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The Development of a Lean Digital Construction (BIM) innovation framework for Irish Construction SMEs

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The adoption of Building Information Modelling (BIM) within small and medium-sized enterprises (SMEs) must overcome several challenges to succeed. Potential barriers include the need for financial resources, correct BIM guidance, and training. In recent years, SME organisations have investigated how the complementary application of BIM and Lean principles can maximise digital construction practices. For this approach to be successful, structured guidance is paramount. This paper presents the results from an extensive literature review that explores BIM and Lean capabilities, focusing on synergies and existing frameworks. Based on the results from the literature review, the paper suggests an experimental framework that will address the key obstacles and provide a structured approach to BIM and Lean implementation for SMEs. The authors envision that the output of the proposed framework will assist Irish SMEs in minimising waste and improving productivity within their practices.

Keywords – Lean Construction, BIM, SMEs, Innovation

I INTRODUCTION

Lean construction and BIM are two different philosophies that have significantly impacted the AEC industry. BIM contributes directly to Lean goals of waste reduction, improved flow and reduction in overall time [1]. Additionally, the parallel implementation of these two innovative philosophies can further increase an SME's ability to compete in an overcrowded market. This paper will present a research gap with respect to identifying the key pillars required for successfully adopting both Lean and BIM processes within an SME and the potential barriers that an SME might encounter.

Current studies mostly focus on presenting findings about the benefits of successful implementation strategies of BIM or Lean, but only a few specifically concern SMEs. At the same time, SMEs currently applying BIM or Lean processes might need to be aware of the synergies between them. This paper aims to demonstrate how SMEs can adapt BIM and Lean processes to gain advantages from both. The research focuses on solving problems through innovative BIM and Lean practices, mobilising underlying theories and the enabling processes and technologies needed to deliver value to SMEs.

The paper will also investigate the current knowledge of BIM and/or Lean frameworks related to SME management and examine current methodologies regarding existing frameworks. Finally, it will present the key synergies to enable the development of a future Lean Digital (BIM) Innovation Framework. This framework aims to provide an essential supporting structure to introduce digital construction (BIM) and Lean processes into SME organisations in Ireland.

Exploratory research has been selected as the primary methodology because it is best applied within new or relatively under-researched topics or concerning approaching a topic from a different perspective to generate new outcomes [2]. The difference between exploratory research and other types is that the ultimate goal is to present something new and avoid repetition [3]. Another advantage of exploratory research is that it can vary how an experimental study is conducted, but it is suggested that each research fact be conceptualised and continuously verified [3]. This paper will refer to prior studies to establish the key synergies enabling the key pillars to provide a structure for SMEs to harness BIM and Lean practices.

II LEAN CONSTRUCTION

"Lean construction is a way to design production systems to minimise waste of materials, time, and effort to generate the maximum possible amount of value" [4]. In other words, Lean construction's primary goals are believed to be effective systems that decrease time, effort, and waste in projects and can be defined by objectives, principles, methods and tools [5]. Some of the main issues that led to the development of Lean construction principles were poor quality of construction projects and high costs. In addition, Lean principles in construction, unlike the manufacturing industry, vary, making standard processes and workflows difficult to achieve [6]. Another feature of Lean is increasing process speed by focusing on what customers want and sequentially considering the importance of quality [7].

Enterprises embrace Lean philosophies by developing long-term sustainable excellence strategies through Lean tools and principles [8]. However, effective implementation will depend on the readiness and the training required before fully implementing each Lean tool [9]. By effectively implementing Lean standards, the AEC industry can direct an enterprise to find and create strategies with the best tools and methods to achieve Lean construction objectives [10]. Lean construction is becoming prevalent in prefabrication by promoting standardised components, such as off-site techniques [6].

Examples of Lean tools widely used in the construction sector include daily huddle meetings and pre-task planning exercises for discussing each day's tasks. If executed correctly, they can help reduce accidents, eliminate waste, and improve efficiency [5]. Other tools include A3, a control mechanism that can be used to track and report on the progress of any project from start to finish. The A3 process, with an 8-step approach, ultimately focuses on defining the problem in-depth and developing a solution that addresses the potential cause of each situation. The Six Sigma methodology highlights variability and, at the same time, aims to establish high-quality projects. In working toward the same goal, the pull approach pays attention to materials management [8].

