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# BIM Maturity Model Specific to the Renovation Sector

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## Highlights

- The renovation sector is worthy of interest because of the market share that it represents in most countries.
- In the coming years, it could be impacted at various levels by Building Information Modeling, as justified by this article.
- A study of the existing means, tools and implementation aids that could make BIM compatible with the particularities of renovation actors (a majority of small-sized companies) is then proposed.
- A specific BIM Maturity Model for Renovation purposes is established as a result.
- In the complex environment of renovation works, the proposed Maturity Model will be valuable for small companies willing to monitor their own innovation process and to measure their own strengths, weaknesses and opportunities.

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## 25 Abstract

This article focuses on the relevance of a digital approach, Building Information Modeling (BIM), in the dynamic and diversified renovation sector, which is mainly driven by micro enterprises. Currently few scientific references are devoted to this subject. Interest in the use of BIM for such purposes, as well as opinions on its feasibility, differ. Scientific reviews also demonstrate that there are not plentiful or sufficiently appropriate technologies and tools available to encourage the widespread use of BIM inside the type of company that would be engaged in renovation work. The aim of this study is to propose the synthesis of scientific data that justifies the introduction of BIM in renovation work. An analysis of the tools and Critical Success Factors makes it possible to determine the specifications for a Maturity Model (MM) that is adapted to the renovation sector and to the actors within it. A BIM Maturity Model For Renovation (BiM<sup>2</sup>FR) purposes has been established as a result. The origins of, and the content contained within it, are detailed in this article. The results are validated through three case studies of businesses that are engaged in BIM processes.

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**Keywords: Building Information Modeling (BIM), BIM Maturity Model, Renovation, Micro enterprise, BIM Execution Plan, Critical Success Factor (CSF).**

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## 1 Introduction: Research Methodology and Plan

In recent years, Building Information Modeling (BIM) has spread throughout many Architecture, Engineering and Construction (AEC) companies and contributes to “digitizing” these sectors. Many management consulting firms predict that “*construction companies that continue to ignore the digital wave will struggle to survive*” [1]. More objectively, AEC companies must be aware of their digital capabilities and might need to dramatically modify their behaviors, practices and organization in the near future. Certainly, even the renovation sector will be impacted at various levels. Its particular characteristics imply that any development would likely be a long and complex process. Therefore, it is of interest to examine this specific sector in more detail. To better understand the issues and challenges that lie ahead for this sector, it is first necessary to define the terms and the stakes for the sector. According to Barlish *et al.*, the many definitions used to define BIM sometimes make it difficult to understand [2]. In this study, the definition proposed by The National Building Information Model Standard Project Committee is used, which states “*Building Information Modelling (BIM) is a digital representation of physical and functional characteristics of a facility. A building information model is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition*” [3].

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## 1.1 Target market

55 Why shed light on the renovation sector as a whole, and not on only the energy renovation portion of it? A recent review by the author revealed that very little scientific or industrial data is currently available to facilitate or advise on the implementation and use of BIM in such an industrial context [4]. Nevertheless, this sector is worthy of interest because of the market share that it represents in most countries and the particularities of the professions involved in renovation projects. Statistical data reveals, for example, that the annual revenues goes from 30 to 300 billion dollars in the Australian Home Renovations Market [5] and residential improvements and repairs in the USA [6]. In France, renovation represents 56% of the construction market, and 68% of these activities, which represent an annual revenues of close to 48 billion Euros, is shared by companies that employ fewer than 20 individuals [7]. In Europe, a 2015 study, shown in Figure 1, highlights that the prospects and requirements in energy renovation will far exceed the needs and volumes of new construction in the next 30 years [8].

