BIM EXECUTION PLAN CONTENT AND DEVELOPMENT: A GLOBAL REVIEW

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Abstract

The BIM Execution Plan (BEP) is a process management document that includes the standards, the responsibilities and the protocols used as a basis for a BIM project. Despite the increased interest in BIM implementation, there are a few studies in the literature specifically tailored to the development of the BEP. This study aims to review and analyse the literature and synthesise existing knowledge relevant to the topic. The authors develop a thematic framework of BEP content aspects and trends to define grounds for developing BEPs by examining 34 publications from different organisations worldwide. Based on the framework, this research analysed a total of 29 topics classified into functional, informational, organisational and legal issues and identifies their influential relationships where applicable. This study has practical implications for defining project-specific BEPs, highlights the research gaps and provides recommendations for future development of BEPs, to be used both as an instrument for advancing the use of BIM and as a regulator of the digitalised and collaborative practices.

Keywords BIM Execution Plan, BEP, Execution planning, Execution process,
ICE keywords Building Information Modelling, BIM, project management
Paper type Literature review

1. Introduction

Building Information Modelling (BIM) is increasingly recognised as the best practice in the Architecture, Engineering and Construction and Operation (AECO) industry. BIM is defined as a digital representation of physical and functional characteristics of a facility, creating shared knowledge resources for information

about it and forming a reliable basis for decisions during its life cycle, from earliest conception to demolition (NIBS, 2007b). During the last decade, BIM has been the solution to fragmentation, poor project coordination and information management problems; still the project-wide benefits, such as the reduced rework, enhanced building value and improved productivity are subject to collaboration among the participants in a construction project that BIM facilitates (Eastman et al., 2011). As a result, several BIM documents have been developed in the industry to support the collaborative procedures and information management in a BIM project. These include standards, collaboration guidelines and project-level BEPs (Building Smart, 2016).

The BEP has many definitions and interpretations among the various guides, protocols and specifications and although the requirements of the BEP may differ in different contexts, the fact that the BEP is a central component of any construction project using BIM is generally accepted as a means of implementing BIM. The BEP is a process management document executed between the different parties of a BIM project and captures the team's overall vision and implementation details to follow throughout the project (PSU, 2011).

The value of a well-constructed BEP for the implementation of BIM has been acknowledged repeatedly in research. The BEP is defined as an example of a tool that reduces waste by bringing clarity to roles and deliverables and helps teams to develop a common understanding of how BIM will be used on the project (Fischer et al., 2017). In addition, it emerges as a business and managerial concern for projects; it is perceived as a solution procedure to implement BIM and enhances project delivery in construction (Hadzaman et al., 2016). Furthermore, the BEP facilitates industry players with BIM processes and constitutes a conceptual and practical link between conceptual construction processes and practice. As a result, the use of BEP in BIM implementation creates several legal and organisational challenges and seeks to streamline processes, minimises the possibility of missing or clashing information and ensure optimised project coordination (Hooper and Elkholm, 2010).

Despite the increased interest in BIM Execution Planning, there are a few studies in the literature specifically tailored to the development of a BIM Execution Plan. This paper aims at (1) a comprehensive literature review of BEP creation, implementation and research and (2) at the identification and discussion of current trends gaps in this area. The scope includes the development of the BEP in BIM-enabled projects and the identification of its content topics and structure in different contexts. The results of this research are useful for industry professionals and researchers involved in the development of BEPs in BIM projects.

The following Section 2 describes the research methodology applied in this research, Section 3 focuses on the state-of-the-art BEP research in academic publications, Section 4 examines the content of a selection of worldwide BEP publications by academic, governmental and industry organisations and discusses the results and research gaps, and Section 5 concludes the study's findings.

2. Research methodology

2.1 Originality

The literature review reports on a growing number of BEP documents published worldwide. Research shows prevalent differences in the content, structure, practice methods, contractual requirements, code compliances, project characteristics, social and cultural barriers amongst the various BIM execution planning guides (Sacks et al., 2016; Gercek, et al., 2015; Cheng and Lu, 2015). Existing BEP reviews focus on the presence or absence of selected BEP components (Ramirez-Saenz et al., 2018), or propose a simplified BEP framework (Bakar et al,. 2020) but no in-depth content analysis of all BEP elements is provided and as a result, all the aspects of the BEP as a process management document are not highlighted.

Some studies focus on the development of a BEP template to be used in a specific context, such as in Mega projects (Hadzaman et al., 2016), in the pre-operation phase (Lin et al.,2016), in a restoration building site (Lucarelli et al., 2019), or in green buildings (Issa et al., 2015), and sustainable design process (Zanni et al., 2014). Furthermore, few studies focus on developing a BEP template at a national or regional level, such as a BEP for India (Thirumeni, 2019) and the Check Republic (Hrdina and Matejka, 2016) or the United States (Ayerra et al., 2021).

Although a significant element of BIM implementation, the BEP has limited existing studies that mainly focus on the development and use of the BEP in a specific context or the creation of a BEP template; therefore, instead of proposing another BEP template, this study aims to identify and analyse the content topics of a BEP to identify the conditions that affect its development as well as provide an understanding of the influential dependencies between topics of a BEP.

2.2 Methodology

The research design follows a two-step approach (Figure 1). In a first step, publications in academic databases and conference proceedings related to BEP implementation were identified, published from 2010 to 2021. The keywords used for the search were "BIM Execution Plan", "BEP ", Execution Planning", "Execution process", and have been reviewed to identify key contributions. The review excludes research currently underway that is not available in databases or studies which have not been published in English yet.

In a second step, publications are identified that contribute to the development of a BEP from a) academic institutions, b) government authorities or agencies or states, c) industry professional organisations, d) national standards agencies, e) private companies. The main method used to review and analyse the BEP documents was conventional inductive qualitative content analysis, while the content types and topics that are used for the analysis were compiled from the documents themselves, with an additional organisation of topics according to their relevance (Hsieh and Shannon, 2005).

The first goal was to identify the occurrence of the topics used in the BEP to understand the document content and structure and the second goal is to identify the relationships and influential dependencies between the content topics to understand the factors that affect the development of a BEP.