Lean principles permit opportunities for improvement to be identified and applied to future projects. As a result, projects come on time and within budget and create empowered teams [10]. While significant strides have been made regarding Lean construction, the manufacturing industry's efficiency still needs to be fully integrated into the construction industry. For example, automation, the utilisation of information systems, superior supply chain administration, and progressed collaboration tools [11].

Also, changes need to be clearly defined in enterprises. As a result of uncertainty, employees may be hesitant to walk into the unknown. Addressing this employee fear is a component of any successful Lean enterprise [7].

III LEAN FRAMEWORKS

A structured supporting system must be implemented for a successful Lean construction strategy. Therefore, the authors undertook an extensive literature review of existing Lean frameworks. An initial study found that focusing only on frameworks designed for SMEs resulted in a narrow search, so it was expanded to concentrate on all sizes of enterprises.

The literature review aimed to investigate the interrelationships between different frameworks and common points. According to the findings, some methods used to collect data that eventually led to creating a Lean framework were conducting a literature review or using state-of-the-art or case studies. Moreover, using surveys and questionnaires to collect data, review existing frameworks, use data analysis and even interviews. Correspondingly, examples of strategies used for validation include force field analysis, interviews or validating a framework through case studies.

Different Lean frameworks' goals included improving the performance and decision-making capability of the construction processes. Also, analysing various types of waste and investigating waste reduction strategies. Other purposes include minimising variations and rework, promoting innovation through new technologies and increasing productivity.

Furthermore, some frameworks identified and presented drivers and barriers to Lean implementation. Other frameworks had a green approach to Lean to improve construction processes' environmental impact or achieve more sustainable solutions in the construction sector. Continuously, various frameworks offer ways to reinforce Lean principles and improve performance levels.

The research findings through the different frameworks explored encourage enterprises to implement Lean construction principles by selecting the correct tools and methods based on their targets. Sequentially, targets and functionalities of the various tools can be effectively caught on and then employed. The findings highlight the prospects of using Lean methods and tools to minimise waste and increase the productivity of construction enterprises.

It is important to highlight that coaching and training for smaller enterprises can be quicker than for larger ones. A key problem with much of the literature on Lean is that there needs to be more literature regarding Lean implementation frameworks concerning SMEs. This observation raises many

questions about the gap in academic knowledge regarding Lean for SMEs [12] - [21].

IV BIM

2D drawing-based information can result in additional wasted time. It can be limited when considering cost estimations or different types of analysis [1]. This fact has seen a rise in the adoption of 3D modelling software by many architecture schools and large and small enterprises since the nineties. This has allowed new and complex geometries to be modelled that were previously difficult to communicate [22]. Furthermore, the overreliance on traditional practices leads to problems concerning a project's life cycle, as the owner receives information in a 2D format that may need to be updated later on [23]. This has resulted in BIM becoming a key practice within the global AEC sector.

A BIM model can contain important information about the whole asset life cycle, from construction to demolition [24]. BIM is also a database of information regarding building components, material properties, construction techniques, and even the costs of building materials [25]. BIM is more than just modelling and has evolved to include preferred methodologies, protocols, and standards. BIM's benefits include accurate material take-offs, identifying clashes, and optimising construction sequencing [25].

In addition, uncertainty and the potential for risky cost estimates that might lead to conflicts between team members can be reduced [26]. The BIM model can also plan maintenance and track usage throughout the building's life cycle [26].

V BIM IN IRELAND

The third national survey about the level of BIM adoption in Ireland (2017) revealed that 85% of the enterprises that took part in the survey believe that Ireland should follow the United Kingdom's example and mandate BIM [27]. As of today, 2023, BIM is no longer relatively new to employers, consultants, contractors, subcontractors and even some clients.

