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Public Sector BIM Adoption: Development and Evaluation of Government Policy Interventions: A Systematic Literature Review

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Abstract. Rapid technological advancements in the Architecture, Engineering and Construction (AEC) sector have provided a significant opportunity for improving the industry's efficiency, performance and sustainability. Building Information Modelling (BIM) is an innovative approach to information management in construction that provides a structured methodology for storing and analysing building information exchanged between project stakeholders. However, successful interventions and supports introduced by the public sector in accelerating BIM adoption can be seen through BIM mandates, promotion of information management ISO standards, guidance, funding and procurement integration. In this study, a systematic literature review is adopted to identify BIM policy interventions. The study aims to analyse national BIM interventions with varying degrees of success, compare their general impacts, and identify how the Irish Government could deploy these interventions to address current challenges and establish a formal BIM implementation plan. The outcomes of this study will potentially act as a guideline to industry players for the future development of BIM-based projects.

1. Introduction

BIM has emerged as a transformation solution to unlock increased productivity in the construction industry (WEF, 2018; Mcgraw Hill, 2021). The definition of BIM has evolved over time to capture the various applications of the technology, with the International Organization for Standardization (ISO) defining it as the "Use of a shared digital representation of a built asset to facilitate design, construction and operation processes to form a reliable basis for decisions" (ISO 19650-1, 2018).

The AEC sector is facing several significant challenges, including productivity, energy efficiency, increasing project costs, and labour shortages (WEF, 2018). The COVID-19 pandemic has further highlighted the importance of virtual communication between construction stakeholders (Global Alliance of Buildings and Construction, 2021). In response to these challenges, many jurisdictions are seeking to implement digital transformation programmes that can benefit the AEC sector (Qin et al., 2020; Global Alliance of Buildings and Construction, 2021).

The public sector has recognised the importance of BIM (Kassem & Succar, 2017; Qin et al., 2020; Wang et al., 2021), with more than 50% of countries having a regulatory requirement for BIM or planning to implement one shortly (Hore et al., 2017).

While many public sector agencies and governments worldwide are recommending or mandating BIM to address prevalent industry challenges, numerous issues have arisen during the actual implementation process. These issues include an outdated industry culture, making it challenging to learn new knowledge (Edirisinghe & London, 2017), a shortage of talent with the necessary expertise in BIM application (Lee & Borrmann , 2020), high economic investment in BIM has made policy implementation challenging, and a lack of industry guidelines for adopting new technologies (Alwan, 2017).

Therefore, this study seeks to achieve a greater understanding and use cases of BIM international policy interventions. Given the above perspective, this study's objective is to identify the key enablers and mechanisms to support government policy objectives through the increased use of BIM on public sector projects.

2. Methodology

This study aims to collect policy enablers for BIM implementation from the literature. To achieve this goal, the Systematic Literature Review (SLR) method was utilised, which is a technique used to identify and appraise relevant studies following clearly defined criteria/guidelines to answer research questions (Budgen, 2006). The review process consisted of three phases: planning process, conducting the review and reporting the result.

In the planning phase, this study defines research questions and develops a plan to execute the review. To achieve the aim of this study, a research question was formulated: "What are the enablers, frameworks or models adopted by the public sector to drive BIM/ innovation adoption and diffusion in construction?"

In the review conducting stage, four databases (including Scopus, Science Direct, Google Scholar, and Web of Science) were selected as the search basis to provide a more comprehensive literature review. The literature search keywords (such as BIM policy enabler/framework) were extracted from the research aim, and a quality assessment was designed to select the most relevant literature for the study. Inclusion and exclusion criteria were set, and the relevance between the study and the research question was compared. Non-English literature and articles that do not primarily discuss BIM policies were excluded. The selected papers were then reviewed using a quality assessment that included four checks: relevance to the research question, methodological rigour, research contribution and logical analysis.

In the reporting phase, the shortlisted publications were selected based on qualitative assessment. The selected publications were thoroughly reviewed, and every time an enabler was identified, it was recorded in an Excel document. The enablers were categorised into three groups: policy development stages, policy emphasis and policy output. The researcher mapped each enabler into the category that was most relevant. By the end of this phase, the authors could determine a comprehensive list of enablers impacting BIM policy adoption and match each enabler to previously established categories.