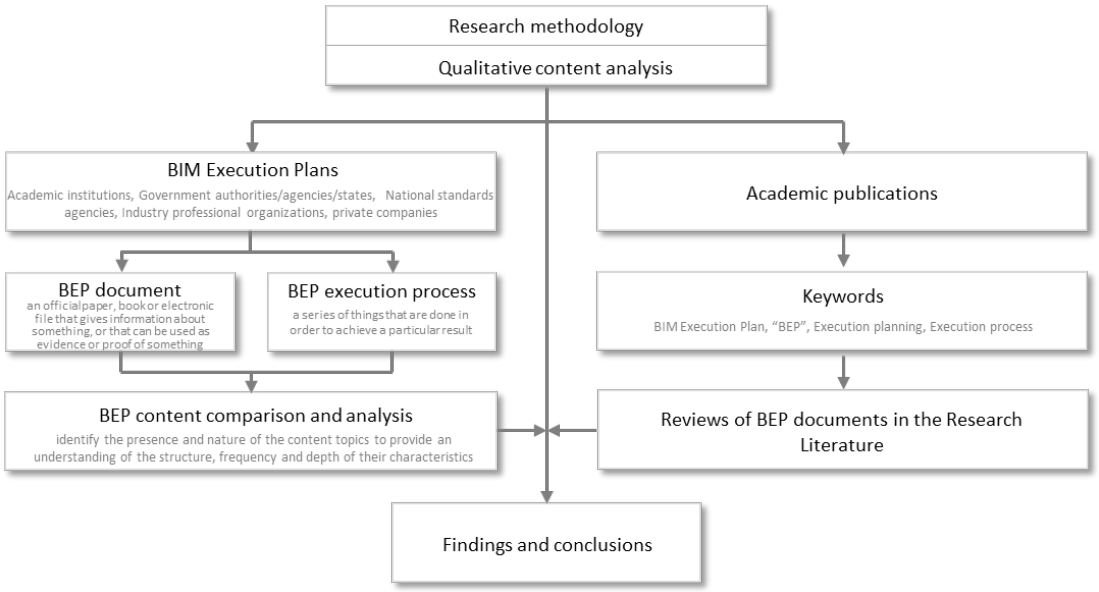


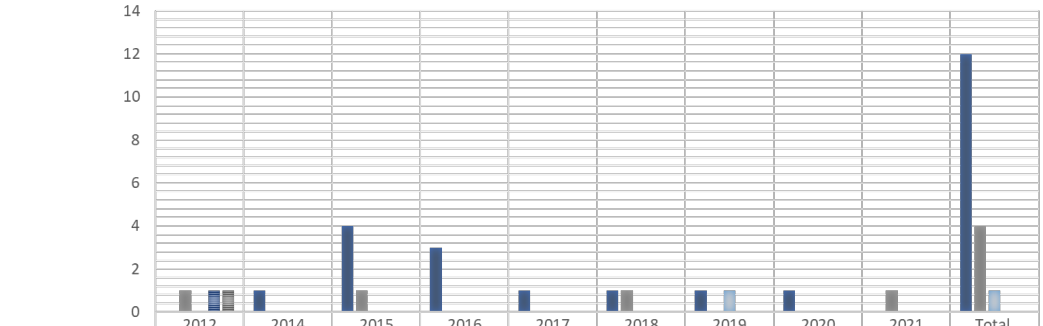
Fig. 1. Research methodology, qualitative content analysis diagram.

2.3 Data analysis

For the first step of the literature review, publications in academic databases and conference proceedings related to BEP implementation were identified, published from 2010 to 2021. Figure 2 shows the frequency of the reviewed publications per year of publication.

For the second step of the literature review, 34 documents in total were selected (Table 1,2) from national, governmental, academic and construction owner organisations that have published a plethora of BIM documents, including mandates, (prescriptive and dictated) guides, (descriptive and optional) and protocols, (prescriptive and optional) (Kassem et al, 2014) First, the review conducted by (Lin et al., 2016) on 123 publications, part of government bodies and non-profit-organisations BIM initiatives (from 2007 to 2015), was used to track the BEPs worldwide. Second, other resources, such as standards, collaboration guidelines and project-level BEPs, were collected from the listings in the BIM guides project (Building Smart, 2010).

The sole criterion for selecting these documents include their relevance to the BEP. Some publications include all the necessary information inside the BEP template, others provide a BIM guide and not a template, and some include both a template and a BIM guide. The publications of BIM manuals, guides, standards, or guidelines that do not include a requirement for a BEP were excluded. In addition, publications currently underway and not available in databases or studies not yet published in English were also excluded.



	2012	2014	2015	2016	2017	2018	2019	2020	2021	Total
journal papers		1	4	3	1	1	1	1		12
conference papers	1		1			1			1	4
Other							1			1

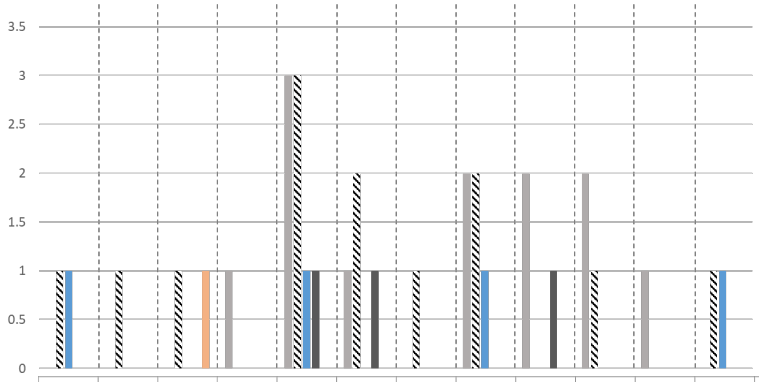
Fig. 2. Frequency of reviewed academic publications per year of publication.

The selected 34 documents represent four types of organisations:

- Academic institutions (13)
- Government construction authorities and agencies (13)
- Industry professional organisations / associations (4)
- National Standards agencies (3)
- Private companies (1)

Figure 3 shows the frequency of the selected publications per year of publication. The review examines not only the content of the BEP documents but also the guides, guidelines and BIM standards that support the development of the BEP, where applicable. Table 1,2 provides a list of the selected documents in review, organised by the type of the publishing organisation. The remainder of the paper refers to the documents using the short document name provided in Table 1,2.

From the review of the 34 documents, the following aspects emerged; BEP was perceived and described both as a) document (an official paper, book or electronic file that gives information about something, or that can be used as evidence or proof of something) (Oxford English dictionary, 2020a) and b) as a process (a series of things that are done to achieve a particular result*)* (Oxford English dictionary, 2020b).



	2007	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	Total
Total number of publications	2	1	2	1	8	4	1	6	3	3	1	2	34
Publications by Academic institutions				1	3	1		3	2	2	1		13
Publications by Government authorities and agencies	1	1	1		3	2	1	2		1		1	13
Publications by industry professional organizations / associations	1				1			1				1	4
Publications by National Standards agencies					1	1			1				3
Publications by Private companies			1										1

Fig. 3. Frequency of the 34 reviewed BEP publications per year of publication.

Based on this concept, the analysis of the content and structure of the BEPs revealed four major types of content. These are (1) the Scope of implementation, (2) Document procedures, (3) Infrastructure (organisational and technical), (4) Implementation process (Table 1,2). Each type is further analysed into specific topics related to the subject matter and the frequency of their appearance in the reviewed publications is also documented. The 29 topics within the four types of content selected for the BEP documents review are listed below.

Scope of implementation: If the document includes the BIM goals and/or uses to plan the BIM implementation, their depth of analysis and the description of delivery strategies included in the documents.

Document procedures: The availability of a BEP template, if the document is descriptive or prescriptive and legally binding. This type also includes document procedures to support the evolving nature of the document, the owner's BEP approval and data ownership and intellectual property issues.

Infrastructure: This type is divided into organisational and technical infrastructure sub-types. The organisational infrastructure addresses the roles and responsibilities in a BIM project and the description of the BIM Manager (leader or champion). The technical infrastructure includes the BIM software and hardware descriptions.

Implementation process: This type is divided into four sub-types. A short description of the content of each sub-type is provided below:

- Data/model generation: How the model is generated regarding the LOD reference (Level of development, or Level of Detail) file naming, modelling guidelines or standards, and model minimum requirements.
- Data/model management: The management and control of the model; the strategy to access and share data (e.g., Common Data Environment, CDE, the model strategy/division strategy (e.g.,

spaces, zones, levels), the data formats used for transmission, (e.g., Industry Foundation classes, IFC or native files), and the requirement of Construction Operations Building Information Exchange (COBie) data for operation and maintenance.

- Collaboration/information exchange: The use of process maps to define processes, the definition of information exchange, the data/model exchange and collaboration plan, the use of the information exchange worksheet, and the description of coordination meetings.
- Deliverables/project close down: The requested BIM deliverables and delivery format, the use of a schedule of deliverables, the quality control strategy, and the archiving/record requirements.

3. Reviews of BEP documents in the Research Literature

Many researchers have reported on the growing number of BIM documents published around the world. Sacks et al.,(2016) analysed 15 BIM documents and confirmed that the BEP content differs in different contexts while playing a central role in regulating the working process between the project participants. Lin et al., (2016) studied 123 BIM documents by non-profit agencies and government bodies in four regions; the study showed that very few standards cover all BEP content aspects, while almost one-third include the BEP, but no further details were provided. Ramirez-Saenz et al., (2018) reviewed 20 BEP documents and found the content of the complete BEP, but no additional analysis of the BEP elements is provided. Bakar et al., (2020) conducted a global comparison of 20 BEPs and proposes a simplified BEP framework to be followed for the BEP development. Gercek et al., (2015) conducted a comparative analysis of 23 BEP documents comparing the occurrence of their topics and highlighted the need for the use of standards in BEP development. Kassem et al., (2014) examined 13 BIM documents and proposed protocols for BIM collaborative design that can be used at a project level and aid in preparing BEPs to guide the project implementation.