Nevertheless, the Irish government has actively promoted the use of BIM for major complex projects. Continuously, as of 2019, the Irish government has stated it will require a BIM Level 2 implementation on complex projects, with medium and simple projects potentially being phased in over the upcoming years [28]. From January 2024, the construction of public works contracts with a value exceeding €100m will include BIM requirements. Also, over the next four years, these requirements will be extended to include the construction of projects with a value of less than €1m.

The BIM adoption strategy includes digital delivery requirements as part of the overall Government's strategy to digitalise the construction sector by 2030. The strategy will be launched with the International Cost Management Standard, enabling decisions based on the total cost of ownership, including the environmental impact of decisions concerning material selection, foundation design, energy use, and production [29].

In response to the Irish construction industry's needs, the following research focuses on BIM implementation in Irish Construction SMEs regarding advancing BIM and Lean capabilities. While the outcome of this research is an innovative framework primarily designed for SMEs based in Ireland, it can also be suitable for SMEs in other countries with similar targets of using BIM and Lean practices.

VI BIM FRAMEWORKS

Similar to the literature review for Lean frameworks, the same template was used to investigate synergies between BIM frameworks for general use or SMEs. The literature review highlights a variety of BIM frameworks. Sequentially, utilising a set of BIM principles is an effective tool for upgrading the outcomes of an enterprise, especially for SMEs. Furthermore, the research shows the idea of utilising BIM strategies and tools, including diminishing costs and anticipating the loss of time and effort.

Literature reviews, pilot studies, case studies, surveys or questionnaires, or the use of a roadmap are the main methods used to collect data. Other methods noted include data analysis, critical discussions, or using a design thinking process. Examples of strategies used for validation are through surveys, case studies, or validating with the use of a prototype.

Some of the goals of the different BIM frameworks include managing risks and rewards by using BIM methodologies to increase profit. Also, finding the main barriers preventing the effective use of BIM. Another common finding is implementing BIM to achieve optimum, cost-efficient solutions. Furthermore, to improve communication and cooperation and obtain sustainability goals.

Other findings include the application of BIM to precisely estimate building systems costs and alternative schemes during the life-cycle of a project and to reduce and eliminate construction errors. Similar to the Lean framework findings, educating the employees and improving documentation quality is important. The professionals in the industry are critical to its success.

The behaviours and the experiences gained and shared are essential to the growth of a BIM-enabled process. Progressively, some of the main goals of the BIM frameworks are similar to the Lean ones,

especially in trying to achieve less cost, reduce variations, and promote innovation [30] - [39].

VII BIM AND LEAN

There are 56 synergies between BIM and Lean construction [1]. One of the main connections between Lean construction and BIM is that they share the same principles and focus. A few of those synergies are a better appreciation of the early stages of designing that can also assist in the initial functional evaluation of the design. As a result, the quality of the final design is more consistent [40].

To assist in categorising BIM and Lean capabilities, the researchers narrowed the scope to a European level due to Ireland's association with the EU. This has resulted in the selection of findings from the EU BIM Task Group Handbook, which was formed to deliver a pan-European approach to best practices in BIM. The group combines national efforts into a common and aligned European approach to develop a world-class digital construction sector. To this effect, the organisation in 2017 published their EUBIM task group handbook to encourage the wider introduction of BIM to the European public sector as a strategic enabler [41].

This report established four categories to categorise the different BIM capabilities, as detailed in Figure 1.

Figure 1: EUBIM task group. The four pillars.

Moreover, an enterprise must consider many parameters and overcome many barriers before eventually implementing BIM and Lean. In addition, the four categories of technology, processes, policies, and people and skills were used to categorise BIM and Lean synergies [41].

a) Technical

Technology and, at the same time, software usage are key enablers in supporting BIM and Lean principles. The elimination of waste associated with Lean techniques, such as value stream mapping, can be achieved by linking BIM with project schedules, which can help support collaborative decision-making. The BIM model can also assist with identifying potential problems and, therefore, eliminate waste from the supply chain. BIM, in partnership with advanced technologies such as augmented and virtual reality, can empower Lean Construction Management by reducing construction time and minimising the waste of materials [42] [43] [44]. Also, BIM facilitates Lean measures through design to construction and, at the same time, contributes directly to Lean goals of waste reduction [45].