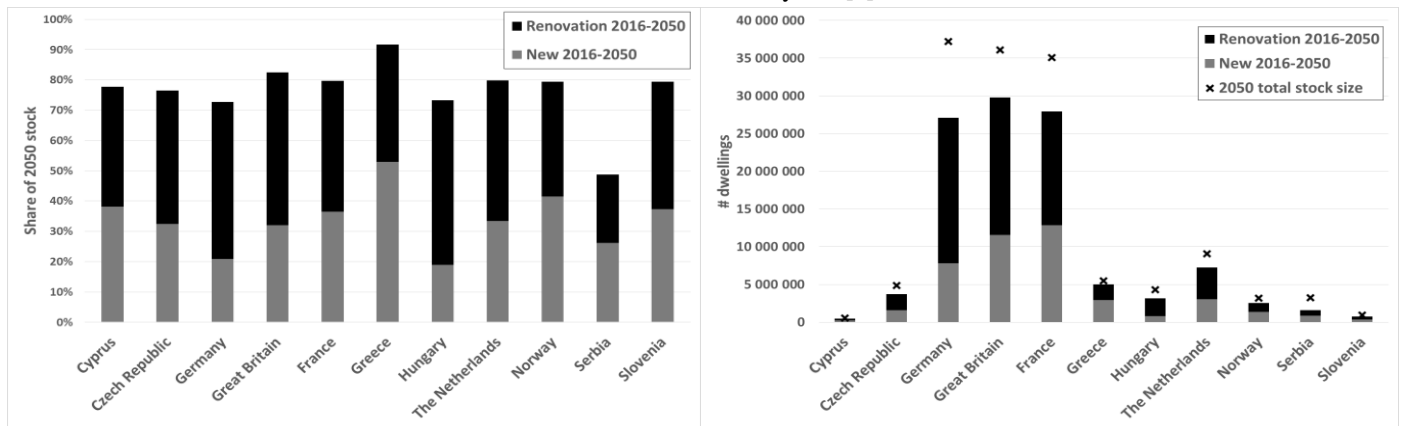


Figure 1: The number of dwellings that are to be constructed or renovated in the period of 2016-2050 in Europe. Left: the percentage of market share in each country. Right: the absolute number of dwellings. According to Sandberg *et al.*

65 It should be noted that unlike in new construction, in the renovation sector, normative acts or standards and shared or universal business processes do not exist; for renovation activities, a wide variety of situations exist [9].

For all of these reasons, implementing BIM in renovation requires development with and for users in a logical, step-by-step progression, taking place on-site, and through gradual capitalization [10]. Important gaps must be addressed, and thus, BIM should adapt to the realities of this sector; additionally, the environment should adapt to BIM. These are all areas of interest when focusing on this sector, which represents a significant share of the construction market.

## 1.2 Actors and companies

Other important characteristics related to this sector can be added and there is concern, in particular, about the size of the companies within this sector. Indeed, according to EUROSTAT, 75% of the building industry's players work in companies with fewer than 50 employees, and these companies generate more than 65% of the value added of the profession in Europe [11]. The typology of companies defined by the European Commission is considered to be the framework for this study: micro enterprises ( $\mu$ Ent) are enterprises that have fewer than 10 employees. Small enterprises (SmEnt) are those that have fewer than 50 employees, while small and medium-sized enterprises (SMEs) employ fewer than 250 individuals [12]. The concept of BIM in renovation is all the more complex when considering that the majority of the companies that are engaged in these activities are small. In his work, Owen highlights that in the UK, three quarters of all firms that work on residential properties employ three or fewer people [13]. Ultimately, most of this market is shared by companies that employ fewer than 20 individuals [4]. Furthermore,  $\mu$ Ent represents 93% or 95% of the construction sector in the UK [14] and France [7], and there are certainly more in the renovation sector, with a large proportion of individual companies.

This situation is not without consequence. With regard to manufacturing SMEs with Industry 4.0 [15], building companies will have to evolve toward BIM, and they will do so with certain difficulty. As Moeuf *et al.* explain, the organizational structure of SMEs, and even more for  $\mu$ Ent, is characterized by proximity management; there is strong involvement of managers in all of the company's decisions and usually a lack of expert support functions [16]. Unlike large firms, they have lower productivity, higher costs and less on-time delivery performance. The introduction of new technologies and practices are always risky in SMEs, especially because their requirements are still not fully known. However, a change in paradigm appears to be taking shape. Fewer than 20 years ago, most SMEs had a short-term strategy that was incompatible with long-term investments [17]. Ultimately, recent studies have shown that the spirit of SMEs and the apparent lack of strategic planning in SMEs are more closely related to the owner-manager and to his motivation, rather than to organizational barriers [18]. The rapid and recent changes in business, society and consumer expectations also explain these fundamental changes. Commitment to sustainability in SMEs necessarily requires a long-term projection [19]. Long-term thinking is also necessary and enacted via a wide range of managerial choices in sectors or activities, such as *Maintenance and Repairs; Research and Development or Innovation; Employee training*; and so on