Other researchers proposed and validated the content of a BEP in different contexts and provided insights about creating BEPs when working with different phases of a project. Lin et al., (2016) study on the during the pre-operation phase shows that the lack of skilled BIM-FM personnel and the amount of time to check the as-built models are of major importance. In addition, the involvement of both design and construction personnel and Q&M partners in the BEP development is critical to optimising project success (McArthur and Sun, 2015). Pruskova and Kaiser (2019) highlight the necessity of solving key issues for the proper use of BIM and BEP, such as technical standards, the content of BIM documentation, ownership and intellectual property, electronic building permitting and others. Cekin et al., (2020) showcase the benefits of using the BEP in line with ISO 19650-1 and ISO 19650-2 in residential projects. The need for the BEP template to be used in contracting is also highlighted in the reviewed publications (Hrdina and Matejka, 2016).

In addition, one of the most recent approaches to the BEP development refers to the Digital Execution Plan, DEP, which is perceived as the evolution of the BEP. The DEP is considered a response to the ongoing technological advances that can be incorporated in the design processes to reach the point where all software used by the design team is integrated seamlessly into the federated model, giving real-time feedback on proposals (RIBA, 2020). Last, the need for the advancement of the BEP, from a document type to a digital tool is reported in research (Klusmann, 2020).

4. Results and Discussion

4.1 Overview of the BEP content topics

The 34 reviewed documents suggest creating a formal BEP that documents how, when, why, to what level, and for which project outcomes BIM will be used. The fact that the BEP is not static, but a living document,

is highlighted in most of the documents, following the beginning, development, and completion of a construction BIM project.

The BEP is referred to by different terms in different publications (Table 1,2). For example, the term BIM Execution Plan, BEP or BIM Project Execution Plan is used by 25 publications. In the rest of the documents, the following terms are used: BIM Management Plan (BMP) (NATSPEC, 2016b), Integrated delivery plan, (IPD) (Indiana, 2015), Integrated Project Methodology Plan, (IPP) (GT, 2016), Project BIM Work Plan (LACCD, 2017a), Implementation plan (COE 2009), BIM plan (Senate, 2012), BIM Manual (Statsbygg, 2013), Project implementation plan (CIC, 2015), Autodesk BIM Deployment plan (Autodesk, 2010) and the Project Building Information Modelling form (AIA, 2013c).

The author performed a statistical analysis from Tables 1 and 2 to determine the complete BEP in terms of the topics identified in the four examined types. As a result, the three most complete BEPs are the VA (2017a) at 73.50%, followed by the GSA (2007a) at 70.58% and the DCAMM (2015b) at 67.64% (Figure 4). However, the higher percentage is not an exact indication of a better BEP performance and should be considered in terms of the context and the specific conditions it is developed.

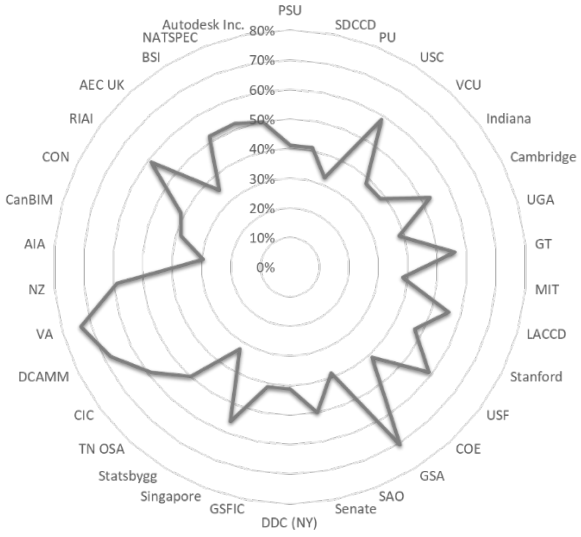


Fig. 4. The most complete BEP in terms of the topic identified in the study of the 34 documents in the review.

Figure 5 shows the total percentage of the 29 topic's occurrence over the 34 documents. The analysis reveals that the topics (1) BIM goals, (2) roles and responsibilities (3) BIM deliverables, (4) archiving/record (5) LOD specification (6) coordination meetings (7) data formats for transmission (IFC) and (8) file naming conventions have the highest occurrence in the reviewed documents (over 70%). The topics with the lowest occurrence (under 40%) are the (1) hardware, (2) process maps, (3) legally binding and (4) prescriptive.

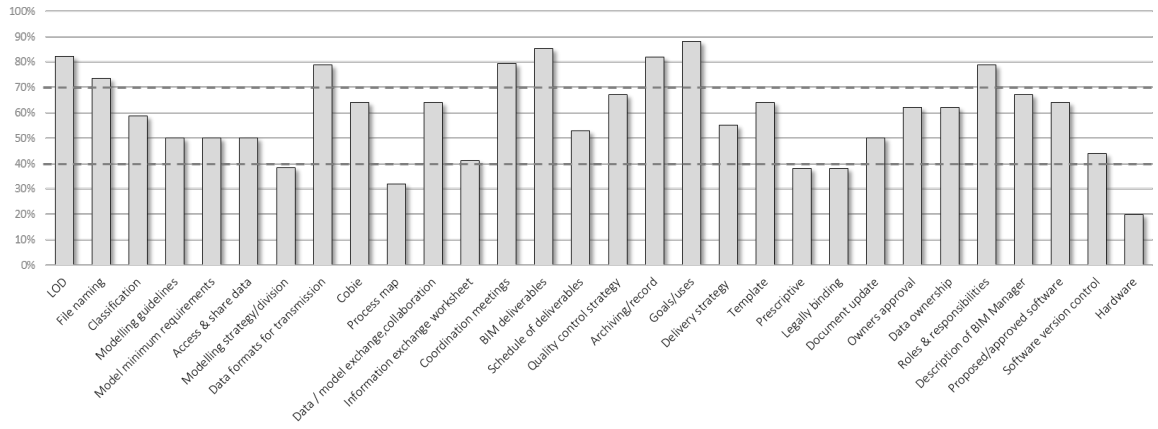


Fig. 5. The total percentage of the 29 topics frequency in the 34 reviewed documents.

In this paper, the content types and topics are further organised and classified on a thematic framework developed for this study (Ritchie and Lewis, 2003). This framework (Figure 6) lists five major categories, the Functional, Informational, Technical, Organisational and Legal issues categories (Volk et al., 2013). In this study we refer to Functional issues as those relative to BIM uses and goals, delivery strategy, BIM Accuracy (LOD) and BIM Capability issues. The Informational issues include the topics that support the exchange and management of information, such as the CDE and the process maps, and the Technical issues represent the topics that support the generation and delivery of information, such as modelling minimum requirements and BIM deliverables. The Organisational issues category determines the document procedures and the organisational and technical infrastructure, and the Legal issues category includes the BEP relationship with BIM contracts, data ownership and intellectual property issues.