Furthermore, BIM provides better scheduling solutions as tools such as Navisworks make updating schedules much easier. As the tools lead to more collaborative solutions and the industry chooses Lean scheduling methods, traditional scheduling methods will be used less [23].

b) People and Skills

Lean and BIM can provide an effective solution for solving another major problem in the construction industry. The problem is the expectation gaps between all the team members. Nevertheless, Lean promotes collaborative design, which means all team members can participate in the design process, leading to more positive outcomes. Also, all team members should agree beforehand to ensure that only the best practices and best decisions concerning design and construction choices will be used in each project. Furthermore, it pushes the team to achieve the highest productivity possible. Moreover, project optimisation continuously suggests that team members collaborate productively to implement the best solutions possible in each project [5]. Therefore, collaboration is extremely important in the construction industry and can be improved by using BIM and Lean.

Another Lean approach suggests observing meetings, training, and employee interviews, which can lead to helpful conclusions. Also, it is beneficial to determine whether employees know how to eliminate waste and whether they have been provided with the necessary direction and resources [8]. Similarly, training should be combined with a common definition of the target behaviours expected by BIM to create capacity for its effective use. With a consistent definition of the required skills, training providers will likely be able to develop the sufficient capacity of capable, skilled professionals [41].

c) Processes

Innovations such as cloud-based model collaboration can affect a team's ability to complete estimations effectively. BIM permits team members to collaborate in actual time inside the cloud. It is web-based and includes input from several members. Another major advantage of a cloud-based system is that many independent companies can access a project and collaborate by providing the team with information about materials. Furthermore, it allows handling information from any web-connected gadget [23].

BIM and Lean construction provide a more enhanced level of detailed coordination on-site [46]. Lean and BIM adoption synergies can support the

information, materials, equipment, spaces, and teams in construction processes using Lean concepts [1]. As a result, BIM and Lean contribute to a better-improved workflow between all the parties [9].

A new BIM-based Lean management system is characterised by a theoretical combination model for BIM and existing management techniques and a methodology for applying these concepts into practice [47]. The utilisation of BIM permits the advancement of Lean construction methods and standards to enable a construction team to drive to the potential of using prefabrication [48].

The synergy between Lean and BIM can benefit different project phases, especially the design phase, where decision-making significantly impacts the next stages of a project. Also, a Lean method that can be implemented with BIM in the design phase is the Last Planner System (LPS) [49].

BIM with lean design principles were used for the Istanbul Grand Airport (IGA) project. Cloud-based data management tools were used to manage the BIM workflow. Furthermore, a BIM model was used through the design and construction stages of IGA. The automated data processing via an integrated environment across the project stages reflected a lean design and construction practice [50].

d) Policies

Integrated Project Delivery (IPD) techniques utilise BIM to offer a platform for integrated project management and collaboration [40]. IPD is also connected with Lean construction methods and can improve the collaboration and communication between all parties from the first stages of a project [51].

Additionally, a BIM Execution Plan (BEP) helps document the levels of detail required from each professional at each project stage and how the models need to be exchanged [1]. The BEP consists of the pre-contract, the post-contract and the Master Information Delivery Plan [52].

VIII BIM AND LEAN FRAMEWORKS

The findings from the BIM–Lean frameworks presented the benefits of applying BIM and Lean to improve project performance. BIM that supports Lean objectives and management of the Lean processes facilitated the adoption and use of BIM. Also, there are ways that BIM and Lean can help with the achievement of greater cost certainty.

From the frameworks' research, the methods used are literature review, collection of primary data, and use of a pilot study or a case study. An example of a strategy used for validation is pilot studies. The research shows that Lean construction and BIM strategies and tools can diminish costs [53] - [55].

The findings from a conceptual framework for project delivery that combines sustainability, Lean construction, and BIM regarding principles, practices, tools, and techniques highlight the importance of applying the framework in projects in different contexts. Also, it mentions that the benefits of the parallel implementation of sustainable solutions, Lean and BIM, outweigh the individual application with fewer benefits [55].

