A Comparative Review of Building Information Modeling Frameworks

Abdulaziz Banawi[1,*], Obaid Aljobaly[2], Cyril Ahiable[1]

[1]Department of Construction Management and Engineering, North Dakota State University, Fargo, ND, USA

[2] College of Environmental Design, King Abdulaziz University, Jeddah, Saudi Arabia

Emails: abanawi@ndsu.edu; oalgebali@stu.kau.edu.sa; cyril.ahiable@ndsu.edu

Abstract

The building sector influences the Gross Domestic Product (GDP) of many countries. There is a vast amount of waste generated in the building process, with many projects suffering from delivery delays, running over budget, and resulting in buildings of minimal quality. Building Information Modeling (BIM) has shown great potential towards solving these problems. BIM sets frameworks for Architects, Engineers, and Contractors (AEC), enhancing management of the building process. This paper analyzes select framework methods, tools, and processes, identifying key guidelines required to create a BIM framework customized to local requirements; this will have a positive effect on the construction industry by lowering the cost of buildings and improving the communication among parties, and leading to the development of frameworks based on local indicators. A comprehensive literature review was conducted to determine components and factors from structure frameworks with the main findings then classified and categorized into the following sectors -- government support, maturity level measurement, standards, protocol, database, and education plan. This permits the development of a comparison highlighting the frameworks' differences and summing up possible strategies for BIM implementation on several bases, such as region differentiation and the local industries' Political, Economic, Socio-Cultural, Technological (PEST) aspects, allowing for greater understanding of BIM implementation on various scales. The selection of the BIM frameworks was dependent on specific criteria with a minimum score of 4 out of 5 required to merit inclusion. Three strategies for the creation of a BIM framework were discovered and were seen to vary across regions. The discovery of these strategies lays the groundwork for future research into the development of these frameworks to determine the potential advantages and downsides of each.

Keywords: BIM; Frameworks; Implementation; Adoption

DOI: https://doi.org/10.54216/IJBES.020202

1. Introduction

The building industry is a major contributor to countries' gross domestic product (GDP). By the third quarter of 2014, total spending in the construction sector reached over 3.8% in the Middle Eastern and African regions, compared to a stronger growth in Asian-Pacific countries where it rose to 5.5% in 2010 (Economics, 2013). However, this sector also generates an abundance of waste every year (Dania, Kehinde, & Bala); the Gulf Cooperation Countries (GCC), for example, are estimated to generate 120 million tons of waste per year by 2020 (Hoornweg & Bhada-Tata, 2012).

Many initiatives are being developed to address the causes of waste and poor performance within the building sector. According to (Banawi & Bilec, 2014), *lean* (minimal waste, maximal productivity) and *green* (environmental sustainability) are used for waste identification and evaluation and can be integrated with *six sigma* (strategies to improve output quality) to provide an effective method for solving the problem of waste. Furthermore, according to (Allan Fred, 2016) Building Information Modeling (BIM) – a well-known methodology that combines technology and processes in the building industry – in conjunction with lean practices will reduce the amount of waste.

BIM aids with the validation of building processes and solving complex problems; it promotes simplicity and minimization of the occurrence of significant causes of waste, such as changes in orders and delays in data transformation (Banawi, 2017). The Aquarium Hilton Garden Inn Project is an optimal case study to demonstrate the potential cost savings using BIM. Originally the project was not designed using BIM, a Construction Manager at-risk was hired mid-project to coordinate the design and identify potential clashes; 55 clashes were found, which enabled a cost avoidance of $124,500; after considering the cost of BIM services ($90,000), total net savings to the project were $34,500 in the design development stage alone. Overall savings throughout the project were estimated at $200,000; similarly, the cost benefit in a second project, an academic building at Savannah State University in Georgia, United States (US) was approximately $1,995,000 (Azhar, 2011).

Due to the positive impact of BIM, countries such as France, Denmark, and the United Kingdom (UK) are requiring all major and public projects to be delivered using various levels of BIM (Azhar, 2011), however BIM implementation is inconsistent in other countries with similar building sectors, such as Saudi Arabia (KSA) and the United Arab Emirates (UAE). They are taking a divergent approach in implementing BIM, facing mitigating factors such as internal policy, reduction in the initial costs, and reduction in delivery time.

This paper provides in-depth discussion and analysis of prominent BIM frameworks, identifying critical common strategies. The research objective is to identify core frameworks, specifically:

- Allocate and select frameworks to be analyzed, according to the characteristics of the countries involved and the elements used to create BIM frameworks.
- Analyze the specified frameworks, including methods, tools, and processes.
- Identify mandatory guidelines to create a BIM framework customized to local requirements.

BIM implementation frameworks in specific geographical areas such as Asia, Europe, the US, and Australia will be discussed. A comparative study is done of different methodologies for BIM implementation, showcasing the conditions countries face when adopting BIM. The frameworks

DOI: https://doi.org/10.54216/IJBES.020202

to be studied are chosen using specified criteria; this paper then identifies potential frameworks for future research and illustrates them in a comparison table, before the conclusion of the study.

2. Background

2.1. Building Information Modeling (BIM)

Building industry practices in countries worldwide have changed from paper-based design to Computer Aided Design (CAD) (Eastman, Eastman, Teicholz, & Sacks, 2011). In the mid-1980s BIM was used but under different names -- "*Building Product Models*" in the US and "*Product Information Models*" in Finland (Eastman et al., 2011). By the late 1990s BIM witnessed a boom that started when software began to advance and options other than CAD were made possible (Eastman et al., 2011). At the beginning of this new era (by 2002), the concept of BIM -with its ability to create a virtual reality model capable of storing a vast amount of information - started to spread globally (Schlueter & Thesseling, 2009). By late 2009 statistics showed that 48% of American architectural firms had transformed to using BIM technologies in their designs, with regard to BIM ability in modeling and analyzing energy in the early design stages (Yuan & Yuan, 2011). By 2016 many countries were mandating BIM in their construction markets with a variety of options including: open standards, future plan of work, and a clear plan for implementation (McAuley, 2017). Once users began exploring the possibilities introduced by this technology, the idea of BIM went in many directions and definitions appeared to introduce the technology to a wider audience.

The Construction Project Information Committee (CPIC), which provides guidance to institutes and governmental firms, defines BIM as a "*digital representation of physical and functional characteristics of a facility, creating a shared knowledge resource for information about it, and forming a reliable basis for decisions during its life cycle, from earliest conception to demolition*"(Sinclair, 2012b). Other definitions have recently appeared to define building information technology; most of them consider BIM to be a smart technology that helps with visualization and encourages collaboration between all members in the industry to coordinate designs. Despite that, many architecture, engineering and construction (AEC) communities have a faulty understanding of the concept of BIM as a software program or tool (Yuan & Yuan, 2011). Within GCC countries, the UAE has not mandated BIM in all of the emirates but started requiring it in Dubai for specific types of buildings since 2013. (Mehran, 2016) concludes that the implementation of BIM is misunderstood in the UAE and describes the importance of developing educational standards.

The adoption of new ideas requires a framework for proper implementation and use, and the clarity of the framework structure allows for a better understanding of the technology. BIM is considered a process starting from the project kick-off meeting and continuing to facility management. Thus, BIM modeling is a long process lasting throughout the project lifecycle; the frameworks identify the structure of its implementation, operation, and the involved parties.

2.2. BIM implementation structure

BIM implementation is becoming a trend in various developed countries. For the adoption of BIM to succeed, there must be a framework for implementation and extensive investigative studies on lessons learned by countries that have already successfully implemented BIM (examples include studies by the Australian Construction Authority and Ireland's Construction IT Alliance (CitA) on global BIM). At the end of this investigation of previous global lessons, an

DOI: https://doi.org/10.54216/IJBES.020202

assessment study should be done on the current level of BIM in the local sector to create a better understanding of the role each participant in the government sector plays in leading the change to a BIM environment. Many successful work plans are based on standards that manage the use of a framework and cover the minimum quality requirements.