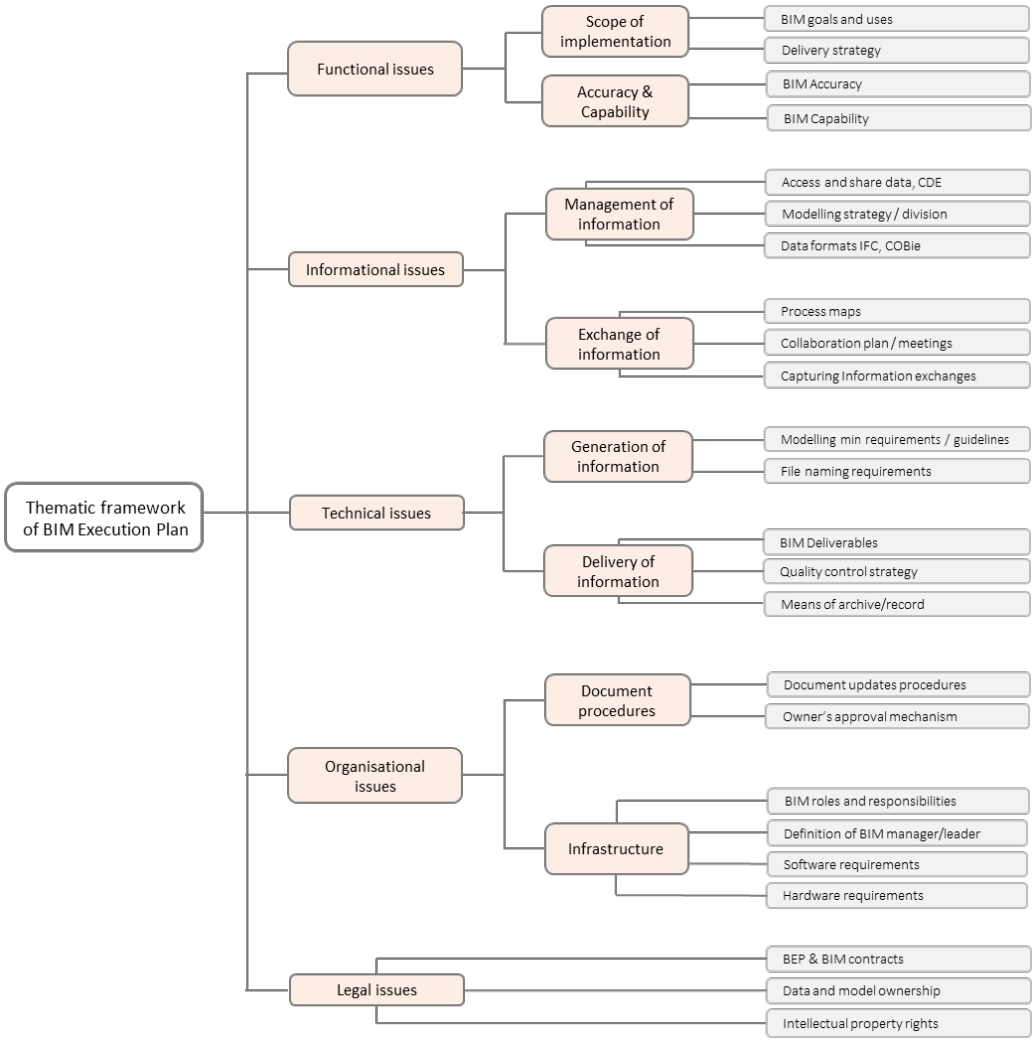


Fig. 6. The thematic framework of the development of a BEP.

Figure 7 shows the influential dependencies between the categories in the framework. The Functional issues depend mainly on project scope and delivery strategy, the BIM accuracy and capability, as well as on the project lifecycle stage (Volk et al., 2013) and determine the Informational, Organisational and Legal issues. Functional and informational requirements again determine the Technical issues, such as the topics related to the model generation and delivery, through the LOD, required model capacities and creation and delivery processes.

For example, for the goal of Achieving sustainability targets, the BIM use of the Energy analysis is required, (functional issue) and specific information is needed relating to detailed weather data and national local building energy standards. The BIM use is then placed in a process map that results in data exchange through the CDE (Informational issues). The organisational and legal structure, in terms of the BIM roles described in the BEP and BIM contracts, determines the access to the data exchange, defines responsibilities for the input and data analysis and the owner's approval mechanism. In addition, the selection of BIM uses for achieving a specific BIM goal (Functional issues) also determines the use of the proposed software and hardware associated with them (Organisational issues) and the data formats (Informational issues) determine the BIM deliverables (Technical issues). In the following, we provide an

in-depth analysis of the 5 categories and content topics in review and present the research gaps and discussions.

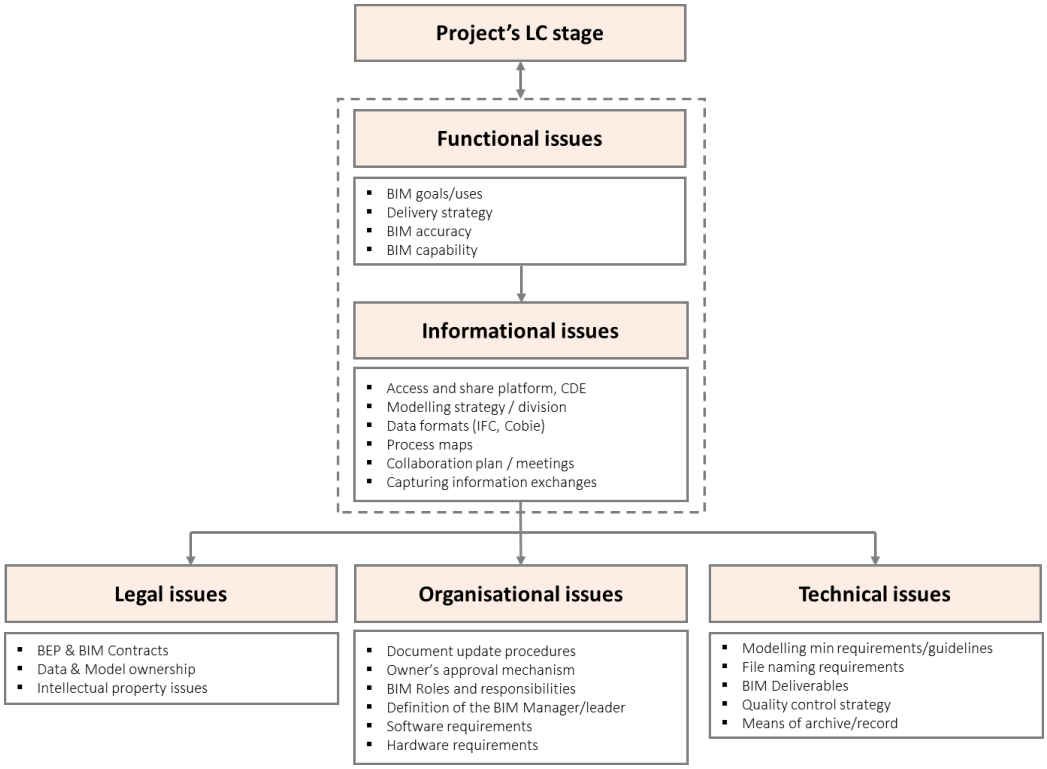


Fig. 7. Relations between Functional, Informational, Technical, Organisational and Legal issues in the BEP development, adapted from Volk et.al., 2013.

4.2 Functional issues

4.2.1 BIM goals/uses

The definition of BIM goals is one of the most critical steps in the planning process; they are based on project performance, the specific BIM uses of the project can be identified (PSU, 2011a). Model uses can be specific to the design, construction, and operation phases or across all lifecycle phases (Succar and Kassem, 2014) to achieve BIM goals (NIBS, 2007b). Thirty from the 34 documents contemplate the definition of the **BIM goals and uses**, however they vary in the depth of analysis they describe. Some focus on the project goals in connection with the potential BIM uses based on a priority sequence (high, med, low) (USF, 2018a; PU, 2012; MIT, 2016a; GSA, 2007a), whereas others require BIM uses to be documented in a separate document and not in the BEP (Stanford, 2017a; Cambridge, 2015b; NATSPEC, 2016a). Some documents list BIM use case templates for each of the project stages (Singapore, 2013a) or provide two distinct types of BIM uses, the mandatory model uses (with a reference to the US National BIM Standard), and optional elective model uses (non-contractual/innovative) to provide the contractor with the opportunity to use non-mandatory contractor-developed model uses (VA, 2017b).

4.2.2 Delivery strategy

The review shows that the BEP development can be aligned with the chosen delivery strategy. For example, for the Design-Bid-Build strategy, a Design and a Construction BEP is recommended, whereas for the Integrated Project Delivery one BEP is considered sufficient (DDC, 2012). There are also cases that three BEPs should follow the design, tender and construction stages (CIC, 2015), or a pre-contract BEP, and a post-contract award BEP are developed (BSI, 2013). Another approach to the BEP development indicates four major BEP milestones: The Mobilisation BEP, the BIM Kick-off Meeting BEP, the Substantial Completion BEP and the Coordination BEP (TN OSA, 2020).

The traditional Design-Bid-Build, Design-Build and Integrated Project Delivery are the three most common procurement methods used in the documents (Figure 8). Some documents go even further and suggest using the Integrated Project Delivery as the appropriate delivery approach for the BIM project to support open line communication between all disciplines (GT, 2016; USF, 2018a; PSU, 2011a; Indiana, 2015; SDCCD, 2012).