2.1 Inclusion and exclusion criteria

The following set of more detailed and robust inclusion and exclusion criteria was established to review the abstract of the papers:

- Topic of the paper: BIM Policy as a broad topic - the papers have to focus on the BIM policy framework and mention the recurring policy themes.
- Language: English language sources only.
- Year of publication: Articles between 2003 and 2022 were considered for this study.
- Academic papers and conference papers with high methodological standards.
- The studies not related to BIM adoption in the construction sector, such as modular computer software development, were excluded.

2.2 Quality assessment

The following checklist was used to assess the quality of the articles:

- Were the inclusion and exclusion criteria appropriate?
- Did the literature review search likely have covered all relevant studies?
- Did the paper have credible and important findings addressing its aim and purpose?
- Were there clear links between data, interpretation and conclusions – i.e. Are the routes to any conclusions clear and direct?

3. Result

3.1 SLR Execution Result Reporting

Figure 1 presents the results of the systematic literature review (SLR) executed in this study. A total of 1435 articles were initially identified from the selected databases. After removing duplicates and integrating them in Endnote, 852 articles remained for further review. Following a preliminary review of paper titles and abstracts, 68 papers were selected for further analysis. Subsequently, these papers were subjected to a rigorous quality assessment based on the pre-defined inclusion and exclusion criteria. After this assessment, 33 articles were identified as the most relevant and suitable for inclusion in the review. Finally, based on further evaluation using a quality checklist, 19 articles that passed two or more assessment criteria were selected for enabler identification.

