and are transforming the design process. Blurring the lines between the physical and digital world, virtual reality (VR) and augmented reality (AR) are helping practitioners visualise projects (Fossett, 2016). Whether supporting public consultation, or engaging stakeholders in the design process, immersive technology is helping clients make better-informed decisions, with confidence (Leeuwen, Hermans, Jylhä, Quanjer, & Nijman, 2018).

Immersive technology is bringing digital models to life, allowing all stakeholders from architects, engineers and contractors to owners and end-users, to intuitively interact with a design in real time, wherever they are (Heydarian, *et al.*, 2015). Clients can now interact with their final project throughout the design process, transforming how they engage with designs. On complex projects with multiple stakeholders, clients can see intricate areas of the design and discuss alternative design solutions. It boasts a platform for more efficient design with real-time updates to the model from all stakeholders, clash avoidance and enhanced client review process, and seamless working across teams and locations. In addition, more efficient construction is instigated by heightened value engineering and constructability in design, operations and maintenance benefits with boosted input from owners, operators and end-users (Bolton, 2018).

Practitioners need to actively embrace digital technologies, thus accelerating digital transformation by expanding their existing digital solutions and nurturing new ideas (European Commission, 2016). Developing and implementing a pragmatic and scalable digital transformation plan is the key to drive an enhanced design practice, improving the technical quality of deliverables by disrupting the BSE industry with a new approach to design deliverables, industry procurement, construction and building aftercare. Practice challenges will include accelerating technological change, driving multi-industry disruption leading to winners and losers, new industries replacing older ones, and practitioners' expectations around work and how/where they want to work.

2.1.3 Building Information Modelling in BSE Practice

In an effort to remedy the issue of stagnant labour productivity in the Irish construction industry, BIM was proposed in the late 1980s as a new solution for streamlining the design and delivery process of construction projects, a digital representation of a building meant to serve all project disciplines as a repository of all relevant data throughout the project's lifecycle. Despite the huge potential for increasing productivity as well as the overall efficiency, the adoption of BIM throughout the construction industry has been observed to be slower than expected (Walaseka & Barszczb, 2017). Fortunately, the Irish BSE industry is small and agile enough to evolve quickly by adapting new technologies to existing expertise, and to learn lessons during this adaption while becoming world class in design (Montague, 2015).

Recent technological and digital developments currently offer an integral BIM 3-dimensional software for BSE design (Szeląg, Szewczak, & Brzyski, 2017) which are demonstrating to be a game-changer in Irish consultancy practice. In particular, MagiCAD was developed as a powerful design tool to save time with more user-friendly, flexible, intelligent, and parametrical user environment (MagiCAD, 2016), and was successfully implemented at the design stage on the case study project. It enabled the MEP design using an extensive product model database, featuring real product families from leading manufacturers across the globe. Each model within the database came complete with accurate dimensions and comprehensive technical data allowing for accurate calculations, advancing the working environment to create a more streamlined workflow that removed monotonous tasks, thus reducing time in the design process. It also provided collision control, and enabled easier and more efficient technical coordination with other disciplines' intentions during the design process, most notably, architecture and structural engineering. Image 2 demonstrates the accuracy of design by applying MagiCAD. The principle benefits of using this digital engineering technology during implementation of the Grandstand included plant space allocation, scenario planning, early and accurate visualisations, automatic maintenance of consistency in design, enhanced building performance and quality, checks against design intent, accurate and consistent drawing sets, earlier collaboration of multipledesign disciplines, synchronised design and construction planning, discovering errors before construction, and lifecycle benefits regarding operating costs of the building. However, the implementation in MagiCAD in Irish BSE practice is in its infancy, and its practicality and effectiveness are difficult to quantify at this stage.