Furthermore, protocols need to be implemented to manage responsibilities and clarify roles. A framework's flexibility relies on the quality and clarity of its protocols and standards; moreover, an effective framework defines the range of coverage provided through documentation, information exchange, and coordination (Bui, Merschbrock, & Munkvold, 2016). Prior to planning for implementation, an imperative understanding is reached regarding factors to enhance the framework, such as the adoption plan and maturity level.

Many challenges face the adopters of BIM such as costs, and technical and legal issues (Alhumayn, Chinyio, & Ndekugri, 2017), but the need for finding solutions for the construction sector has motivated stakeholders to adopt BIM and maximize its business benefits, including time control, quality management, and cost reduction (Azhar, 2011). For example, in the Hilton Garden Inn hotel project in Atlanta, Georgia, US, BIM was used in the design coordination, conflict resolution, and work sequencing stages, leading to time savings of up to 1,143 hours (and cost savings of more than $200,000, as mentioned above)(Azhar, 2011).

The adoption of any new process in a variety of systems will experience inequalities in the level of progress. With regards to BIM, *maturity level* refers to the extent of adoption and collaboration integration levels among systems and industries. In addition, level of detail (LOD) is considered a significant aspect that determines the quality of models, and maturity levels are related to LOD in terms of the growth of BIM within industries. Analyzing frameworks that are already in use creates opportunities to enhance or replicate strategic elements in new frameworks, resulting in a more successful implementation of the technology with deeper understanding.

2.3. BIM implementation frameworks

The global construction sector has started using new technologies and developing the level of integration in the AEC industry, with technologies in use including drones, virtual augmentation, and the implementation of BIM. The level of BIM implementation has increased rapidly from 2016 and is still growing (Oleg KAPLIŃSKI), as governments plan for the use of BIM in their respective industries to enhance construction outcomes.

Regulation of the adoption of BIM is achieved by detailing the implementation process within the framework managed by the BIM champion, as these frameworks have organized the integration of BIM. Every industry has missions to achieve within the built frameworks, which likewise define the roles and responsibilities of the government. Every country has reached a different level of BIM adoption, based on a scale defined by (Succar, 2015) and reported in the CitA. The development of proven processes using BIM frameworks have enhanced the adoption process. In the case of the UK, the government established a BIM task group to set a foundation for leading the implementation of BIM processes, which allowed to it to reach maturity level 2. Other countries have witnessed BIM development in different areas and set individual standards, such as China, or in developed new technologies, such as Korea. There are more case studies of the process of BIM implementation around the world; (Succar,2015) references several about macro-adoptions, determining the conceptual structure and market analysis and thereby enabling BIM frameworks to be a more-defined measurement of BIM performance.

Many researchers investigated the implementation of BIM while focusing on applicability and the technical aspects of implementation frameworks in detail (Alreshidi, Mourshed, &

Rezgui, 2015, 2017); others focused on the implementation processes and regulation, along with the need for protocols or guidelines (Succar, Sher, & Williams, 2012; A. Wong, Wong, & Nadeem, 2009). Government strategies to implement BIM represented in the selected frameworks are reviewed in this research in order to recognize the achievements of all aspects of the frameworks in local construction industries. Analyzing these frameworks highlights their differences as well as the common critical areas that affect the implementation process. Further, the investigation contributes to the development of implementation processes, and creates a more profound understanding of basic requirements for future frameworks. The importance of the analysis is to review the possible strategies for BIM implementation, allowing researchers to understand the differences between frameworks, summing up current BIM frameworks to enable the development of new strategies, and facilitating the creation of new BIM frameworks.

The construction industry is a major contributor to any government's economy, and many countries aim to enhance the performance of this sector by adopting BIM. Finding the critical elements for successful adoption affects the implementation of BIM, from the local sectors to governmental visions and institutional programs. Since BIM relies on digital visual information technology, efficiency in the construction sector can be increased, as shown in approved case studies, by lowering the cost of buildings and improving communication among parties. Developing adoption frameworks based on local indicators is a critical step. BIM frameworks consider many aspects for effective implementation, starting from setting project milestones to the communication and construction processes throughout the project lifecycle. Regulating the processes based on BIM requirements impacts the construction sectors and effects change within the AEC industry regarding the uses of the technologies and tools.

The importance of finding common strategies is that it shows the value of each structural element of a BIM framework in every country, and the critical factors affecting the implementation of BIM. Moreover, the literature revealed a need to develop an understanding of the local construction sectors by identifying possible strategies for BIM implementation and facilitating more research in the field of BIM implementation by highlighting global frameworks and common elements. Thus, the local industries must understand the market and develop the implementation of BIM, and the review of previous frameworks and implementation strategies is part of the process of developing BIM frameworks.

The research value is based on the analysis of the frameworks and representation of national strategies for BIM implementation. As an investigation of the structure of BIM frameworks, this research revealed an in-depth methodology for the implementation of BIM frameworks based on a given criterion.

3. Methodology

A comprehensive literature review has been completed to analyze adoption frameworks in Table 1, including factors affecting the adoption process and the structure of frameworks. Many adoption frameworks have been used to achieve full integration modeling, and every initiative has different criteria related to regulations and standards. For this paper, five BIM frameworks have been selected for analysis and review, including emerging frameworks. The criteria listed in Table 2 were used to select the frameworks in the study, using five major aspects scored 0 or 1, with a minimum total score of 4 out of 5 needed for the framework to be included in the review. A comparison is summarized in a separate schedule in the results of the study.

Table 1: Reviewed Frameworks - the selected frameworks

Country Framework	Authority	Framework title	Publishing year
UK	Royal Institute of British Architects	BIM overlay to the RIBA outline plan of work	2013
US	US General Services Administration	GSA: BIM Guide Overview	2007
Finland	BuildingSMART Finland	Common BIM Requirement 2012	2012
Australia	The Australian Construction Industry Forum and Australasia Procurement and Construction Council	A Framework for the Adoption of Project Team Integration and Building Information Modelling	2014
Canada	BuildingSMART Canada	Roadmap to Lifecycle Building Information Modeling in the Canadian AECOO Community	2014
Singapore	Building and construction authority	BIM Essential Guide For BIM Adoption in an Organization	2013
Hong Kong	The Government of the Hong Kong Special Administrative Region	Building Information Modelling (BIM) Standards Manual for development and Construction	2009
Scotland	Scottish futures Trust	Building Information Modeling (BIM) Implementation Plan	2015
UAE	Dubai Municipality	Circular 196, Circular 207	2013, 2015
Norway	Statsbygg	Statsbygg BIM Manual 1.2.1	2017
Malaysia	Construction Industry Development Board Malaysia (CIDB)	MYBIM Malaysia Publications	-

Table 2: Evaluation for the selected frameworks

Criteria/ Framework	Government leadership	Established national database	Protocol availability	Education and training plan	Mandate for 3 years and above	Total
UK	1	1	1	0	1	4
US	1	1	1	1	1	5
Finland	1	0	1	1	1	4
Australia	1	0	1	1	1	4
Canada	1	0	1	1	0	3
Singapore	1	0	1	1	1	4
Hong Kong	1	0	1	1	0	3

Criteria/ Framework	Government leadership	Established national database	Protocol availability	Education and training plan	Mandate for 3 years and above	Total
Scotland	1	1	0	1	0	2
UAE	1	0	0	0	1	2
Norway	1	0	0	0	0	1
Malaysia	0	1	0	1	1	3

The existing literature fixed the structure of BIM frameworks, but there are different variables within the implementation process, as the factors -- Policies, Economic, Cultural, and Technological (PEST) factors -- change in the construction sector based on the BIM statutes for adoption. Each factor will be investigated and reported in qualitative results, to identify in depth the changes between elements in each framework. The comparison of the reviews included an investigation of the processes and the use of supporting implementation elements as the applied protocols, as well as educational training programs, databases and standards used, and the mandate year; these helped to measure the development of the framework and usage maturity level, while the structure of BIM implementation demonstrated the importance of each element.