IX SME BARRIERS

The main difference between SMEs and larger enterprises is that SMEs might have a simple hierarchy and an integrated set of enterprise functions. On the other hand, large enterprises have a matrix organisation and units. The ownership and management of the enterprise are on the owner in SMEs compared to larger organisations where leadership is shared [56]. One of the main advantages of SMEs is agility. They can combine technological and nontechnological innovations, such as organisational, commercial and business models [57]. A study concerning SMEs in Germany showed that several participating SMEs experience concerns regarding how management is led inside the enterprise. The results indicate a potential connection between management issues and how they can be solved with strategic risk management. The study also revealed an association between employee leadership and successful risk management [58].

Ineffective investments in innovation are an important barrier that SMEs face, especially in technology. This fact brings to light gaps in managing innovative decisions, the difficulty recruiting and adjusting human resources, and the low development of transnational cooperation in innovation and inappropriate public support services [59].

SMEs usually depend on few clients compared to larger enterprises with a larger client domain. On the other hand, innovation is a key source for SMEs. The advantage of large enterprises is access to more resources and good external networking. At the same time, SMEs can have an innovation advantage where scale effects are not that important [56]. Most of the time, SME owners focus on the cost of new investments rather than the benefits [60]. SMEs do not believe their bigger clients will support them during the Lean construction implementation process. There needs to be more collective inventory, meaning SMEs must fully understand the benefits of Lean principles [61].

SMEs need to catch up in implementing BIM compared to larger enterprises. As a result, winning funded projects in the public and private sectors is more difficult without BIM adoption. SMEs will continuously lose contracts in domestic and international markets if they need to catch up in

adoption. They need to pay attention to investing in new technology and reforming their enterprises to meet the industry's requirements [32]. The industry needs to accept BIM as a philosophy of working and collaborating. For this to be accomplished, there needs to be more proof of return on investment for SMEs [34].

Information barriers can also occur through a lack of information between investors and SMEs. For example, most SMEs do not provide audited financial statements with credible financial information. On the other hand, investors will need verifiable information about an enterprise before supporting it financially. Furthermore, there is a lack of financial education on the SME funding market. Securing finance is rarely a core characteristic of SMEs, which often lack the resources to employ a dedicated team to manage their finances [62].

Table 1 highlights the main barriers that need to be taken into consideration during the BIM-Lean transition journey of an SME. There are different categories of barriers concerning "legal," "attitude and market," "education, knowledge and learning," and "technical and software financing" issues [63].

In the technical part, barriers include the need for more funds to cover the high software cost and hardware investment. Substantially, problems such as operational tools and techniques for Lean principles need to be better recognised and understood. In the educational part, barriers include the resistance to cultural change and the lack of BIM, Lean construction and I.T. knowledge. Also important is the need for better collaboration, coordination, and understanding between team members. Management barriers include poor supervision and the need for more top management commitment [64]. Moreover, to adopt IPD and BIM in the design phase, there is a need for a systematic framework pushed by the AEC industry and government to improve deficiencies in training, software interoperability, and general BIM and Lean knowledge. Lastly, the AEC sector has to improve its stakeholders' competence and quality levels [49]. There are E.U. funding opportunities for increasing SMEs' financial capacity and supporting them in overcoming the barriers they face [59].

A European Commission study about BIM in the E.U. construction sector highlights how governments play a key role in BIM standardisation by influencing BIM standards. As a result, through the government's chosen policies and initiatives, they can influence the BIM implementation process. Government policies and initiatives can include public procurement, education, and standardisation. Moreover, governments adopted public procurement amendments or regulations requiring BIM for public infrastructure projects. According to the findings, effective implementation of BIM requires governments and the industry to work together. At the same time, governments faced more difficulties engaging SMEs and enterprises in the operation and maintenance stages of the construction value chain [65].