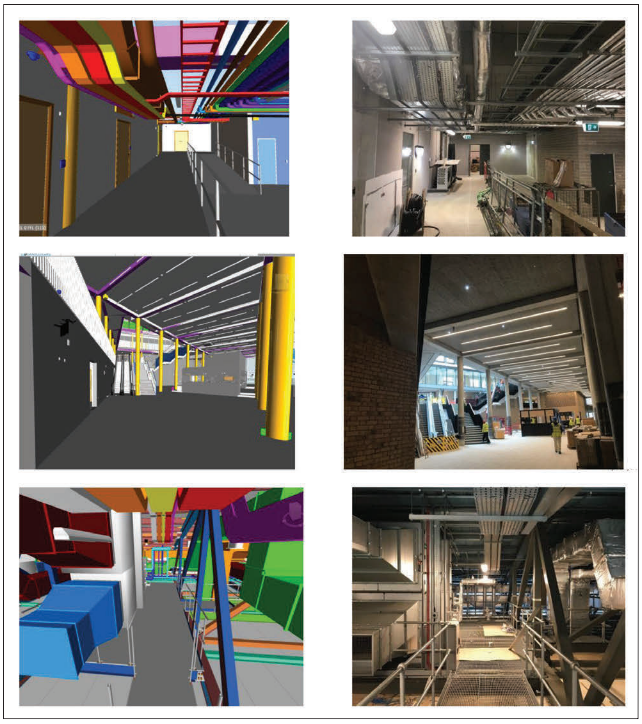

Image 2: Synchronized MEP BIM model applying MagiCAD (Case Study Project).

3. Research Findings and Discussion

A great deal of qualitative material comes from talking with people, whether it is through formal interviews or casual conversations (Woods, 2006). The interview method used for this inquiry offered the researcher access to BSE practitioner experience at design and construction stages. The questions were primarily informed from findings in the literature review, and presented to the participants in the context of the case study, allowing them reasonable opportunity to present phenomena in their own terms (MacDonald, 2012). A sample of 15-BSE practitioners with varying degrees of experience were strategically chosen to participate. There are many practical recommendations regarding a sample size with the most usual recommendation of 12-20 interviews (Onwuegbuzie & Leech, 2007).

3.1 People

Most interview participants agreed that the BSE design process is dynamic and complex due to its multidisciplinary nature, and requires technical competence and collaboration to ensure that MEP systems are designed effectively ensuring a good quality building within a reasonable cost programme. The participants also acknowledged that the design process lasts from project inception to completion, which infers that the design process does not specifically conclude once the design is fully detailed at pre-construction stage, thus contravening theorists design principles. The concept that inferior BSE design is a consequence of poor design coordination incurring significant programme delays and costs at construction stage (Portman, 2014) not only affects MEP installation, but also traverses to other discipline trades, most notably, the structural engineering constructs. This phenomenon infers that such deficiencies lead to *fire-fighting* and *tension* between disciplines, thus concurring with current literature.

The postgraduate experience of each participant ranged from five years to 15 years. All participants agreed that the Irish educational system does not adequately prepare graduates for digital engineering practice. Albeit technical theory underpins successful project design, it is inferred that the lack of practical digital experience in the BSE curriculum is a significant weakness which sees graduates as living in a *2-d world*. Most worryingly, it is believed that graduate engineers are unaware of the *real* implication of *adjusting* detailed design and its inherent impact on other design disciplines, most notably, architectural and structural engineering.

All BSE participants acknowledge working in silos albeit *cognisant* of critical interface requirements between other discipline designs, and argue that this interface is not clearly advocated by management at design stage. It is inferred that there is dependence on *good* contractors at construction stage to rectify the discipline interface shortcomings initiated during the design process, suggesting that improvements in multidisciplinary team coordination at design stage could potentially reduce implications during installation.

BSE practitioners are cognisant of the so-called *half-life* of technical knowledge in engineering practice. While most practitioners are normally keen to evade this *outdated* status, many do not share this vested interest, highlighting that *you can take the horse to water, but you can't make it drink*. Participants also disclose that project time demands negates sufficient time for adequate formal training to enhanced their digital skillset. Moreover, there is a decisive aspiration from practitioners to implement new design tool technologies albeit time constraints continue to limit research in testing the feasibility and accuracy of inherent digital engineering tools.

It is expected that the recent endeavour by the National BIM Council (NBC) of Ireland to roadmap digitalisation of the Irish Architecture Engineering and Construction (AEC) sector will pave the way for greater productivity in digital practice by enhancing leadership, education and training among its practitioners.