4. Review of BIM Frameworks

4.1 United Kingdom

In 2011 the UK Cabinet Office identified the government construction strategy as a plan for growth. Because the construction industry is considered significant (representing 7% of GDP), BIM is one option that would enable the government to derive maximum benefit from this sector. Consequently, key members collaborated to establish an adoption plan named the Government Construction Strategy (GCS) in the same year (Cabinet Office, 2011). The target is to reduce waste in the public building sector by 40%, to decrease costs from £110 (US$140.995) million to £90 (US$115.359) million by 2020. The UK achieved level 2 BIM maturity, and this policy is planned to be a fixed requirement for future projects (GCS 2016–2020, 2016).

To contribute to the GCS, the Royal Institute of British Architects (RIBA) published a Plan of Work in 2013. (Sinclair, 2012a) In response to the government's commitment to BIM in every project in the summer of 2012, this change required collaborative integrated working methods and the standardization of frequently used definitions. In preparation for the 2013 fundamental review of its Plan of Work, the organization published the Green Overlay to the RIBA Outline Plan of Work in 2011, and the BIM Overlay to the RIBA Outline Plan of Work in 2012. Those overlays were integrated into the 2013 Plan of Work, which identifies eight task bars, some more flexible than others. Task bar 1 - Core Objectives remain fixed for all projects, while task bars 2, 3 and 4 - Procurement, Program, and (Town) Planning, respectively - vary widely and must be tailored to individual projects. Task bars 5 (Suggested Key Support Tasks), 6 (Sustainability Checkpoints), 7 (Information Exchanges), and 8 (UK Government Information Exchanges) are optional but recommended (see Figure 1).

The 2013 Plan of Work additionally sets out four main stages: preparation, design, construction, and hand over/in-use; the sub-stages include: strategic review, preparation and brief, pre-concept, concept and development, technical design, pre-construction, construction, in-use, and renovate and demolish (R&D), as shown in Figure 1 (Sinclair, 2012a).

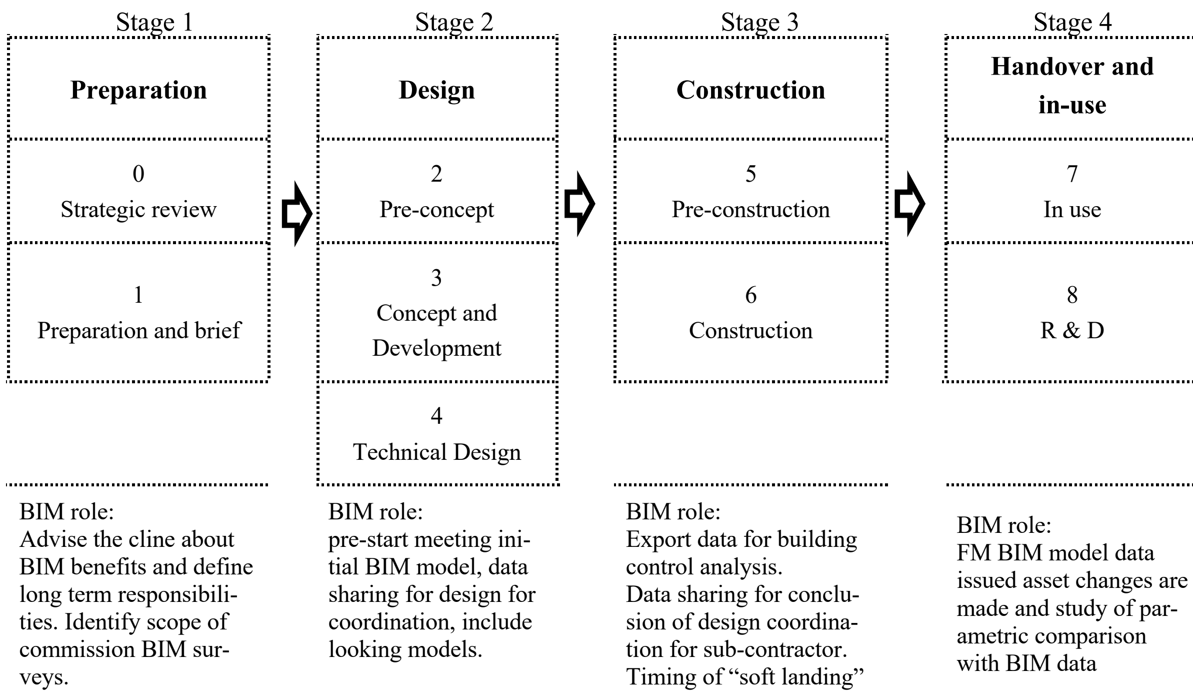

Figure 1. Stages and Sub-stages of Implementation during Project Lifecycle,

Preparation. In the first stage a design brief is created and added to the RIBA Plan of Work to inform stakeholders regarding strategies and specifics of individual projects. In addition, it is used to review feedback on previous projects, to identify procurement requirements, and to establish project objectives and quality standards. These sub-stages reflect primitive tasks outlined in each plan and show clients the benefits of BIM, thereby aiding construction professionals to clarify the cost, time, and facility management benefits for clients, and explain aspects relating to long-term responsibility, BIM input and output, and the scope of post-occupancy evaluation.

Design. The second stage refers to the movement from the conceptual to the technical level, with the inclusion of the outline proposal for structural design and preliminary cost estimation. Design development should involve coordination with structural teams and relevant parties to achieve the final stage. The technical design provides a project strategy and the matrix program. Implementing the design brief, preparing the data, agreeing to project quality standards, and reviewing the concept of BIM completed during the conceptual stage should initiate the pre-start meeting during which the model is initialized and shared with the design team. The BIM level will then acquaint the design team with the project BIM data.

Construction. The third stage involves two sub-stages, first is pre-construction activities and the second is construction. In the pre-construction phase there is the production-information level, representing preparation of the project information and a review of the building contract, which is followed by additional information; and the tender level, which refers to the preparation and collation of detailed tender documentation as relates to tenders for completing the project, also involving the assessment of potential contractors' suitability for the project. Therefore, BIM is used to control the exporting of information in Industry Foundation Class (IFC) format to

DOI: https://doi.org/10.54216/IJBES.020202

promote collaboration; conduct control analyses and detailed modeling, integration, and analysis; review construction sequencing, and work with the contractor.

The construction sub-stage covers closing the building contract, appointing the contractor, and administering the building contract to ensure practical completion. In this instance BIM facilitates the agreements regarding the timing and scope of "soft landings," that is, the coordination and release of the end of the construction level. Furthermore, the use of BIM data allows the effective overview of time and cost (4D/5D) for contract administration purposes.

Handover and in-use. The handover aspect refers to post-practical completion, the administration of the building contract after practical completion, and the commissioning of the building for a final inspection. The in-use sub-stage covers a model utilization for maintenance and facility development. Additionally, it requires a review of the performance of the project once it is in use and comparison with BIM data. This will allow the evaluation of asset changes and the study of parametric object information contained within BIM model data.

The RIBA framework organized the architectural practices and the use of BIM on a regulated level during the project lifecycle. The framework defined the roles of the architects in modeling and reported the responsibilities of the clients in project phases, as this element was clearer in the RIBA plan of work than in other frameworks which allowed for smoother implementation. Also, one of the targets for BIM implementation is to reduce waste, which RIBA achieves by controlling the processes and the pricing thereby reducing the waste of assets, time and resources. Moreover, defining the use of collaboration through BIM in the construction phases will reduce the traditional communication issues and poor timing, to allow for an effective project soft-landing and to manage the administration documentation for project delivery. Reaching maturity level 2 demonstrated the effectiveness of the BIM plan of work, but there are further challenges to drive the infrastructure of BIM to level 3.