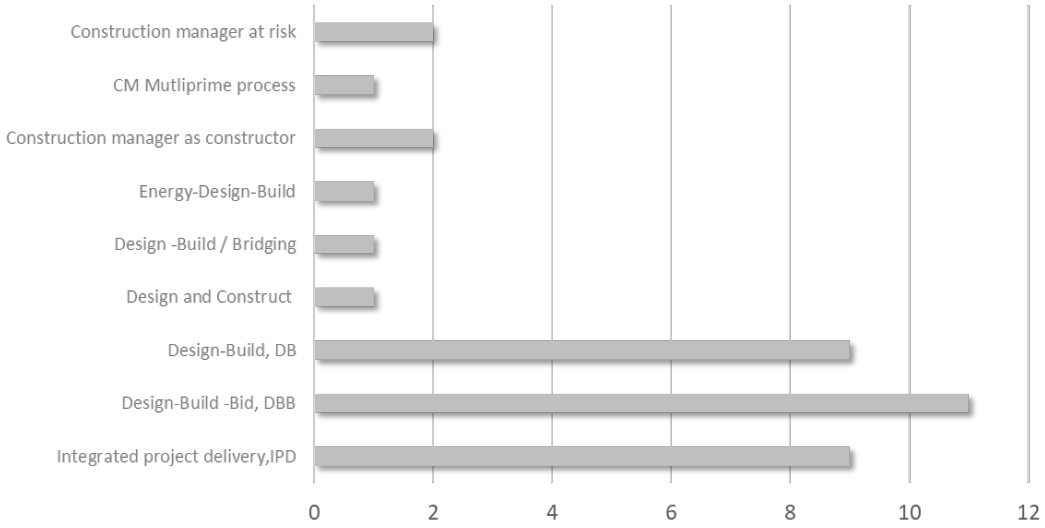


Fig. 8. The variety and frequency of the different delivery methods used in the reviewed documents.

However, IPD is not the only procurement that suits the BIM practice; other delivery strategies that facilitate the BIM development should be considered, such as Project Partnering, Project Alliancing (PA) (Lahdenpera, 2012) Cost led procurement (CLP), Integrated Project Insurance (IPI) and Two-stage open book (Cabinet Office, 2011). Future research might investigate approaches for improving the BEP use in different procurement methods that promote collaboration among parties and enhance project performance.

4.2.3 BIM accuracy

The topic of BIM accuracy refers to information richness and actuality of the underlying data to fulfil their purposes (Volk et al., 2013). The AEC industry standard to describe information richness of BIM is the LOD reference that helps teams to document, articulate and specify the content of BIM effectively. This topic appears in the 28 from the 34 documents in the review. There are two main approaches in the industry used in the reviewed documents: the reference **Level of Development (LOD)** (BIM Forum, 2020) and the Level of Detail (LOD) and Level of model information (LOI) (BSI, 2013).

The confusion of the different interpretations of the LOD in the industry could be minimised by adopting the Level of Information Need Framework (EN 17412-1, 2020) that aims to normalise the quality, quantity and

occurrence of information developed in a BIM project. The Level of information Need should be used to discuss and agree on the information delivery between two or more actors; for example, for the Information requirement of project regulations, the Level of Information Need should be appropriate to the geometry, information, and documentation concerning the planning and building regulations. The acceptance criteria for this case are to be delivered before the design phases. Adopting a coherent industry-wide framework is an essential step for achieving efficient communication in BIM and coordinating expectations between project participants in different contexts.

4.2.4 BIM capability

Although the topic of BIM capability is not extracted from the reviewed documents, it is significant to include it under the category of Functional issues (Volk et al., 2013). BIM capability evaluates if BIM projects and supporting processes reach the desired level of functionality. For example, the Capability Maturity Model assessment framework formulates minimum capabilities and requirements of BIM model and process maturity in ten levels (NIBS, 2007c), or the BIM Maturity Matrix is developed in two axes, the BIM capability and BIM maturity, across 5 stages (Succar, 2010).

The proposed BEP methodology, in terms of how suitable a BEP is for a project, has been considered in several BIM capability frameworks as a capability criterion, such as the VDC Scorecard (under the standards division), (Kam et al., 2017), the University of Pennsylvania (PSU, 2011a), the reference model CAREM (under the BIM collaboration attribute) (Yilmaz et al.,2019), the framework BIM CAT (under the strategic competencies category) (Giel and Issa, 2014), and the IU BIM proficiency Matrix (under the IPD methodology category) (Indiana, 2015). In addition, the suitability and innovativeness of the BEP along with the staff experience are considered the most influential criteria for the overall BIM Modelling success and is closely associated with the delivery of BIM models on schedule (Mahamadu et al.,2018), with the project cost success (Celoza et al.,2021) and with project delivery speed and perceived quality (Franz and Messner, 2019).

None of these studies has, however, specifically looked at the influence of the BIM Execution Plans as the proposed methodology on actual BIM delivery success on projects to aid more informed and suitable BEPs for the implementation of BIM in a project. Further empirical studies on the proposed methodology through the use of BEP and their delivery success on projects could provide insights on the links between BIM capacity and overall delivery success.

4.3 Informational issues

4.3.1 Access/share data

The topic access/share data refers to the use of a CDE and is included in half of the reviewed documents but not with the same description. The CDE is generally defined as a single source of information used to collect, manage and disseminate project information. Examples of a Common Data Environment are a shared network location, an online project portal and cloud-based collaboration tools (AEC UK, 2012). The CDE was first defined in BS 1192 (BS 1192: 2007 + A2:2016, 2007) and is developed in 4 areas, the work in progress, shared, published and archive areas. The review shows that some documents follow the CDE collaboration structure defined in BS 1192 (CanBIM, 2012; RIAI, 2019a; Cambridge, 2015a), whereas others describe an internal specific file-sharing system to share project data (LACCD, 2017a; Indiana, 2015; PU 2012).

4.3.2 Modelling strategy/division

The topic model strategy/division occurs at the 13 from the 34 documents in review and its description differs in the publications. The model strategy division or volume strategy is the manageable spatial subdivision of a project that allows more than one person to work simultaneously and consistently with the analysis and design process (BSI, 2013). The model division usually depends on the size and phasing of the building and could include separate parts, zones and levels (GT, 2016); it can be also developed on a level-by-level division of a multi-storey project (Senate, 2012), or floors can be splitted into zones to reduce file size (USF, 2018a). In other cases, the model containment hierarchy is dictated by the software used (GSFIC, 2013) or is based on separate discipline models (CIC, 2015).

4.3.3 Data formats/IFC, COBie

The use of the IFC Standard as the data format for transmission to ensure interoperability and as a BIM deliverable format is highlighted in most of the documents (27 from the 34), confirming the need for a universal standardised approach to information exchange between different software. When discussing information exchange in a BIM project, there are two paths; the open BIM compatible with the IFC Standard (ISO 16739-1:2018, 2018) or a single platform path that is BIM software specific. Although there is a universal consensus on the use of IFC in the industry, the standard has still some limitations on its implementation, and that is why information exchanges between different software are still considered a challenging task in the AECO industry.

The COBie topic occurs at 22 from the 34 documents in the review. COBie is defined as a deliverable in the construction phase to be used later in the asset's operation and maintenance. Some documents define COBie as a BIM and facility data requirement but provide no specific information (MIT, 2016b), whereas others require specific worksheets to be developed (GT, 2016; Stanford, 2017b; UGA 2015). In addition, Cambridge BEP (Cambridge, 2015a) incorporates a COBie drop schedule in the BEP that monitors and validates major project phases in an earlier intermediate delivery, documenting the state of the project.