3.2 Processes

The introduction of digital specialisms such as BIM, thermal modelling (TM) and computational fluid dynamics (CFD) has in fact initiated *silo* working environments in BSE practice. Participants expressed concerns that current practice is veering towards each practitioner being a *one-for-all* BSE practitioner, which in their view is not practical in modern practice, and consequently, introduces dissonance between designers.

Design coordination problems are known for their ill-definedness and complexities which result as a lack of information (Park & Lee, 2017). The design coordination process is intended to allow each discipline to compare their respective materials that are intended for given space in a building to ensure they will not conflict physically or impair the installation and maintenance of subsequent systems. BSE participants argue that design coordination is performed primarily by BIM technologists with variable levels of effort and results. This affirmation of sorts surmises that engineering design is coordinated and driven by engineers, but the end result is delivered through the hands of others.

Digital information management systems enable the integration of people, processes and data throughout the project lifecycle, allowing the secure sharing and storage of project information, while enabling practitioners to collaborate effectively and provide visibility into the project to essentially mitigate risk. This structure ensures that the right information is available when required in the right format (Portman, 2014). All participants tend to *poach* as much as 60% to 70% of previous designs, cost and programme information for new projects as a means to minimise documentation production time. Consequently, it is imperative that up-to-date industry standards and specifications are managed and easily accessible by practitioners. BSE participants are confident that the adoption of ISO 19650 (Parts 1& 2) will facilitates an excellent common data environment in terms of in-house filing and project templates at both project design and delivery stages.

3.3 Technology

Engineering design is often too complex to carry out manually due to the significant number of variables. The use of digital prediction software tools can often mitigate against human error from manual calculation, and practitioners accept that such software is adopted with an air of caution in terms of accuracy, thus advocating that their design is checked by experienced practitioners who apply their tacitness to this explicit process.

Participants insinuate that CFD software *does not reflect real-world,* and is dependent on accurate input parameters which are often *difficult to define* to simulate a realistic model. This research intimates that thermal modelling software provides a *good guidance*, but similarly, there is reliance on many variables at the outset to achieve an exact simulation. Inherent variables such *as people behaviour, building operation, weather conditions and building construction materials* are imperative in achieving accurate results.

This research affirms that adopting integrative technologies to MEP design projects is essential to enable stakeholders to instantly collaborate on an integrated design platform. Design practitioners that depend on 2-d drawings will be at a professional disadvantage by their inability to fully visualise the building and relevant angle views due to the limitations of drawings. Participants explain that the transition from 2-d to 3-d is a *painful* one. Its adoption demands greater time to coordinate the 3-d model at design stage which incurs higher costs to the design team.

Participants also reveal that although working in a collaborative environment, sharing the BIM model among other disciplines is not a straightforward activity. The BSE team requires other discipline designs to be complete, that is, architecture and structural engineering, prior to their design input. Participants readily admit another major challenge relating to BIM modelling representation; detailed design of 3-d models must be well advanced prior to presenting resultant 2-d drawings. This is a significant drawback for BSE practitioners who aim to produce work-in-progress drawings during the design process. Moreover, MagiCAD is offering BSE practitioners with an illustrative mechanical and electrical engineering design software. The participants believe that its concept is *brilliant* for elements of design, and advocate that its adoption demands intensive training in order to reap the rewards.

4. Conclusion

The BSE design process is fundamentally a function of the quality of the installed systems at construction stage of which BSE practitioners are in a position to influence.

The theoretical path in this research ultimately focused on understanding the empirical system in practice by applying data collection from interviews to test the various components of the BSE design process. Theory generated from this case study makes sense of the complex dichotomy between the design and construction stages that underpins BSE practice in the context of people, processes and technology, thus elucidating efforts to improve the current design process through digital engineering. This triangulated focus ensures that the BSE team consists of people with relevant education, skills and experience who are committed to conducting staged processes throughout the project life, and more importantly, supported by suitable digital technologies to sustain a modern engineering practice.

Notwithstanding the failure of the Irish government to lead and move with the digital evolution, the recent strategic initiative by the National BIM Council (NBC) of Ireland has the potential to overcome the key barriers to digitalisation in the AEC sector. The full implementation of this strategy would provide a more productive way of working in the BSE industry by enhancing leadership, standardising the adoption of a digital platform (BIM), and providing education and training to current and prospective practitioners.

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