4.2 United States of America

BIM implementation increased in the construction sector from 28% to 71% between 2007-2012 (McAuley, 2017). Although BIM is not mandatory in all states, several US organizations -- such as the National Institute of Building Sciences and the US General Services Administration (GSA) -- have taken part in initiatives to lead BIM implementation. The mission of the GSA is to enable federal agencies to serve the public sector. In 2003 the GSA and the Office of Chef Architect (OCA) introduced its national *3D-4D-BIM* program: 3D geometric models represent building components, and design or construction coordination; 4D represents the 3D and time factors that can inform project phasing, sequencing, and scheduling (GSA, 2007).

According to the GSA framework, project stakeholders need to understand the roles and responsibilities of the project teams. Thus, clarity is important to define scope of services and review with all parties concerned, to ensure sustained success through integration between implementation and evaluation when using 3D-4D-BIM. During implementation planning and 3D-4D-BIM services, project teams should reference the applicable BIM Guide Series for the specific best practices and guidelines for technology-specific information (USGSA, 2007).

The framework further plays a role in defining the foundation level of all projects to ensure the use of advanced design technologies in the industry. It enables BIM integration in all future projects -- on smaller projects that require less advanced engineering, the standards of the framework address the BIM workflow; on larger projects the plan of work requires BIM to improve both synchronization and workflow.

The BIM framework is divided into sections A-J as shown in Table 3. Sections A, B, and C consider the basic data of a project, including numbering, site and building address, major milestones, and project contacts. For instance, section A covers the BIM Project Execution Plan Overview based on specifics of the project; it should provide a general overview similar to an executive summary. Section B encompasses the basic information required for the project and the list information related to it; this section affects the implementation of the plan in terms of numbering the participant teams in the modeling phase. Section C lists all the project contacts to ensure that the BIM goal of flattening the traditional project organization is attained; for example, a designer from the mechanical sub-partner must be able to directly contact the architectural designer to resolve any conflicts in the model.

Section D aims to establish objectives and goals for the project; regarding BIM the goal relates to the team, specifically to all team members understanding the project expectations. Therefore, subsection D-1 is used to define the goal clearly and to set out metrics that will be used to measure success in meeting goals on the project. Subsection D-2 clarifies the expectations set out in D-1, as a lack of clarity causes confusion and errors.

Section E represents the heart of BIM—collaboration—and defines it in the implementation of BIM in the project. Subsection E-1 describes the structure of the meetings that will be scheduled to facilitate team communication. Subsection E-2 explains the methodology to follow and indicates when model data is exchanged. Subsection E-3 refers to the tutorial on integration reviews for extended information on how to have successful review meetings. Subsection E-4 preps interactive workspaces, defined as "big-rooms," and provides a layout of the team's workspaces to allow the entire team to work on their models in a single space; typically, for co-located projects, the designer will bring their computers to the co-located site and work collaboratively as a group. Subsection E-5 shares documentation, models, and data with other technology-based communications as necessary; it defines the software required by the teams that needs to be installed and configured. Subsection E-6 defines the required training, promotes open discussions on training and education plans to extend the use of software packages, and requires further analysis of whether the team members understand the process. Finally, subsection E-7 addresses the team's agreement on model integration methodology, including setup, objectives, and facilitation.

Section F represents quality control, a critical factor. This section is a significant checkpoint for GSA. Subsection F-1 demonstrates the implementation of quality control procedures to ensure quality management in both building and data. Subsection F-2 covers the performance of quality checks on the working teams. Sections G, H, and I address details of using the software within the framework. These sections of the plan of work are considered a reminder to the team to consult the BIM standards, and may require support from the IT team. Section J features a free template for teams to allow them to add any additional information that might benefit the project. Several suggested documents are listed, and the team is highly encouraged to add additional documents as needed. The categories, sections, subsections, and associated tasks listed in each section of the GSA 3D-4D-BIM are shown in Table 3.

Table 3: 3D-4D-BIM tasks, US

Description	Section	Sub-section	Task
Basic level	A		project number
	B		site and building address
	C		project contact
Objectives	D	D-1	clear definition of goal
		D-2	expectations clarified
Core	E	E-1	structure of meetings
		E-2	when model data will be exchanged
		E-3	tutorial on integration reviews
		E-4	interactive workspaces
		E-5	sharing through technology-based communications
		E-6	required training
		E-7	model integration methodology
Quality control	F	F-1	implementation of quality control procedures
		F-2	performance of quality checks
Technology and standards	G H I		details of using the software within the framework
Free-template	J		any additional information

The GSA are focused on the federal governance of the implementation of BIM; the scope of the framework has different areas, starting from the foundation for the projects to structuring the meeting in section D and in sub-section E4 the interactive workspaces. This framework showed a significant scope of work for different locations. The GSA covered the technical aspects for the 3D-4D modeling to benefit certain areas from BIM in order to develop the construction practices with the aim of reducing waste in the industry. There are other similarities with the RIBA frameworks, such as in defining a checkpoint for the modeling so that the goal of benefitting 3D-4D modeling is measured on every stage in the project. The framework covers the processes of modeling and conducting different aspects of regulation, as this considered to be a challenge with regards to the geographical coverage of that GSA framework. The ability to implement BIM on a large scale is achieved in this framework, which is applicable to many building sectors aiming to implement BIM and unify the rules of building on all scales, in order to reach higher maturity levels.

4.3 Finland

In 2001 the Finnish Ministry of Finance, through the state-owned enterprise Senate Properties, carried out several pilot projects to develop and study the use of product models (A. Wong, Wong, & Nadeem, 2011). Subsequently, in October 2007, Senate Properties released a series of standards and approved the use of models meeting IFC standards for the first time. More recently the City of Helsinki's Real Estate Department, the Hospital District of Helsinki and Uusimaa (HUS), Senate Properties, and the City of Vanuatu's Real Estate Department produced BIM project guidelines for clients (Bolpagni, 2013), presented as a thirteen-part series, as shown in Table 4.

Table 4: BIM Project Guidelines, Finland

	Document Name	Document description
1	General part	General Technical Requirements
2	Modeling of starting situation	- Modeling of the site and site elements - Source of data
3	Architectural design	- Modeling Principles in Architectural Design - General/ detailed design phases
4	MEP design	- MEP requirement model - System for MEP design - System BIMs for building automation design
5	Structural design	- BIM modeling of a renovation project - Definitions of different design phases - Detailed design phase
6	Quality assurance	- Quality client view/ Designer view - Quality Assurance - Responsibilities
7	Quantity take-off	- Model-based quantity take-off methods and connecting them to project management - decision making and modeling phases - quantity take-off process
8	Use of models in visualization	- The Objectives of visualizations - Illustrations and visualizations - Visualization at different modeling stages
9	Use of models in MEP analysis	- MEP analyses
10	Energy analysis	- Energy analyses in different stages of the project - Energy analyses programs
11	Management of a BIM project	- Principles of information model-based project management - BIM project management tasks from stage to stage - Construction preparation

DOI: https://doi.org/10.54216/IJBES.020202

12	Use of models in facility management	- BIM during operation and maintenance - Design software - Facility management BIMs updating procedure
13	Use of models in construction	- Contractors' Requirements for building Information models - Production data delivery into as-built BIM

The Finnish Government aims to support the design and sustainability construction process by implementing BIM used throughout a building's lifecycle, from the initial design stage and continuing even during use and facilities management (FM) after the construction project has been concluded, through the development of information models. In addition, the government aims to support design visualization, analysis of construction feasibility, enhancement of quality-assurance and data exchange, and the promotion of effective and efficient design processes (Finland, 2012a).

Therefore, the framework includes definitive project-specific requirements, and the setting and documentation of objectives and needs. It intends to provide decision-making support and promote all parties' commitment to the project objectives. To assist in design, the coordination of designs, and moving from the generation of models to the project stages, the framework calls for setting out needs, objectives, area and volume. Additionally, core activities are needed for reviewing site requirements in order to create a layout as per BIM requirements.