95 [20]. This approach is indeed the vision that is shared in this study. Profound changes must be opted for and a long-term vision adopted. To ensure that this analysis is even more accurate when describing potential implementations of BIM technology, for example, in  $\mu$ Ent, the next suggestions are based on a set of data and existing uses that were characterized following surveys from 34 companies that were conducted and detailed in a recent study [9]. These interviews enabled a better understanding of the current situation, the needs and the potential step-by-step improvements for companies.

### 100 1.3 An under-analyzed setting

The targeted companies are characterized, and the context of our study is raised. A complementary analysis of the literature on BIM and renovation also reveals under-analyzed settings and unparticipative stakeholders. In the UK, Kouider and Paterson noted in 2013 that for large organizations, BIM can offer competitive advantages that are easily afforded [21]. They affirmed even then that  $\mu$ Ent had been left on the margins of the debate. A few years later, the situation appears to be the same. As in France, and even 105 in a leading country such as the UK, “approximately 75% of construction SMEs, which form the backbone of the construction market, are non-BIM” and prefer working with only 2D drawings. These data come from a survey conducted in 2016 by Ghaffarianhoseini *et al.* [22]. Moreover, as explained above, the needs of the sector and the actors are poorly addressed in the literature [4]. According to Ilter and Ergen in 2015, the renovation sector as a whole is seldom studied. In their review of 500 articles related to BIM, fewer than 2% specifically addressed renovation topics [23]. The same proportions emerge from a more 110 recent “bibliometric analysis and review” of 381 papers [24]. SME and renovation terms are, indeed, virtually unused (on fewer than five occasions) and not specifically considered in the syntheses, despite their specificities and market shares. Finally, studies that present strategies to implement BIM in a practical renovation context can be considered, but the input models are not always consistent with the goals of this work [25]. Indeed, the project costs, the sizes of the companies, and the systematic use of accepted construction project management practices are considered to be out of the present scope, and transposing these to the major portion 115 of renovation actors could be too risky.

The fact is that for now, the process of evolution and implementation of BIM is only very rarely initiated in the renovation sector. All of the presented aspects and a fear of change or a fear of selecting inappropriate tools, in an isolated way, are certainly partly responsible for the reluctance to implement BIM that exists among the players in renovation professions. For example, in 120 early 2017, a French survey of 400 SmEnt construction companies highlighted that only 32% had heard about BIM, and only 1% of the executives interviewed revealed having a BIM approach [26]. From a more general point of view, one of the challenges that must be overcome is that the actors in AEC renovation are, for example, not familiar with ICTs (Information and Communication Technologies), the use of computer-aided design (CAD), updating or data exchange [9].

Last, the substance of a recent study conducted by Ireland to define a governmental roadmap is proof that much remains to be done [27]. The overall proposal, which represents (p6) the countries' progress, summarizes the diversity of approaches and the strong heterogeneity that still exists across and within continents. It highlights the long task list ahead, even outside the scope of the renovation sector. The authors also identified a number of themes or pillars that must be deepened to elaborate upon a roadmap: Procurement, BIM Guidelines, Training and Education, Process Data Exchange, Regulatory Framework, Pilot Projects, and more. These are some of the concepts that must therefore be studied and used later in this research.

### 1.4 Approaches based on Maturity Models

130 Previous sections summarize the specific aspects of the companies and the sector that we are interested in exploring. The diversity of the businesses and trades, the lack of available, significant and ready-to-use scientific data by small companies with tight budgets, and the fact that this sector is set to evolve for many more years to come, all justify this study and a desire to deepen this research.