4.3.4 Process maps

The review shows that the topic of process mapping has low occurrence among the documents; only 14 documents include process maps, although process mapping is generally acknowledged as a means to clarify workflows in a BIM project (VA, 2017a; PSU, 2011a; GT, 2016). The alignment of process mapping with the BEP is acknowledged as a lean principle (DCAMM, 2015b) and process maps can be attached to the BEP to clarify workflows and the collaboration strategy (PSU, 2011a; GSA, 2007a). Some documents follow the development of process maps in compliance with the Information delivery Manual, IDM (Building Smart, 2010) that documents the team's strategy to specific project requirements and performance goals; others align with the Level 1 and 2 process maps to describe information exchanges and process flow, following the PSU guide (VA, 2017a). In addition, the process execution planning can be aligned with the stages of the procurement method, such as the Design-Bid-Build, the CM multi-prime and the Design-Build workflows (SDCCD, 2012), or follows the design, tender and construction stages (CIC, 2015).

4.3.5 Collaboration plan/meetings

Although the topic of data/model exchange that refers to a collaboration plan has high occurrence (it is included in 22 from the 34 documents) only a few documents include a detailed description; it may include the meeting's frequency and attendees, the model conversion and the exchange of information (SAO, 2010), it may be captured in a three-step diagram including model creation, model coordination and frozen and released models (Singapore, 2013b) or it may include five major areas; document management, bid management, construction management, cost management and project closeout (Autodesk, 2010). The

collaboration plan may also include quality control measures and the as-built modelling plan (SAO, 2010), or it may include items such as electronic communication requirements and procedures, document management, software versioning, file transfer and updating and record storage (VA, 2017b).

BIM managers or leaders use coordination meetings to manage, control and validate project information; regular coordination meetings reduce coordination issues, such as Request for information, RFIs and change orders (VA, 2017a). The review shows that coordination meetings appear at the 27 from the 34 publications. Some documents require mandatory meetings (NATSPEC, 2016a; NZ, 2019a; RIAI, 2019b), whereas others require only clash resolution meetings (VCU, 2013). The collaboration meetings could be type-specific, such as the BIM requirements kick-off, the BEP development, the design coordination, and the construction over-the-shoulder progress reviews (USF, 2018a).

4.3.6 Capturing information exchanges

Most of the reviewed documents define information exchanges as models in both native and IFC formats. The information exchange worksheet as means of capturing information exchanges occurs at 14 of the 34 reviewed documents and is being developed according to the model uses (MIT, 2016a), or to each discipline (USC, 2012). In addition, the information exchange worksheet identifies the responsible parties, the frequency, the design authoring software, and the version to be used with the associated BIM uses, along with the collaboration exchange format (NZ, 2019b). In two publications, the information exchanges and the collaborative practices are not defined in the BEP but in the Exchange information requirements, EIR (BSI, 2013; RIAI, 2019a).

4.4 Technical issues

4.4.1 Modelling min requirements /guidelines

Half of the reviewed documents incorporate both modelling guidelines and model minimum requirements highlighting the need to adopt a structured approach at the early stages of a BIM project. They may include discipline modelling guidelines, model set-up requirements and model coordination (CIC, 2015; NZ, 2019a, Indiana, 2015; Singapore, 2013a) or they are divided into BIM modelling, and 2D drawings requirements (NATSPEC, 2016a) and this is evidence that the industry transition from the 2D processes to the integrated 3D digital model's environment is not yet completed.

The model minimum modelling requirements have different approaches; they are defined by the BIM use cases for the design and construction phases (Stanford, 2017a) or each discipline model (COE, 2009; CIC, 2015; Statsbygg, 2013). Minimum requirements could also include the site, building and system models (SDCCD, 2012) or they are set for Tier I (spatial program BIM), Tier II (Geometry and Applications) and Tier III (Object Intelligence and BIM applications) (GSA, 2007a).

4.4.2 File naming requirements

Although the topic of file naming appears in the 25 from the 34 documents, it is not defined equally. A consistent file naming structure is considered critical for BIM referenced files to function properly across teams and end-users, so teams shall define a file protocol during the development of the BIM Management plan (NATSPEC, 2016b). In addition, some documents require specific file naming conventions in line with the industry standard BS 1192: 2007 + A2:2016 (2007) (CanBIM, 2012; RIAI, 2019a) whereas others develop internal file naming guidelines (DDC, 2012; TN OSA 2020).

4.4.3 BIM Deliverables

The BIM deliverables topic has the highest occurrence among all the topics in review. They can be developed with the content, level of detail and format as required by the BEP and should be consistent with the Level of Development for each phase (USF, 2018a; VCU, 2013). They can also be defined according to the design and construction stages (VCU, 2013; SAO, 2010; DDC, 2012; CON, 2015) or are aligned to the BIM uses (DCAMM, 2015a). The BIM deliverables can be either captured in a schedule in the BEP (MIT, 2016a; Stanford, 2017a; Singapore, 2013c) or they can be listed in the Task Information delivery plan (TIDP) and the Master Information delivery plan (MIDP) (BSI, 2013; RIAI, 2019a).

The review shows that BIM deliverables are most commonly a combination of 3D modelled information and two-dimensional outputs (Cambridge, 2015a; NATSPEC, 2016a) and this highlights the fact that earlier CAD process outputs still influence BIM implementation, and this is in contrast with the general concept of using 3D digital models as the primary means of working with BIM. However, the national standard agencies reflect a more holistic approach based on the standardisation of BIM processes and deliverables.

4.4.4 Quality control strategy

The review shows that the quality control strategy appears in the 23 from the 34 publications. The quality control strategy includes quality modelling control and assurance checks at each project milestone, in line with the modelling quality control guidelines and exchange protocols (Indiana, 2015). The quality control procedures include visual checking, intersection and clash detection, the standards and the model data check and automated BIM checks as they are described in the Exchange Information requirements (Cambridge, 2015a) or the Quality assurance guide (Senate, 2012). BSI (2013) requires a detailed check review and approval process to be carried out before issue to the Shared area of the Common Data environment, CDE by the employer or the representative.

4.4.5 Means of archive/record

The topic BIM archiving/record occurs at 28 from the 34 documents. This topic refers to the construction of as-built models delivered to the owner at the end of the project and includes graphical and non-graphical information relating to the asset (NZ, 2019a). The construction as-built BIM models can be archived in native and ifc. formats (Stanford, 2017a) while the record files could be print files in pdf. or tiff. formats to avoid creating an excessively large file (MIT, 2016b); they could also be provided in a digital form that allows information to be easily retrieved by anyone with basic computer skills (NATSPEC, 2016a).

4.5 Organisational issues

4.5.1 Document update procedures

In terms of the document updated procedures, half of the publications acknowledge the need for the continuous development of the BEP during a BIM project. For example, the BEP update procedures may be time-specific; the BEP should be updated 30 days after the contract award (SAO, 2010; UGA, 2015). In addition, the BS EN ISO 19650-2 (2019), provides a list of prerequisites for updating the BEP during the activities within the project lifecycle, while in other publications, the document update procedures are aligned with the key milestones of the project (TN OSA, 2020).

4.5.2 Owner's approval mechanism

The BEP is also considered an effective tool for the owner to coordinate expectations from the design and construction teams and to set clear goals for using BIM in a project and at the same time constitutes a formal response to the Employer's Exchange Information Requirements (BSI, 2013; RIAI, 2019a). This topic occurs at 21 of the 34 documents and while some publications have a provision for BEP client approval (Singapore, 2013a; NATSPEC, 2016a; BSI, 2013), others are not explicit on this topic, resulting in an increased risk for the owners (Ashcraft, 2008). Some documents (Singapore, 2013c) require that any changes to the BEP should be made with the permission of the employer or the appointed BIM Manager, and in the publications that the BEP content is developed in more than one document, they should be all submitted to the client for review and approval (NATSPEC, 2016a; Indiana, 2015; GT, 2016).

4.5.3 Organisational infrastructure

The definition of roles and responsibilities occurs at the 27 from the 34 documents. These roles extend beyond the traditional roles in a construction project, generally representing the strategic, management and production functions in a BIM project (AEC, UK 2012). The findings also reflect the differences in the definition of the BIM **roles** used in the industry; 35 different BIM titles are used in the 34 publications with an organisational structure that follows a similar hierarchy with some differences in the terms used; with a simplified view, the BIM manager leads the project, the discipline BIM lead manages a specific discipline, and the model element authors create and manage the models (NZ, 2019a). Figure 9 shows the variety of the BIM role titles specified in the reviewed documents. The most frequent titles are the BIM manager, the project manager and the BIM coordinator.