The next stage is creating alternative designs by investigating suitable basic options using rough spatial models. The design models from each discipline are expected be available to all disciplines, which is ensured by agreeing to sufficiently frequent uploads to the project server; a suitable schedule at this stage could be, for example, linked to regular design meetings. The early design stage follows the design of alternatives stage and involves the further development of architectural BIM. The client's requirements are updated in the previous stage to conform to the decisions made; in the early design stage, the client's tasks include overseeing the design and approving the design solution for the subsequent detailed design phase. BIM enables fast, illustrative, and interactive visualization and analysis, which support communication and decision-making (Finland, 2012b).

The detailed design stage is similar to the early design stage, with the exception that the level of accuracy of the information generated is significantly higher. The design solutions are finalized to be released for tenders, and all models prepared for the project are further inspected using detailed information. It is noted however, that a substantial part of the detailed design stage information still needs to be generated in the form of traditional design documents. The information content and accuracy levels of the models are defined in Series 3–5 of the domain-specific BIM instructions.

In the construction stage, the use of BIM by contractors relates to organizing the production processes. This section is a description of the primary applications of the models. 3D visualization creates benefits on many different levels: models offer a better way to study the designs and structures, and they facilitate the planning of installation procedures and the coordination of the work as well. A quantity that is BIM-based launches a rapid calculation process and provides an accurate result, effective models, and report templates to reduce duplicated work significantly. This improves the productivity of construction overall. During the last stage in the framework, commissioning represents the generation of documents out of the model formats to create a direct manual for maintenance, essential to generate as-built models (Finland, 2012c).

DOI: https://doi.org/10.54216/IJBES.020202

The Finnish government has established a series of manuals published in this framework to organize communication during the modeling and implement the protocols to avoid problems. Still, the level of governance of BIM processes is not clear, and as shown in the review this framework relies on open standards to benefit from its practices. The main objectives for BIM implementation are not clear, which is one of the missing elements even though BIM has been considered a tool in Finland since the 80s. The implementation of BIM over this long period of time has resulted in a rich framework with detailed modeling and clear polices. The process of BIM in the Finnish industry considered the energy analysis of building models as well -- this is considered to be a valuable element that doesn't exist in many frameworks. Moreover, much information detailing was added for project coordination and management (which also appears in the RIBA framework). The richness of these frameworks included aspects of facility management protocols and guidelines, covering the quality of the facility while running and as-build drawings, resulting in the Finnish government being ready to develop more processes and regulation of BIM technologies.

4.4 Australia

Construction industry productivity is fundamental to Australia's economy. The building and construction industry accounts for 7.8% of Australia's GDP, employing 9.1% of the workforce and contributing AUD$99.4 billion to the local economy in the 2011–2012 financial year. By the end of June 2012, the building and construction industry generated $305 billion in total income (ACIF, 2014). A study by the Allen Consulting Group determined that accelerated adoption of BIM would increase GDP growth in Australia by 0.2 basis points in 2011, with an estimation of a 5 basis points increase by 2025 (ACIF, 2014). Moreover, the benefit-cost ratio of early adoption of BIM would be around 10 (assuming a $500 million adoption cost). These statistics clearly indicate potential benefits and productivity gains through the adoption of BIM.

The Australian Construction Industry Forum (ACIF) and Australasia Procurement and Construction Council Inc. (APCC) took the lead to establish the Australian BIM framework, aligning the government with key stakeholders to adopt information modeling. ACIF and APCC have identified seven elements, supported by objectives and actions, where industry and government could encourage and promote increased adoption of Project Team Integration (PTI) and BIM. The Australian framework discusses the adoption level as four stages: 1) from the standard base to the 2D manual drawing; 2) the modeling level; 3) collaboration; and 4) reaching full integration (ACIF, 2014).

Reviewing the Australian scope of work is the first objective towards constructing a framework as it relates to adoption levels, the various projects using BIM, and innovative procurement processes. The challenges ahead of the international adoption for BIM were also documented. These primary elements were reviewed before setting the guidelines for communication, investment, methodology, policy, skills, social acceptance, and the role of qualified "change leaders" to determine the success of the plan, as observed in the implementation of technology (in this framework, change leaders are referred to as "BIM champions"). In addition, educational needs are identified, specifically the role of universities and training programs in highlighting the technology, educating practitioners about its benefits, and leading change.

Procurement and contracting are identified as crucial factors in implementing BIM in the Australian framework, with the importance of early engagement of the contractor in the initial design stages to maximize benefits. Factors during the contractual level -- arrangements with the working teams, the priority of documents, expected risks and attendant risk management and

DOI: https://doi.org/10.54216/IJBES.020202

sharing, and legal considerations (copyright, licensing, data access, etc.) -- are addressed. Another aspect, procurement cover, is the tender approach with a goal of increasing integration on a competitive basis.

Controlling human responses to the framework requires protocols, and the National Building Specification (NATSPEC) guidelines were established to clarify roles, responsibilities, and the standards expected of project teams. Of primary importance is to create a solid foundation for clients to evaluate their projects, save money, and to improve performance; another objective is to assist management via controlling the organizing, planning, and design processes (NATSPEC, 2011).

The BIM framework extends the construction stage to facilities management, clarifying and maximizing the benefits of BIM throughout the lifecycle of the project and as an aspect of asset management. The objective of information exchange and the use of an object library, such as the UK NBS library, allows design teams to use fully specified generic objects in designs, promoting the pooling of resources and the provision of the best service possible for project stakeholders. Consequently, standards are required in the framework to manage the use of data, and as in any computer-based technology, information standards allow and facilitate universal use and understanding

The Australian framework has included a strong foundation for the implementation of BIM within the industry, as their study has covered many aspects to find the best practices in BIM. The framework defines the use of BIM on a governance level, but without considering the execution and local measurement of the existing conditions for BIM, which are not highlighted in the framework. NATSPEC was intended to fulfil the need for BIM protocols in practice; however, compared to the Finnish framework and GSA, the Australian framework has a shortage in practical areas for implementation of BIM within the industry. Their work defining the milestones, objectives and the minor aspects, including contracting details, are essential elements of a BIM framework, but the technical aspects, roles and responsibilities and the hierarchy of execution in all project phases is likewise important. Several aspects could therefore be improved as defined in the existing maturity level, with the goal of achieving higher levels in determined years. Achieving the phases of BIM implementation and reaching the checkpoints for each stage will increase the level of understanding within the sector; open standards assist in the development of the framework but cannot fill the local sector standards, as an assessment of the local industry was not included.

4.5 Singapore

The Building and Construction Authority (BCA) in Singapore began the use of BIM in 2010 by creating the initial version of a BIM roadmap; in 2015, the second version of the roadmap was published authorizing the use of BIM (McAuley, Hore, & West, 2017). The second version is similar to the Hong Kong roadmap, focusing on the transformation process, research and development of BIM applications, and facilities management. The organization's publication focused on leadership, planning, information, processes, people and client involvement as major factors in creating a guideline (Committee, 2013). The Singaporean construction authority published a BIM guide in 2013 to define the deliverables and processes for BIM in construction projects for the involved professionals. Table 5 illustrates the main components of the guide for BIM implementation.

Table 5: Singapore BIM Guide 'version 2', Singapore

Section	Sub- Section
1. Introduction	1 BIM Deliverables 2 BIM processes 3 BIM professionals
2. BIM execution plan	-
3. BIM deliverables	1 BIM elements 2 Attributes of BIM elements 3 BIM objectives and responsibilities 4 Compensation expectation 5 Other additional value
4. BIM modeling and collaboration procedures	1 Individual discipline modelling 2 Cross-disciplinary model coordination 3 Model and documentation production 4 Data security & saving 5 Quality Assurance and quality control 6 Workflow of design-build projects 7 Workflow of design-bid-build projects
5. BIM professionals	-

The Singaporean building industry has a basic layout for the implementation of BIM, but the level of assessment in the local sector is not included which makes it challenging to reach an in-depth understanding of BIM in the sector. Measuring is associated with setting the maturity of the framework and defining the areas where further development is needed to develop comprehensive frameworks. In the case of Singapore many practical aspects are not displayed, such as modeling and phasing of a project and the guidelines and standards for modeling.