Companies that are still reluctant to implement BIM must be convinced of, they must understand the stakes that are involved in 135 introducing BIM and be open to advice. To be able to evolve in a complex and unknown environment, it is necessary to have a clear picture of this environment and to position organizations within it. In other words, it is necessary to have a consensus Model or Referential. Since this is an environment that involves skill development, the concept of Maturity Model (MM) is usually used. The synthesis proposed by Proença and Borbinha summarize what we intend to propose [28]: “MM is a technique that has been 140 proven to be valuable in measuring different aspects of a process or an organization. It represents a path toward an increasingly organized and systematic way of doing business in organizations. This technique provides organizations with (1) A measure for auditing and benchmarking; (2) A measure of progress assessment against objectives; (3) An understanding of strengths, weaknesses and opportunities”. At first sight, it is not clear that the current models correspond to the expectations of companies that are so small in size and are adapted to the characteristics of the renovation sector. Ghaffarianhoseini shares the fear of a lack of an adapted tool and highlights that for a BIM novice (or BIM infant), for SMEs, using an inappropriate BIM assessment and 145 adoption strategy might result in a waste of valuable time and resources [22].

In any case, a suitable MM for the renovation sector could be, according to some adjustments, the translation of all helpful elements found in the scientific literature, and it could match the needs and the requirements of the renovation sector/actors. The study of these helpful elements (tools, methodological approach, key success factors) will therefore be at the heart of this article. These and the genesis of this MM are helpful for implementing BIM and will be presented as follows: Following this 150 introduction, in Section 1, our research methodology to assist business evolution is developed in five sections. Section 2 aims at validating our intention to work on BIM implementation in the renovation sector, while considering a majority of small-sized

companies. For this goal, a synthesis of the many possible contributions and expected benefits of BIM for the sector to counteract certain weaknesses is proposed. Elements that enable an implementation and that encourage the chance of success of such an approach are detailed in Section 3. Section 4 will justify and present an original BIM MM whose features will be presented through three case studies in Section 5. Finally, the conclusions in Section 6 will list the added values of BiM<sup>2</sup>FR, future work and upcoming developments as this study continues within the region of Burgundy (France).

## 2 SWOT analysis about BIM in renovation

Opinions are still divided on the use of BIM in renovation, let alone by very small businesses. The potential gains of and interest in such technology are not always understood. The supposed weaknesses of these companies and the risks involved during the implementation of BIM all too often stem from negative prejudices. Many points of view, remarks, fears or arguments, positive experiences and case studies are, however, present in the scientific literature about BIM. They can correspond to a renovation topic, but when renovation is not the case, the points raised can, however, bring up questions about the relevance of BIM in this sector and in small businesses. A synthesis of the data, which is of course not exhaustive, is proposed to determine whether an obvious trend (in favor or against BIM) could emerge. To justify the present study and to provide ongoing reflections, the following SWOT analysis summarizes the different opinions that were found. SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. This approach is a business strategy tool that is used to identify possible options at the level of a strategic activity sector [29]. This tool was selected because it is considered to be relevant in guiding this work. The SWOT synthesis proposed in Table 1 **serves to support the analysis of some of the strengths and weaknesses of the companies in the face of certain difficulties that result, for example, from BIM implementation. It also highlights the opportunities that are expected or brought about by BIM, and it describes the current threats incurred by the sector.** These threats could, depending on the circumstances, explain the observed caution; or, conversely, they could help firms to see a measure of urgency in such a paradigm shift. **Data relating to SME or renovation appears in bold in the table.**

The realization of such a synthesis is sometimes complex when positioning certain scientific studies. Indeed, to round out this analysis, it would have been of interest to mention other recent research [30]. Authors have studied and listed the initial information needed to start a renovation project in relation to functional renovation cases. The various components that are mentioned as structural properties, spaces, all of the MEP systems in place, the characteristics and construction types of all fabricated elements (walls, roofs, floors, windows and doors), the year of construction, and other factors, are usually missing when starting a renovation project. These deficiencies can be perceived as **weaknesses** and constitute a risk that is incompatible with the introduction and use of BIM. Conversely, it can also be important sources of progress for companies. These **opportunities** will inevitably lead to an increase in quality and a decrease in litigation, which probably outweigh the extra costs of overpreparation of projects in relation to the current situation.