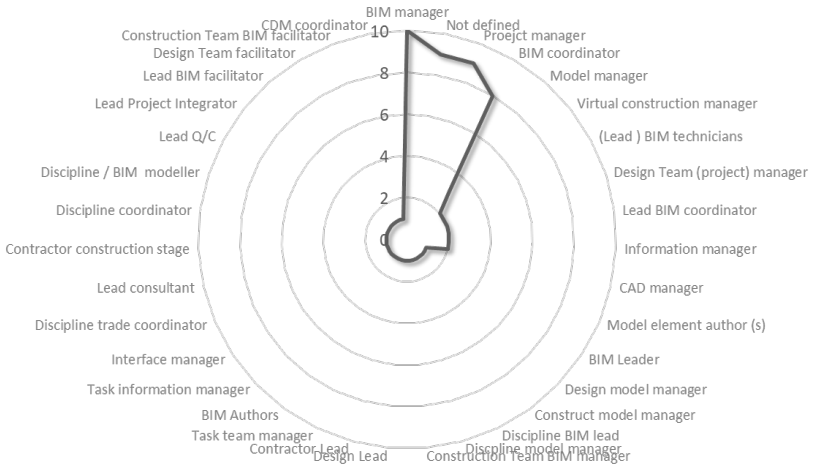


Fig. 9. The variety and frequency of the BIM roles titles used in the reviewed documents.

In terms of the definition of the leading role of the BIM Manager, most of the documents describe both technical and organisational responsibilities; it is defined as the person who oversees the project and is responsible for carrying out, directing, and coordinating all work associated with the BIM models. In addition, the BIM manager can also be responsible for providing authoritative advice, assistance and information on all matters related to BIM (COE, 2009). The occurrence of the BIM leading role titles described in the reviewed documents is shown in Figure 10. The title of the BIM manager is used in 10 documents, the project manager in 6, and the Information manager and the BIM coordinator titles occur two times each. In some cases, the BIM manager role can also be played by a Lead consultant or BIM specialist (Singapore, 2013a) or it can be supported by a model manager that advises on all the BIM technical related issues (Stanford, 2017b). In other documents, there is more than one leading role; (DCAMM, 2015a) the BIM

manager responsibilities are divided into the Design and Construction BIM manager roles, and in the case of the Design-Build, there will be a separate Model manager for the Architectural Engineer team and the General contractor (VA, 2017b). In smaller projects, the BIM manager could perform all functions (CanBIM, 2012).

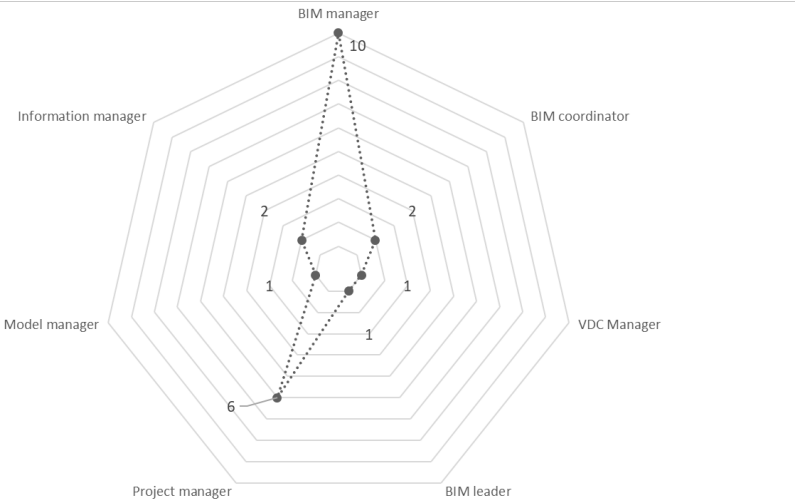


Fig. 10. The frequency and variety of the leading BIM role titles used in the reviewed documents.

4.5.4 Technical infrastructure

Almost half of the reviewed documents include software specifications, while most of them are software vendor-neutral and suggest software that complies with the Industry Foundation Classes, IFC format. Some publications include a list of approved software for BIM authoring, collaboration and clash detection (USF, 2018a; UGA, 2015), and others require a specific BIM model type, such as the rvt. file (Autodesk Revit) for all the BIM authoring software and the nwd. viewer (Navisworks) for reviewing the 3D BIM models (Indiana, 2015). MIT (2016a) goes even further and dictates the production of dwg. and pdf./tiff. formats according to the National CAD Standards and lists the acceptable formats and versions for the construction and record documents. Other publications suggest a specific software for each BIM use (GSA, 2007b; Senate, 2012; GSFIC, 2013; GT, 2016; DDC, 2012). The hardware specifications occur only in 7 documents and include the operating system, CPU, memory, video cards, hard disk space and network speeds (CIC, 2015; GSA, 2007b).

4.6 Legal issues

4.6.1 BIM contracts

The review highlights the need of addressing legal issues in BIM contracts and their relationship to the BEP; from the 34 reviewed documents, only 13 are legally binding documents and prescriptive in nature. The review shows that major legal issues arise when a BEP is used. First, the BEP generally does not form part of the contract (Hardin and McCool, 2015; Oluwole, 2014) and the unclear roles and responsibilities give rise to legal liabilities (MacAdam, 2010; Fan, 2018). Second, there is a lack of contract forms that clearly mandate BIM practices and address legal concerns (Ashcraft, 2008). In addition, in BIM-enabled projects, it is usually impossible to define every aspect of BIM early in the contracting stages and as a result, the BEP can provide the mechanism to discuss some details later in the project (Abdirad, 2015). Therefore, further studies should focus on the contractual relationships, particularly the definition of the

boundaries between the BEP and BIM contracts; due to the legal issues related to collaboration caused by duties and obligations that transcend boundaries (Lowe and Muncey, 2008).

4.6.2 Data ownership

The ownership of digital data and intellectual property topics occur at 21 of the 34 documents. The review shows that they are no consensus on this topic among the publications. The ownership of the model author is limited to the duration that fulfils the scope of the project (Singapore, 2013b) while the project participants own the copyright license of their contribution and do not possess rights in a Model, or a joint work greater their contribution (CON, 2015). In other cases, the ownership of data may be transmitted from the design to the construction suppliers (BSI, 2013) or the copyright of digital data belongs to the transmitting party and once transmitted, the ownership of the data does not exist (AIA, 2013a). In addition, the BIM model may be considered an instrument of service defined in the contract (GSFIC, 2012) or the BIM and CAD files are not contracted documents and they should not govern instead of them (TN OSA, 2020). A clear definition of the intellectual property rights, model ownership, liability issues, and the decision whether the BIM model is a co-contract document prevents unwanted disputes between parties in BIM-enabled projects.

5. Conclusions

The conducted literature review presented the state-of-the-art implementation and research of BEP content and structure in BIM projects. Despite the fact that the development of the BEP has always been a fundamental requirement for successfully delivering project objectives in BIM-enabled projects, there are limited studies in the literature specifically tailored into the issues that influence the development of BEPs. This study has addressed this gap by identifying and analysing 29 topics within 34 BEP documents, published from different organisation types, sizes and countries of origin, to identify the ground that needs to be explored for defining successful project-specific BEPs. The BEP content topics are organised in a thematic framework with 5 major categories, the Functional, Informational, Technical, Organisational and Legal issues. In the discussions section, the topics within the 5 categories are analysed in terms of their content and occurrence, and their influential relationships are discussed where applicable.

The analysis highlights the importance of the Functional issues that determine the Informational, Technical and Organisational and Legal issues; therefore, an industry consensus on the definition of accuracy and capability as determine factors of the BIM execution planning process is vital. In addition, the study shows that the Informational issues form the link between the Functional and the Technical, Organisational and Legal issues and should be considered the core content of the BEP by the BEP developer. The analysis of the Informational issues also shows that there is a higher level of maturity in some topics, such as the use of the IFC, COBie requirements and coordination meetings, whereas other topics have not the anticipated occurrence, such as the model division strategy, process mapping and the access and share data/platform topics. The generation of a unified, standardised approach to capturing the components of the implementation process in the BEP could reduce conflicts between different organisation types and contexts.