4.6 Hong Kong

The Construction Institute Council (CIC) is leading Hong Kong to implement BIM. In 2015 the CIC published a roadmap for the strategic implementation of BIM in Hong Kong in the construction industry to enhance the construction sector, introducing BIM in stages ("CIC Building Information Modelling Standards (phase One)," 2015). The implementation plan is designed to focus on main areas that create the framework, including: collaboration, benefits, standards, insurances, information sharing, education, digital capability, risk management, and global competitiveness. The transformation of these areas via initiatives is part of the concepts underpinning the framework; in contrast the Hong Kong Housing Authority has mandated the use of BIM in all of their projects and published a series of guidelines and library manuals for users and designers (Region, 2009).

The use of BIM on a small scale can be managed with internal regulations and processes as in the Hong Kong Housing Authority. On the other hand, a broader level of strategic planning requires deep investigation and creation of a foundation; the CIC's efforts towards strategic implementation is clearer but in the case of BIM there are more elements needed, such as databases and an organized level of governance over the implementation processes.

4.7 Scotland

The government of Scotland planned to mandate BIM for public sector projects in 2017, digitizing the construction industry by following British implementation standards to achieve level 2 ("Building Information Modeling (BIM) Implementation Plan," 2015). The stages of implementation have been segregated into five periods: 1) assess BIM maturity and define thresholds; 2) mobilization; 3) pathfinder project; 4) development of Scottish government guidance; and 5) launch of BIM level 2. The first stage started in 2015 with the measurement and definition of the BIM implementation plan, assessing BIM maturity level, and defining qualified BIM projects. The second stage outlines the government's role, communication during implementation, and the education plan. By 2016, a selection of pathfinder projects determined the delivery team and the methodology. The previous stages required the Scottish government to review the components of maturity level 2, which led to the development of BIM guidance (fourth stage). The final stage started in 2017 by launching level 2 of BIM: setting the level of communication between authorities, the industry, and the public sector; and monitoring the implementation.

The framework of the Scottish government, considered in the early stages of the implementation and its approach, is oriented to find a practical solution for the local constriction sector -- starting from the assessment of BIM maturity to create better understanding of the possibilities of BIM enhancements, to working on pathfinder projects to examine the strategies of the implementation of BIM. The strategy of moving towards direct implementation requires rapid developments, as appearing in stage two, that focus on communications and later on government-level coordination. The Scottish plan of work focuses on guiding the change from the bottom of the hierarchy, starting from projects to changing decisions in the last stage.

4.8 Norway

The government of Norway mandated the use of BIM in the construction industry in 2016. Their framework focuses on guidelines throughout the building process. First, generic requirements define the deliverables and BIM requirements obtained from clients. Second, domain requirements focus on practices such as architecture; landscape; interior design; geotechnical, structural, electrical, and acoustical elements; fire safety; engineering and as-built modelling; and facility management. Third, the quality and practices division complete their required analysis and the practices of modelling. Finally, scientific classifications are based on technical spaces, and mechanical and electrical entities (Statsbygg, 2013).

The implementation of BIM in the Norwegian construction industry is in early stages, but the level of detail within the framework shows a practical and fast orientation towards implementation. The checkpoints for the processes and quality of the modeled project in the framework show a high technical consideration. Still, many needed areas can be defined as the objectives of BIM.

4.9 United Arab Emirates

The government of the UAE has initiated the adoption of BIM in the city of Dubai in 2013. The leading champion of this effort is the Dubai municipality, with a mandate for using BIM (published through Circular 196) for specific types of projects - buildings with a height above the 40th floor, and any building project with an area equal to or greater than 400000 square feet. In 2015 the requirements were updated (through Circular 207) to include all governmental projects, and projects for buildings with a height above the 20th floor and/or an area equal to or greater than 200000 square feet (Hany, 2015).

The strategy of the Dubai municipality for BIM implementation focuses on mandating the use of BIM in the private and public sectors via regulations, as with many guidelines adopted from global standards to regulate the implementation of BIM. The framework of BIM in the Dubai municipality considers the use of BIM as a tool without setting a foundation for its implementation or a roadmap for the use of BIM.

4.10 Canada

Canada intended to develop a plan to integrate BIM into their construction industry in 2014, and since then the Canadian BIM council has issued a roadmap for BIM adoption with a target to achieve integration by 2020. After establishing the roadmap a protocol was placed to manage implementation, with levels of implementation ranked from *level 0* to *level n*: level 0 for isolating in modeling, level 1 for networking and coordination, level 2 for collaboration, level 3 for reaching the full integration, and level n represents “unified” (McAuley et al., 2017). The roadmap objectives therefore are achieving engagement, development, education, deployment, sustainability, and evaluation of BIM. The plan extended to 2020 to enable the adoption of BIM at all levels. The approach for 2017 was to engage and create a movement to adopt BIM, develop a BIM guideline and standards, and create an education plan to deploy information and work by representing it through a collaboration plan. Evaluating the maturity level can be associated with measuring the adoption, moreover the Canadian government is planning to sustain the adoption via integration with international frameworks ("Roadmap to Lifecycle BIM | buildingSMART Canada,"). The Canadian framework is not in the execution stage. The framework target is to achieve full integration with the further aim to increase education and sustainability. The main lines for the framework are clear, but the foundation of the framework is missing -- the technical aspects as well as the databases and communication -- showing there is a need for an investigation of the technical aspects. The stated intention for the integration of BIM by 2020 shows that the plan is still in progress, and the Institute for BIM in Canada (IBC) has launched BIM and Revit protocols.

4.11 Malaysia

The strategic implementation of BIM in the Malaysian construction industry was started in 2015 by the Construction Industry Board (CIDB). The main framework schemes include standards, collaboration, education, BIM library, BIM guidelines establishment, and legal issues. Those elements are to be researched in the context of Hong Kong and Singapore, as well in relation to local industry needs (Latiffi, Mohd, Kasim, & Fathi, 2013). On the other hand, the Construction Industry Transformation Program (CITP) developed the implementation of BIM within the construction industry in response to the economic growth, by launching a series of publications to clarify the roles of BIM within the industry in awareness, readiness, and adoption; likewise, a BIM execution plan was announced by myBIM Malaysia.

The plan of Malaysia is to develop the implementation of BIM within the industry by execution, and as result of that action issues in the legal aspects were found. This led to a reassessment of the process of BIM, its adoption, and defining the strategic layout. Determining leadership for BIM adoption could help achieve better results.

5. Results

The review highlighted the most critical areas for the researchers in the field of BIM implementation, as well as the essential factors within every country and organization strategies, and contributions to the process of adopting BIM. The study covered many aspects, such as the role of the protocols within the frameworks, the objectives of the frameworks, the structure that supports the implementation within countries, in addition to other strategies. The comparison of the frameworks was the critical aspect of the study. The differences between the frameworks were highlighted based on political, economic, socio-cultural, and technological (PEST) factors, as this allowed in-depth insight into the processes placed to achieve the objectives of BIM implementation and clearly showed the strategies within the frameworks.

Comparisons between the frameworks based on the PEST factors are shown in below. The first factor, Political, highlights the purpose of using BIM within the industry. Setting the governmental objectives of the implementation is essential, and the possible benefits should be clarified associating the champion needed to achieve it. Every country has set milestones for the implementation of BIM, and the leader of measuring the outcomes of the frameworks, as shown in Table 6.