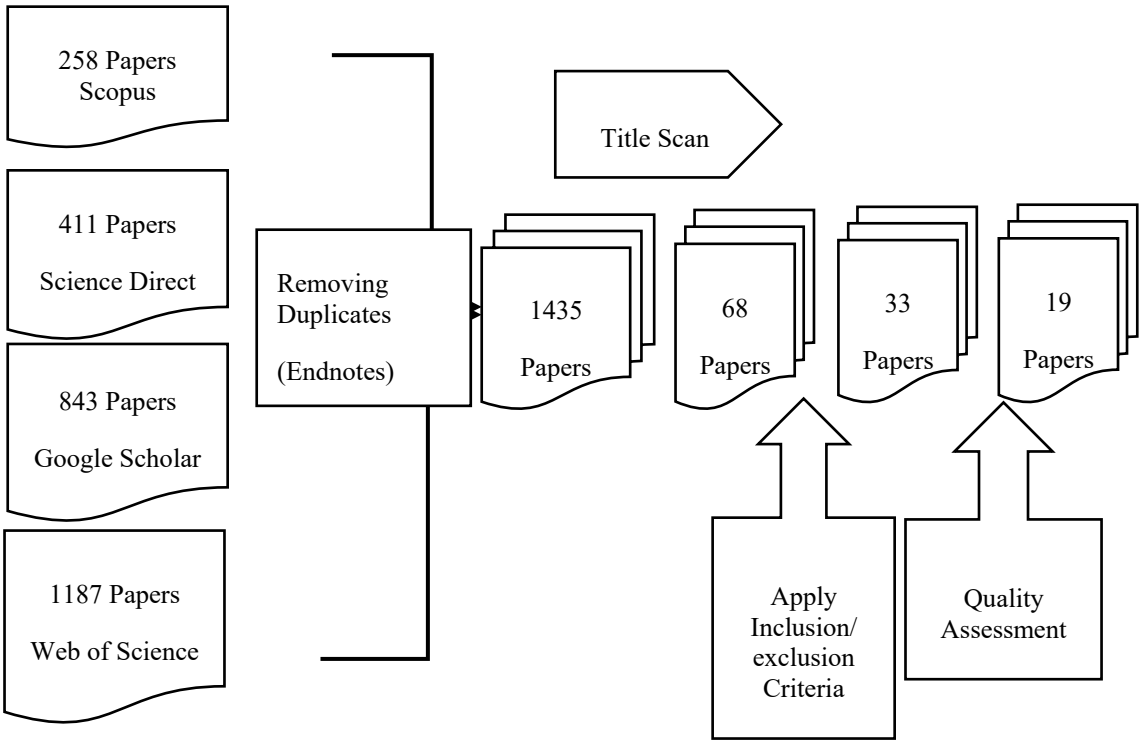

Figure 1: The SLR execution process

3.2 Reporting the SLR Data Extraction Results and Discussion

This section presents the analysis and discussion of the systematic review results. The list of the 19 selected papers is provided in the appendix, and each paper was assigned a unique code starting with the letter “S” for “Study” followed by the publication year (e.g., S1, S2, S3, etc.) Based on the review of the 19 publications, governments have played three roles in the AEC sector: Motivator, Collaborator and Enabler. Specifically, 26% of the studies emphasised the importance of policy as a motivator for industry, 15% of the studies highlighted the role of the public sector as a collaborator with the industry, and all studies acknowledged the policy enablement for the industry. For instance, a "Case study" was found to be both a motivator and an enabler. The benefits documented in the case study were considered a motivator, while the focus policy-making king was viewed as an enabler. As a result, the publications were classified according to Table 1.

As per the literature, the primary way in which the public sector influences the construction industry is through policy enablement. Additionally, of the 13 recurring themes identified, the three most commonly mentioned themes in the literature were the Development of the BIM evaluation system, BIM regulation, and Case studies relating to policy enablement. On the other hand, the three least common themes identified were "BIM Library, BIM Collaboration, and BIM Incentives”.

4. Findings

BIM policies are driven by multiple factors. Therefore, before establishing BIM policies, a systematic investigation should be conducted to determine industry objectives. This should be followed by case studies before attempting policy implementation （Ahmed et al., 2017; Wang et al., 2022). Policy establishments should consider the cost of the operation and management phase, practical possibilities and conveniences, national industry culture, and governance methods when designing the distribution of BIM standards or pre-assessment frameworks for better use of BIM (Nepal et al., 2014; Edirisinghe & London, 2017; Lu et al., 2018).

Recent research highlights the need to achieve the best cost-benefit ratio on a large scale while assisting each project in achieving its objectives (Lee & Borman, 2020). Successful integration of BIM in the same project can be achieved by ensuring all stakeholders follow the same guidelines, leading to a regulated system (Xu et al., 2018).

The successful implementation of BIM has been established through the experiences of various countries. To better leverage the advantages of BIM, future policies should ensure that the interests of both stakeholders and the public sector are safeguarded (Davies et al., 2015; Yang & Chou, 2018). Many governments have also provided various BIM incentives by establishing BIM projects and committees and organising BIM events and seminars (Cheng & Lu, 2015). One thing to note is that the industrial environments, such as government-driven or industry-driven applications, and the degree of policy participation vary （Yang & Chou, 2018), and the consideration of the local culture should be investigated first. For example, combining high industry motivation and policy ultimately leads to higher diffusion and BIM adoption rates (Hamma-adama & Kouider, 2019). However, countries with relatively well-developed policies have already overcome many obstacles encountered earlier, so these obstacles may be hidden during empirical investigations. Countries that have implemented BIM policies relatively late must be aware of these obstacles when designing their policies (Charef et al., 2019).

In policy refinement, it is important to consider both the distinct goals of public projects and the needs of stakeholders (Oti-Sarpong et al., 2020). Various methods, such as procurement

policies, tax refunds, and BIM project funding, have been successful in incentivising BIM adoption in the industry and increasing the willingness to use BIM (Boya et al., 2014; Oti-Sarpong et al., 2020). Establishing regulations, providing education and certifications, and utilising BIM standards and implementation cases can be used as successive steps to guide the AEC industry (Smith, 2014; Lu et al., 2018).