Strengths of companies	Weaknesses of companies
Study highlighting openness and the desire of some SMEs to acquire new skills [31,9]	<b>Cultural resistance to change - comfortable with traditional process</b> [32,49]
Orders are already made online (the existence and uses of some business software for visualization, order components via WEB portals and QR and barcode scanning on smartphones) [9]	<b>The immediate implementation costs take a psychological edge over benefits</b> [32,22,9]
Small companies are therefore potentially flexible and responsive [9]	<b>Lack of capital to invest and use the appropriate hardware and software</b> [32,39,38,49,31,50,22,36,9]
<b>Important relationships between actors such as architects, project managers, construction consultants, designers or quantity surveyors, and geometrician experts able to perform, for example, 3D scanning</b> [9]	<b>Lack of standardization</b> [49,9]
BIM Opportunities	Deficit and complexity of interorganizational relationships [35,51]
<b>Usefulness of BIM during facility management activities, during tracking warranty, for as-built renders/heritage and historical documentation</b> [32][33,34,35]	Difficulties in diffusing interorganizational innovations that require changes of processes, in a coordinated way, in multiple firms working in silos [32,52,22]
Appearance of augmented reality for new nDimensions features (cost, schedule...) [32]	Importance of the cost of BIM training [32,39,31,50,22]
Creation of new roles and jobs (BIM manager, 3D or environmental modeling Designer, Information or Data Manager) oriented to a newly qualified young workforce [36]	Lack of BIM knowledge or BIM guideline [39,49]
The arrival of young recruits with more computer skills and knowledge in BIM will facilitate the introduction of BIM [36]	<b>Strong involvement and new roles for architects to be considered and paid</b> [9]
Development of new management and organization solutions due to Information Communication Technology (ICT): tablets, RFID Building Management System [36]	Disclaimers of liability by designers [39]
<b>Strength of collective works and interests of the alliance concept</b> [22,37,9]	Interlocutors and methodologies of work that change for each new project [9]
<b>Many opportunities are available for companies working with BIM, skills of niche, new features to improve customer services, earnings of growth for SME, access to subcontracting ...</b> [38,36,37]	<b>Practically no 3D for renovation in micro enterprises</b> [9]
<b>Need for decompartmentalization and migration to new construction projects or larger markets. Ability to compete with the same tools and skills as large organizations</b> [37]	<b>Effort required is difficult for micro enterprises</b> [36,53,9]
BIM enables an increase in productivity and work efficiency (for example workflows) and to access up-to-date information. It improves by visualizing the management and the communication of complex information. This approach allows error reduction/elimination and to reduce reworks [32,39,40,36]	<b>Very few indicators or standard operating procedures / need to upgrade Quality Assurance systems</b> [22,9]
<b>Current and future constructions built with BIM will one day need to be renovated</b> [9]	<b>Relatively few 2D plans and dedicated software for drawings or diagrams</b> [36,54,9]
Reduction of costs, completion time and overruns due to BIM [41,40,37]	Appearance of legal concerns related to the ownership of the model, the security/privacy of data, copyright issues on project information and reluctance to share data [32,39,49,50,55]
<b>Potential benefits on retrofit planning</b> [32,40,33]	<b>Little software for quotes or simply using MS EXCEL</b> [9]
Facilitates the Integrated Project Delivery (IPD) approach and quality control [32,40,33,39,42]	<b>Frequent interventions in occupied environment; conflicts due to design changes, and inaccurate design information and 2D plans</b> [56,9]
<b>Monitoring / management / maintenance of equipment and facilities thanks to integrated sensor technology</b> [33,43]	<b>Difficulty managing many unforeseen events</b> [56,44,9]
<b>Emergence of generic BIM objects and components may be used early on in the design and for simulations or test performance</b> [36]	Need to upgrade personnel skills [50,22,36]
BIM allows benefits on design/engineering/scope clarification and to reduce litigation [32,40,41]	<b>Difficulties looking ahead in a difficult economic climate where business survival is the priority</b> [32,36]
<b>Facilitates decision-making for an affordable refurbishment solution at the early design stage</b> [30,44]	SMEs do not have an implementation strategy [22]
<b>Valuable help for energy renovation</b> [44,45,4]	<b>Small firms equate BIM to 3D modeling, while large firms perceive it as a way of managing the design and construction (4D, 5D, exchange of information...)</b> [33]
Quick visualization and revision of problems [32]	Appearances of new management and organization solutions (but complex!) due to Information Communication Technology (ICT): tablets, RFID Building Management System [57]
BIM improves effective coordination among consultants [39,40]	Difficulties in implementing BIM for their projects [38]
It can improve construction and facilitates Lean Design [32]	<b>Significant benefit from the introduction of enhanced BIM technologies are most likely to accrue to larger companies, since they are the principle adopters</b> [33]
BIM helps reduce waste and accomplish waste management during building and demolition [46,32,39]	<b>Most companies are not familiar with BIM</b> [9,22,32]
Material flow optimization [47]	Threats
Optimization of employee safety during work [48]	<i>"The chicken egg causality dilemma"</i> : little available productivity data to estimate financial sustainability, but BIM should be practiced to know this sustainability [58]
	<b>BIM is too risky from a liability standpoint to warrant its use. Smaller organizations are more exposed given their limited infrastructure and ability to sustain sudden change</b> [32,49,36,31]
	Little demand for BIM use [32]
	<b>Absence of a national / clear and consistent professional BIM strategy</b> [36]
	<b>Increasing workload and red tape year after year</b> [9]
	Lack of interoperability of BIM software to allow easy exchange of data [39,49,50,40,53]
	<b>BIM is still immature for full adoption in refurbishment projects</b> [53]
	<b>No change at all is definitely synonymous with perish. For SMEs</b> [1,36,33]
	Laborious, costly and sometimes inaccurate manual procedures of point cloud reconstruction processing [50]
	<b>New BIM business start-ups are emerging. They are logically less conservative and will not have to implement BIM since they are innate users</b> [9]
	<b>Few studies of BIM in µEnT and renovation</b> [4,24]