Technical	**People & Skills**	**Processes**	**Policies**
-BIM is an expensive investment [32] [34]. - Due to the lack of cooperative supply chain integration, SMEs cannot always realise the benefits of implementing lean [61]. -The implementation of BIM comes with several risks. SMEs have a harder time weighing the risks of investing in BIM and estimating when the investment will pay off [32]. -High software cost and lack of funding for investment in hardware for both [64]. -Lack of BIM and Lean Knowledge [64]. -BIM software to a standard method [64].	- Difficulty changing the existing culture [64]. - Clients are not interested in using BIM on their projects and do not know the benefits BIM can offer [31]. -Lack of top management commitment [64] [66]. -Lack of leadership characteristics [64]. -Lack of support from the government [64]. -Difficult to understand the various team's different levels of knowledge and experience [64]. - SMEs might lack an internal Lean training system and will likely require an external training mechanism run by Lean consultants [66].	-Not strategically changing the organisational processes and the lack of long-term organisational strategy for SMEs [31] [64]. -Not facilitating employees in all hierarchy levels to support the BIM-Lean implementation [64]. - Collaborative planning is an example of a Lean Construction technique that is not standardised enough and might differ for each enterprise [66]. -Lean operational tools and lean principles techniques are poorly understood [64]. -Issues in current BIM and Lean practices and processes [64].	- Difficulties with contracts and standards. For example, model ownership concerns or finding optimum procurement arrangements [61]. - The Lean implementation at SMEs requires more than knowing the Lean processes, tools and training needed. Collaborative contractual arrangements that share profits and risks are required. IPD agreements can address SMEs' requirements [66]. - Lack of contractual standards around BIM models [64]. -The lack of a stable policy for Lean and the lack of standardisation [64].

Table 1 – SME Barriers.

X Draft Framework

The first step of this research was analysing Lean construction and BIM individually to establish common synergies and capabilities. According to all the findings and using the EUBIM task group framework for guidance, the key pillars considered for implementing BIM and Lean for an SME are presented in Figure 2. Figure 2 represents the key criteria that must be addressed for BIM and Lean capabilities to be realised, resulting from synthesising the literature findings detailed above.

The second stage involved exploring BIM and Lean frameworks. The framework's literature review findings will be incorporated later in the research, resulting in version two of the framework. Hopefully, this will provide additional commonalities and structure to assist SME adoption.

Before an SME considers adopting the framework, they must address the key barriers detailed in Table 1 for each pillar. This will affect the level of implementation but will also assist in helping to set tangible goals. This will also ensure that the developed pillars are being customised for SMEs.

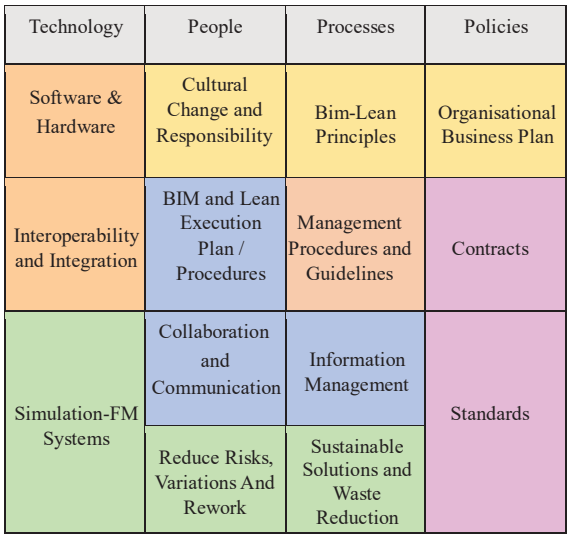

Figure 2: Key pillars for using BIM-Lean in an SME.

The colours present an order of using or implementing each pillar, with each stage needing completion before moving further. Figure 3 shows the five stages of implementation. Stages 1 and 2 focus on creating the organisation's required BIM and Lean ethos, while Stages 3-5 are more project-focused.