Table 1: Recurring Themes from Policy Framework

	Recurring Themes	Breakdown	Studies
Motivator	Case Study	Bring the successful experience of BIM to promote confidence.	S1,S3, S19
	BIM Incentives	BIM funds, tax refund, competition, award and support, including the cost of software, hardware and training.	S1, S6, S18
Collaborator	BIM Procurement	The use of the Public Previous Partnership (PPP) framework and People, Process, Technology and Policy (PPTP), Macro-Diffusion Responsibilities Model, and People, Process, and Technology (PPT) framework.	S3, S9, S17
	BIM Collaborations	Events, seminars and collaborations with other bodies and vendors.	S6, S18
Enabler	Case Study	Projects supporting the policy-making process.	S3, S7, S10, S13, S18
	BIM Adoption Evaluation System	Evaluation of project use of BIM, BIM Maturity, BIM engagement, Industry awareness, BIM capabilities, policy impact and industry culture for change.	S1, S2, S3, S7, S8, S10, S12, S14, S15
	Education and Certification	BIM conferences, skill certificates and training projects.	S3, S6, S11, S12
	BIM Roadmap and Action Plan	Crucial steps, processes or plans.	S6, S9, S14, S16
	BIM Mandates	Mandates in select scales.	S3, S4, S8, S11, S18, S19
	BIM Regulations	BIM standards, guidelines, procedures and BIM guided structure of projects.	S3, S4, S8, S9, S11, S12, S13, S15, S16, S19
	Special Interest Group	BIM committee, group and people to share the information.	S6, S11, S15, S17, S18
	BIM Library	BIM library standards and national BIM library.	S3, S6
	Research and Development	Research funds and sponsor.	S6, S9, S11, S12

5. Conclusions

The successful adoption of BIM requires a government framework. A government framework is necessary for successful BIM adoption (Kassem & Succar, 2017). Policy frameworks should

be developed according to development that follows their respective regional culture and government strategy to achieve industry targets (Edirisinghe & London, 2017). While BIM policies have significantly impacted public projects (Lee & Borman, 2020), they have failed to attract industry stakeholders due to various challenges, including a shortage of experts, technology layout, irregular information transfers, and unclear standards in the AEC sector (Alwan, 2017).

Many policy studies make recommendations establishing BIM policies based on the experiences and lessons learned from other countries (Handayaniputri & Latief, 2018; Xu et al., 2018; Oti-Sarpong et al., 2020). However, countries with relatively well-developed policies have already overcome many of the obstacles encountered earlier. Hence, these obstacles may be hidden during empirical investigations (Charef et al., 2019). The establishment of policies should follow the consideration of governance methods to design the distribution of BIM standards to pursue better use of BIM (Edirisinghe & London, 2017).

The public sector can employ several measures to promote the use of BIM in the industry. These include activities such as seminars, tax refunds, project funding and awards 'motivate' industrial use of BIM (Nepal et al., 2014; Boya et al., 2014; Hadzanan et al., 2015; Charef et al., 2019). Collaborative use of BIM within the industry on projects is also encouraged as it enhances teamwork and improves communication use of BIM 'collaboration' within the industry on projects (Smith, 2014; Edirisinghe & London, 2017; Lee, 2020). Additionally, the public 'enablement' industry the right way of using BIM, such as setting BIM standards, evaluation systems, and training programmes, can help guide the industry in the right way to use BIM (Chen & Lu, 2015; Alwan, 2017; Hamma-adama & Kouider, 2019; Oti-Sarpong et al., 2020).

The main contribution of this paper is the identification of recurring themes in BIM policy and their grouping into appropriate categories. The key contribution of this paper is identifying an exhaustive set of recurring themes in policy and their groupings into suitable clusters/categories. These findings can be used as a starting point to explore the needs of policy-making stages, including:

(1) A BIM adoption evaluation system should be established during the pre-policy-making stages to identify BIM maturity, engagement, industry awareness, technical capabilities, policy, and industry culture.

(2) After identifying policy targets, motivators, collaborators, and enablers should be mandated and provided to the industry through roadmaps, action plans, and BIM regulations.

(3) BIM interest groups, education, and research should be established, and more seminars, expertise, and studies should be provided to enhance industry understanding and confidence in the use of BIM.

(4) BIM libraries, standards, guidelines, templates and mandates should be established for the industry to follow appropriate steps in their projects.

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