Furthermore, the relationship of the BEP and BIM contracts is not yet mature in BIM implementation, and this gives rise to legal liabilities between project participants. The BIM contract protocols, such as the ConsensusDOCS 301, the AIA Document E203-2013 and the CIC BIM Protocol define clearly that each party owns its personal contribution and provide a comprehensive intellectual property licensing procedure, over other contract documents. The review also shows that the chosen procurement method, as an organisational arrangement is considered a critical factor for defining the number of BEPs in a BIM project. If the BEP is a practical link between the conceptual construction processes and practice, then teams need

a structured approach to the BEP development in line with the project stages and milestones, following the beginning, development, and completion of a construction BIM project.

Finally, this study has some limitations. Although the findings are valid, they do not reflect all the potential advances in BEP development as they lack empirical implementation of BEP in BIM projects. Although a "one solution fits all approach" would support BEP standardisation, the analysis shows that several contextual factors should be considered for the successful use of the BEP. Future research should focus on a large-scale data collection using BEPs from the industry where the BEP is implemented in different types and scales of BIM projects, to reflect issues that optimise the use of BEP and provide standarlisation across the industry. Future research could also use the proposed framework and content topic analysis to examine how the different types of projects and local contextual and contractual factors affect the development of the BEP in practice.

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BEP documents		Detail level	Term used	Scope of implementation		Document procedures						Infrastructure				
												Organizational (Roles and responsibilities)		Technical (Software, Hardware)		
Publication date	Document short name	Highly detailed*** detailed ** few details*	Abbreviation	Goals / Uses	Delivery strategy	Template Y or N	Descriptive D Prescriptive P	Legally binding Y or N	Document update procedures	Owners approval	Data ownership	Roles and responsibilities	Description of BIM manager / leader	Software requirements	Software version control	Hardware
Universities																
2011	PSU	**	BEP	●	●	Y	D	N						●	●	●
2012	SDCCD	*	BEP	●	●	N	D	N		●	●			●		
2012	PU	*	BEP	●		Y	p	N	●					●	●	
2012	USC	***	BEP	●	●	Y	P	Y	●	●			●	●	●	
2013	VCU	**	BEP			N	P	Y		●	●	●	●	●	●	
2015	Indiana	**	BEP - IPD		●	N	P	Y		●	●			●		
2015	Cambridge	***	BEP	●		Y	P	N	●	●		●	●		●	
2015	UGA	*	BEP	●		Y	P	Y	●			●		●		
2016	GT	***	BEP - IPP		●	N	D	N		●	●	●	●	●		
2016	MIT	**	BEP	●	●	Y	P	N				●	●	●		●
2017	LACCD	**	BIM Work Plan	●	●	N	P	N		●	●	●	●	●	●	
2017	Stanford	**	BEP	●		Y	D	N			●	●	●			
2018	USF	***	BEP	●	●	Y	P	N			●	●	●	●	●	
Government authorities / agencies/states																
2009	COE	*	IP	●	●	N	P	Y	●	●	●		●	●		
2007	GSA	***	BEP	●	●	Y	D	N	●	●	●	●	●	●	●	●
2010	SAO	*	BEP	●	●	Y	D	Y	●	●	●	●				
2012	Senate	***	BIM plan	●		N	D	N		●		●	●	●	●	
2012	DDC	**	BEP	●	●	Y	D	N		●	●	●	●	●	●	
2012	GSFIC	*	BEP	●	●	Y	D	Y			●	●		●		
2013	Singapore	***	BEP	●	●	Y	P	Y	●	●	●	●	●	●		
2013	Statsbygg	**	BIM Manual	●		N	P	N				●		●		
2014	TN OSA	**	BEP	●		N	D	N	●	●	●	●	●			
2015	CIC	***	PxP	●		N	P	Y	●	●		●	●			●

2015	DCAMM	**	BEP, BIMxP	●	●	Y	D	Y	●			●	●	●	●	●
2017	VA	***	BEP; PxP	●	●	Y	D	N	●	●	●	●	●	●	●	
2019	NZ	**	BEP	●	●	Y	D	N	●		●	●	●			
Industry professional associations																
2007	AIA	**	Project BIM protocol form	●		Y	P	Y		●	●	●				●
2012	CanBIM	***	BEP	●		N	D	N				●	●			
2015	CON	*	BIM Addendum	●		N	D	Y		●	●	●	●			●
2019	RIAI	***	BEP			Y	D	N	●		●	●	●	●	●	
National Standards Agencies																
2012	AEC UK	*	BEP	●		**Y**	D	N		●						
2013	BSI	*	BEP	●		N	D	N	●	●	●	●	●		●	
2011	NATSPEC	***	BMP	●	●	**Y**	D	N	●	●		●	●			
Private company																
2010	Autodesk	***	BDP	●	●	N	D	N	N		●	●		●	●	

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617 **Table 1.** The occurrence of the types "scope of implementation", "document procedures" and "infrastructure" and their topics in the
618 34 reviewed documents.

BEP documents		Implementation Process															
		Data / model generation				Data / model management				Collaboration/ Information exchange				Deliverables / Project close out			
Publication date	Document short name	LOD	File naming conventions	Modelling guidelines or standards	Model minimum requirements	Access, share data CDE,	Modelling strategy/ division	Data formats for transition of data (IFC)	Operation and maintenance Cobie	Process map	Data / model exchange, collaboration	Information exchange worksheet	Coordination meetings	BIM deliverables	Schedule of deliverables	Quality control strategy	Archiving / record
Universities																	
2011	PSU	●	●					●		●	●	●	●	●	●	●	
2012	SDCCD	●			●			●	●	●			●	●	●		●
2012	PU		●	●		●					●	●	●				●
2012	USC	●	●	●		●		●	●		●	●		●	●	●	●
2013	VCU	●		●									●	●	●	●	●
2015	Indiana				●	●			●				●	●	●	●	●
2015	Cambridge	●				●		●	●		●	●	●	●	●	●	●
2015	UGA	●	●	●	●			●	●					●		●	●
2016	GT	●		●	●		●	●	●	●	●		●	●		●	●
2016	MIT		●					●		●		●		●		●	●
2017	LACCD		●	●		●		●	●	●	●		●			●	●
2017	Stanford	●	●		●	●		●	●	●		●	●	●	●		●
2018	USF	●	●	●	●		●		●		●	●	●	●	●	●	●
Government authorities / agencies/states																	
2009	COE				●		●	●	●				●	●		●	
2007	GSA	●	●	●	●			●	●	●	●	●	●	●	●	●	●
2010	SAO	●	●					●			●			●		●	●
2012	Senate	●		●	●		●	●	●		●		●			●	●
2012	DDC (NY)	●	●										●	●			●
2012	GSFIC	●	●	●	●		●	●	●					●	●		
2013	Singapore	●	●	●	●		●	●			●		●	●		●	●
2013	Statsbygg		●	●	●	●		●						●		●	
2014	TN OSA	●	●					●	●	●	●		●	●		●	●

2015	CIC	•	•	•	•	•	•	•		•	•		•	•	•	•	•
2015	DCAMM	•	•	•	•			•	•	•	•	•	•	•	•	•	•
2017	VA	•	•		•	•	•	•	•	•	•	•	•	•	•	•	•
2019	NZ	•	•	•		•		•	•		•	•	•	•	•	•	•
Industry professional associations																	
2007	AIA	•			•	•						•					
2012	CanBIM	•	•			•	•	•	•		•		•				•
2015	CON	•							•				•	•	•	•	•
2019	RIAI	•	•			•	•	•	•		•	•	•	•	•	•	•
National Standards Agencies																	
2012	AEC UK	•	•	•		•	•	•			•		•	•			
2013	BSI	•	•			•	•	•	•		•			•	•		•
2016	NATSPEC	•	•		•	•	•	•	•		•		•	•			•
Private company																	
2010	Autodesk	•	•	•		•		•			•	•	•	•	•		•

Table 2. The occurrence of the "implementation process" type topics (data/model generation, data/model management, collaboration/information exchange, deliverables/project closeout) in the 34 reviewed documents.

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