Figure 3: The five stages of BIM and Lean implementation in an SME.

a) *Stage 1 – New way of working.*

- **Cultural Change and Responsibility** - Each member of an enterprise should accept and commit to new workflows, processes and practices. A change management strategy/framework should be consulted based on the intended level of implementation. Staff should be able to acknowledge their unique role in the enterprise and their new responsibilities. It will be important that there are recognised BIM / Lean champions that will assist in driving the organisation forward. High-level information events/training should be organised by the organisation to make staff aware of fundamental BIM and Lean principles.
- **BIM-Lean Principles** - BIM and Lean introduced in an enterprise effectively change a workflow and introduce new principles to benefit the enterprise. At this stage, the organisation should outline what BIM and Lean principles they seek to realise and how they complement each other. This should help establish the key synergies to be realised.
- **Organisational Business Plan** - The organisational business plan should be reviewed, and the BIM and Lean principles outlined previously must be aligned with the organisation's short-, medium- and long-term goals.

b) *Stage 2 – Preparing for implementation*

- **Software & Hardware** – With an appreciation from stage 1 of what Lean and BIM synergies are to be targeted, an organisation must establish the necessary software and hardware to achieve its Organisational Business Plan.
- **Interoperability and Integration** - To effectively work with BIM and Lean, all enterprise members should know the correct way to exchange files and data to achieve the set practices. This will help to refine the software and hardware requirements.
- **Management Procedures, Training and Guidelines** - The correct management procedures, specific training requirements and guidelines for applying BIM technology and Lean quality control must be established. This will focus on how best to integrate Stage 2 technologies in alignment with Stage 1 Organisational Business Plan. It is suggested that these documents/requirements should be organisation-focused to begin and become adapted for each individual project, i.e., the selected standards and contract detailed in stage 3 will further shape these documents.

c) *Stage 3 - Learn the processes and practices*

- **Contracts** - The implementation of BIM demands changes to be made in traditional contracts. A BIM contract will affect the obligations and duties that all parties have. The correct contract must be chosen to maximise

BIM and Lean capabilities. The contract should refine the management procedures, specific training requirements and guidelines.

- **Standards** - BIM standards should be considered and, at the same time, follow the government's policies concerning BIM usage.

d) Stage 4 – Start working together productively.

- **BIM and Lean Execution Plan / Procedures –** The enterprise must establish a BIM and Lean execution plan that should be project-specific. This should define and answer how the project deliverables will be achieved through a foundational framework to ensure the successful deployment of BIM technologies and Lean principles. Stage 2 and 3 outcomes should form the foundations of this plan.
- **Collaboration and Communication** - The digital transformation that BIM will bring in combination with Lean practices demands new collaboration methods. Ongoing training and monitoring must be enforced to ensure that management procedures, training and guidelines are followed and updated accordingly.
- **Information Management** - The validation of BIM deliverables/information exchange in the context of achieving Lean principles should reviewed on an ongoing basis to maximise Lean exposure and capture lessons learnt.

e) Stage 5 – New sustainable solutions

- **Simulation-FM Systems -** Simulations can help with making early design decisions. Another example is energy simulations and using the BIM model for the F.M. system. There is a synergistic potential of Lean concepts with the BIM-FM system.
- **Reduce Risks, Variations and Rework** - The BIM and Lean implementation should eventually lead to advanced practices for an enterprise to learn from each project, improve their workflow, and transfer the knowledge to gain more profits by minimising mistakes and reducing rework.
- **Sustainable Solutions and Waste Reduction -** BIM and Lean are connected with promoting best practices and sustainability. Any enterprise should aim to reach a stage where sustainable solutions should be implemented and used in each project and promote the long-term advantages of sustainable solutions.

XI CONCLUSIONS

The AEC industry should promote equal rights for each enterprise, regardless of size, and encourage innovation-enhancing BIM and Lean practices for SMEs. This paper put forward an initial framework for SMEs that will enable opportunities through the combined use of BIM and Lean for SMEs. The findings highlight that categorising Lean tools and methods that can be deployed with BIM can lead to a more rewarding implementation methodology. The next research phase will focus on producing a 2nd draft by incorporating the findings from the literature review of existing frameworks. This will enable a more robust framework that will be tested through field research. The final framework is hoped to provide a scaffolded implementation structure for SMEs within Ireland to harness BIM and Lean capabilities to better position themselves for the 2024 mandate.

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