Table 6: Political factor in the frameworks

Framework	Description	Champion
United Kingdom	The aim was to maximize the benefits of the construction sector, digitize the industry, and improve communication within the industry.	BIM Task Group
United States of America	Not all states mandate the use of BIM, but GSA applied it in federal projects, taking the lead to benefit from 3D-4D features.	GSA and the National Institute of Building Sciences
Finland	The government has supported the use of BIM since 2007, aiming to encourage effective design by supporting the champion of BIM adoption.	Senate Properties
Australia	The Australian and New Zealand governments are aware of the benefits of BIM and look to enhance the industry as the construction sector is considered the fifth large industry in the economy.	ACIF and APCC
Singapore	The government adopted BIM to improve benefits 20-30% and use a highly integrated technology.	BCA

The second factor is the Economic response to the embedding of technologies and processes, as this factor focuses on the government role as an investor in the technology and developer of regulations. The respective GDPs of the countries show the need for BIM development, considering expenditures, returns and the waste in the industry. Establishing the level of the investment and the expected Return of Investment (ROI) considered in the frameworks shows the level of the support of BIM; this is viewed as a valuable factor, delineated in Table 7.

DOI: https://doi.org/10.54216/IJBES.020202

Table 7: Economical factor in the frameworks

Framework	Description	Champion
United Kingdom	The government found the need to develop the GDP of the construction sector and reduce waste by 2020 to 40%.	UK Cabinet office
United States of America	Aims to improve productivity and reduce waste throughout all phases of the building industry, as GSA found a waste of US$15.8 million in 2002.	GSA
Finland	The government invested in BIM through the efforts of Senate Properties, to lead implementation and benefit long-term from investment in BIM.	cubism
Australia	The rapid growth of the construction GDP shows a high value for developing the industry, and the framework to implement BIM and PTI has been placed for maximum benefit.	ACIF and APCC
Singapore	The government aims to improve the construction industry's productivity by 20-30%. The BCA launched a funding program to support the implementation of BIM.	BCA

The third factor is Socio-cultural, and many sources from literature considered the resistance to transformation as a barrier to BIM implementation. The frameworks define roles and responsibilities, as shown in the protocols, to clarify the tasks for the stakeholders. The amount of awareness by the AEC workers and their willingness to embrace the protocols, is critical for an effective implementation of BIM. Hence, every country developed a training program and, in some cases, even required the embedding of BIM within the education system. Table 8 shows the Socio-cultural factor in the frameworks.

Table 8: Socio-cultural factors in the frameworks

Framework	Description	Champion
United Kingdom	The cultural resistance to change is considered a barrier to the mandated accelerated adoption; RIBA developed an education plan and training for BIM.	BIM Task group, RIBA
United States of America	Section D, established by GSA, clarifies the roles and responsibilities of all working team members.	GSA
Finland	The workers within the government reached 93%, and the construction industry has relied on BIM, ICT from 2007, showing a high awareness of the use of BIM.	coBIM
Australia	The challenges related to socio-cultural elements are considered to be solved by the support of the top of the hierarchy -- management leads the transformation as the champion and facilitates training programs.	ACIF and APCC
Singapore	There is an objective of building a hub to support the AEC in developing the implementation. Also, a certification is provided for undergraduate students as well as a diploma and training in BIM.	BCA

The main forces in BIM lie within the technological factor, as the relations and communications among parties and the applied ICT are defined in this section of the framework, in addition to the level of collaboration among stakeholders, the national databases and library in-use. The technology in use has many aspects covered and defined, and this section is considered the foundation for BIM implementation. Table 9 shows the relation between the frameworks as regards this factor.

Table 9: Technological factor in the frameworks

Framework	Description	Champion
United Kingdom	Transformed to the use of E-procurement within the UK, and maturity level 2 shows that the industry achieved the level of collaborative modeling.	BIM Task group
United States of America	GSA established a technical specification as section E, with seven sub-sections to cover the technical aspects within the series of implementation.	GSA
Finland	The use of IFC within the industry of Finland, as the minimum requirements of BIM implementation, follows the publication by coBIM in 2012.	coBIM
Australia	The framework aims to create an interactive platform for workers within the industry, and to build a cloud-based service and high security system.	ACIF and APCC
Singapore	Singapore has applied e-submission, and BCA has mandated the use of e-submission for digitizing the industry by BIM and IDD.	BCA

Every country has different milestones and objectives for the implementation of BIM, therefore the order of the framework components is different; however, there is a fixed component for the implementation of BIM. The UK framework has developed based on many aspects, starting from setting a framework to measuring the outcome and fixing the framework – with that task assigned to the BIM Task Group. On the other hand, the USA framework placed by GSA targeted the application of 3D-4D practices to many projects in the entry stage; also, the established series of documentation showed that it is the main focus on all aspects of the implementation. The Finnish framework covered many aspects in standardizing the implementation, focusing on the publications of modeling specifications the role of the stakeholders within the AEC. The Australian framework has formatted the main lines of the implementation process, covering the aspects related to BIM implementation by the stakeholders, applied protocols, standards, and technology; this allows development within the process of the implementation. The Singaporean BCA supported the implementation of BIM through funding and training programs. Use of BIM has been recognized as important for one of the goals targeted to digitize the industry; all of the plans were targeting improvement in the areas of time and cost as contributors to enhancement of industry productivity.

For the other frameworks, as shown in Table 10, the level of BIM adoption is differentiated based on the construction industry statutes within the country – whether the methods for BIM implementation follow the approach of using open standards, or mandating the use of BIM, or no specific requirements.

DOI: https://doi.org/10.54216/IJBES.020202

Table 10: The secondary frameworks comparison

Framework	Description	Mandate year
Hong Kong	The construction industry has developed the implementation of BIM, with academia taking a role in education. The framework shows the strategic implementation plan and assessment of the industry.	Mandate in place since 2014
Scotland	The Scottish government has mandated the use of BIM, dividing it into two phases aiming to achieve level 2, relying on pathfinder projects to establish the implementation of BIM by Scottish Futures Trust.	Introduce level 2 in 2017
Norway	The Norwegian government has outlined the framework in-use to define professional practices for the AEC, the updated development was established in 2015.	2016 open standards
UAE	The implementation of BIM is mandated in the city of Dubai with specific requirements; there is local standard, but misunderstanding of BIM and the local standards.	Restricted mandate in place
Canada	Canada is still processing the implementation and the framework in-place is considered a roadmap, with protocols to implement BIM with an open standard to achieve level *n*.	2014 - 2020 mandate will be placed
Malaysia	The plan of Malaysia aims to adopt BIM based on a series of publications clarifying the roles of BIM within the industry in awareness, readiness, adoption, and BIM execution plan.	CIDB

Table 11 represents a summary of the data collected (including the maturity level, standards, procurement system, and the champion role) from each of the five BIM frameworks chosen for analysis, comprising a comparison of the reviewed frameworks and the criteria formulating them, including: governmental support and leadership; mandatory periods; development and maturity level; and availability of standards, databases and protocols.

Table 11: Summary of the major components of BIM implementation frameworks

Criteria/ Framework	United Kingdom	United States of America	Finland	Australia	Singapore
Government leadership	Exists	Exists	Exists	Exists	Exists
Mandate year	2006	2009	2001	2012	2015
Maturity level	Level 2	N/A	Level 1	Level 0	N/A
Standards availability	BIS	GSA technical standards	ISO	ISO	Singapore BIM Guide
Protocol availability	Exists	N/A	Exists	Exists	Exists
Database availability	NBS national BIM library	IFD Library and International Standards	N/A	NATSPEC	Building Smart

Criteria/ Framework	United Kingdom	United States of America	Finland	Australia	Singapore
Procurement systems	E-procurement	Design-bid-built	IPD	N/A	N/A
Education and training plan	Mandatory	N/A	Mandatory	Optional	N/A
BIM Champion name	RIBA	GAS	Senate Properties	ACIF and APCC	Building and Construction Authority

5. Conclusion

Several aspects of BIM implementation and adoption were considered in this study to show the importance of assessment of frameworks and to learn from previous lessons (as is being done in Malaysia) and create a better understanding of the processes for effective BIM implementation. The work of BIM Champions ("change leaders") in each location is to evaluate the implementation of BIM and control the direction of its development, as in the UK where their strategy has included it as part of its Plan of Work. These Champions have proven to be a key element in measuring and assessing needs to enable achievement of technology adoption, GDP ratio enhancement, or avoidance of exceeding budget and time targets within projects.

As one of the objectives of this study is to analyze selected frameworks to create better insight into the main elements of the frameworks, it is noted that there are many strategies for the creation of BIM framework: first, the assessment of the industry (as in the case of the UK and Canada), which results in a longer process for forming the framework; second, developing the framework within the implementation process (an approach followed by the UAE and Australia) which allows for a longer process and quick solutions; and third, staging the building process in consideration of specific sectors (as in the UK-RIBA), where the framework focuses on targeted areas – in the UK context, the architectural practices and the roles between the AEC and the clients based on the stage of the project.

Another objective of this research was to investigate the importance of local requirements to set BIM frameworks. The differences between the PEST factors showed the need for understanding the complexity of BIM implementation and aligning the common elements that are necessary for BIM implementation. Even more, the importance of the assessment of the local construction sectors to find the critical success factors (CSF's) for BIM in the different building sectors is required to facilitate the implementation of a BIM framework. The creation of BIM implementation strategies requires many elements, skills, and an understanding of BIM, as the construction industry is linear process that requires a hierarchy and chain of order. The different strategies uncovered through this research are considered a valuable asset for further framework development -- summing up the possible strategies for BIM implementation, and determining the potential issues of region differentiation and the PEST aspects of local industries.

Essentially, the development and adoption of BIM-related technology are significant for the building industry with regards to the global trend of adopting BIM and including it in plans of work. This study facilitates future research on the topic of BIM adoption by providing an overview of the frameworks available, with a future goal of creating a fixable BIM framework. The current study highlights the importance of assessment in the framework creation process and directs further study to investigate and identify local BIM Champions. Future studies can also critically compare these identified frameworks to facilitate decision making on the most suitable method for a project.

References

[1]. ACIF, A. (2014). "A Framework for the Adoption of Project Team Integration and Building Information Modelling". In. Australia: The Australian Construction Industry Forum and Australasia Procurement and Construction Council.

[2]. Alhumayn, S., Chinyio, E., & Ndekugri, I. (2017). "The barriers and strategies of implementing bim in saudi arabia". *WIT Transactions on The Built Environment*.

[3]. Allan Fred, O. (2016). "Interaction between Lean Construction and BIM: How effectiveness in production can be improved if lean and BIM are combined in the design phase A literature review". In.

[4]. Alreshidi, E., Mourshed, M., & Rezgui, Y. (2015). "Cloud-based BIM governance platform requirements and specifications: software engineering approach using BPMN and UML". *Journal of Computing in Civil Engineering*.

[5]. Alreshidi, E., Mourshed, M., & Rezgui, Y. (2017). "Factors for effective BIM governance". *Journal of Building Engineering*.

[6]. Azhar, S. (2011). "Building information modeling (BIM): Trends, benefits, risks, and challenges for the AEC industry". *Leadership and management in engineering*.

[7]. Banawi, A. (2017). "Barriers to Implement Building Information Modeling (BIM) in Public Projects in Saudi Arabia". *The International Conference on Applied Human Factors and Ergonomics.*

[8]. Banawi, A., & Bilec, M. M. (2014). "A framework to improve construction processes: Integrating Lean, Green and Six Sigma". *International Journal of Construction Management*.

[9]. Bui, N., Merschbrock, C., & Munkvold, B. E. (2016). "A Review of Building Information Modelling for Construction in Developing Countries". *Procedia Engineering.*

[10]. Building Information Modeling (BIM) Implementation Plan. (2015). In: Scottish futures Trust.

[11]. Cabinet Office, U. (2011). Government construction strategy. In: Cabinet Office London.

[12]. CIC Building Information Modelling Standards (phase One). (2015). In: Construction Industry Council.

[13]. Committee, B. I. M. S. (2013). BIM Essential Guide For BIM Adoption in an Organization. In.

[14]. Dania, A. A., Kehinde, J. O., & Bala, K. A study of construction material waste management practices by construction firms in Nigeria.

DOI: https://doi.org/10.54216/IJBES.020202

[15]. Eastman, C. M., Eastman, C., Teicholz, P., & Sacks, R. (2011). BIM Handbook: A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers and Contractors. *John Wiley & Sons*.
[16]. Economics, I. (2013). Global construction outlook: executive outlook. *IHS Economics: London, UK*.
[17]. Finland, B. (2012a). COBIM-Common BIM Requirements 2012 Series 1: General Requirements. *Cobim: Common BIM Requirements, 1*.
[18]. Finland, B. (2012b). COBIM-Common BIM Requirements 2012 Series 2-Modeling of the starting situation. *Cobim: Common BIM Requirements, 2*.
[19]. Finland, B. (2012c). COBIM-Common BIM Requirements 2012 Series 13: Use of models in construction. *Cobim: Common BIM Requirements, 2*.
[20]. GSA, U. (2007). GSA: BIM Guide Overview. In: General Services Administration Washington, DC.
[21]. Hany, O. (2015). Solutions for the UAE Architecture, Engineering, and Construction (AEC) industry to mandate Building Information Modeling (BIM). In.
[22]. Hoornweg, D., & Bhada-Tata, P. (2012). *What a waste: a global review of solid waste management* (Vol. 15): World Bank, Washington, DC.
[23]. Latiffi, A. A., Mohd, S., Kasim, N., & Fathi, M. S. (2013). Building Information Modeling (BIM) Application in Malaysian Construction Industry. *International Journal of Construction Engineering and Management*.
[24]. McAuley, B. (2017). BICP Global BIM Study - Lessons for Ireland's BIM Programme.
McAuley, B., Hore, A., & West, R. (2017). BICP Global BIM Study - Lessons for Ireland's BIM Programme.
[25]. Mehran, D. (2016). "Exploring the Adoption of BIM in the UAE construction industry for AEC firms". *Elsevier Ltd.*
[26].NATSPEC. (2011). NATSPEC National BIM Guide. *Construction Information Systems Limited*.
[27]. Region, T. G. o. t. H. K. S. A. (2009). Building Information Modelling (BIM) Standards Manual for development and Construction Division of Hong Kong Housing Authority. China
[28].Roadmap to Lifecycle BIM | buildingSMART Canada. Retrieved from https://www.buildingsmartcanada.ca/roadmap-to-lifecycle-bim/ Retrieved from files/176/roadmap-to-lifecycle-bim.html
[29].Schlueter, A., & Thesseling, F. (2009). Building information model based energy/exergy performance assessment in early design stages. *Automation in Construction.*
[30]. Sinclair, D. (2012). *BIM Overlay to Plan of Work 2013 | Building Information Modeling*. RIBA Publishing Retrieved from https://www.scribd.com/document/188293181/BIM-Overlay-to-Plan-of-Work-2013 Retrieved from files/86/BIM-Overlay-to-Plan-of-Work-2013.html
[31]. Sinclair, D. (2012)." BIM overlay to the RIBA outline plan of work". *RIBA*.
[32]. Statsbygg. (2013). *Statsbygg BIM manual*. Norway
[33]. Succar, B., Sher, W., & Williams, A. (2012). "Measuring BIM performance: Five metrics". *Architectural Engineering and Design Management*.
[34].USGSA, G. (2007). BIM Guide Overview.*The National 3D-4D-BIM Program Office of the Chief Architect, Public Buildings Service, US General Services Administration*.

DOI: https://doi.org/10.54216/IJBES.020202

[35]. Wong, A., Wong, F. K., & Nadeem, A. (2009). "Comparative roles of major stakeholders for the implementation of BIM in various countries". *The International Conference on Changing Roles: New Roles, New Challenges, Noordwijk Aan Zee, The Netherlands*.

[36]. Wong, A. K. D., Wong, F. K. W., & Nadeem, A. (2011). "Government roles in implementing building information modelling systems: Comparison between Hong Kong and the United States". *Construction Innovation,11*.

[37]. Yuan, Y., & Yuan, J. (2011). "The theory and framework of integration design of building consumption efficiency based on BIM. *Procedia Engineering*.

DOI: https://doi.org/10.54216/IJBES.020202