Table 1: SWOT Analysis related to the decision on whether to implement BIM in renovation

185 Basically, the overview synthesized in the SWOT table reveals more weaknesses in companies (whether or not they are related to the prospects of implementing BIM) than strengths, which highlights a situation that is uncomfortable and uncertain for small businesses that conduct renovation projects. On the other hand, opportunities that are revealed or foreshadowed outweigh these negative points and justify the desirability of working in close contact with the actors who have interest in implementing and working with BIM in the coming years. **In other words, according to the SWOT analysis, there is little doubt that**

190 **construction SMEs will develop BIM competency in the future.** In the following section, we will study the solutions that have been proposed in the scientific literature as well as those that have been set up by professionals to facilitate implementation. It will then be easier to take them into account while completing them with our own observations.

### 3 Literature review of BIM implementation and "facilitator levers"

195 BIM implementation is a complex process; its rules and methodologies must be respected for it to be a success, as in any industrial or organizational project. Its implementation requires setting up and monitoring indicators, following a project management process, and establishing a minimum process for documentation and collaboration. The actors must be able to use support tools or resources and be on the lookout for advice. This section is devoted to the study of the adequacy between these necessary elements and the present scope. **The knowledge of all of these levers, and their characterizations will therefore**

200 **allow them to be transposed or even to be easily adapted into a framework that is conducive to the rollout of BIM in this sector.** The purpose of this section is summarized in Figure 2.

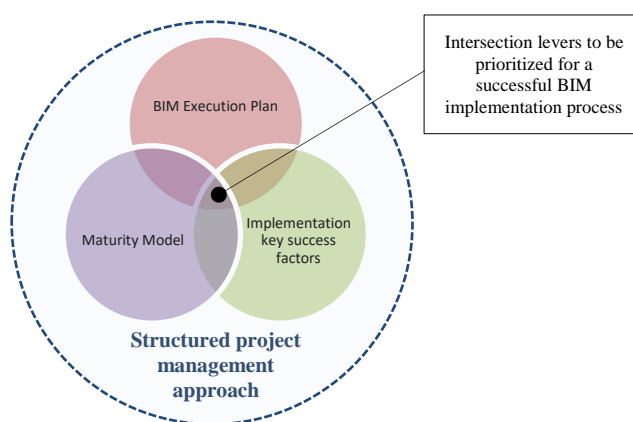


Figure 2: Major BIM implementation levers

#### 3.1 Key success factors

In the framework of BIM uses, some studies dwell on the determinants of accepting new technologies and the factors that influence the choice to adopt digital solutions [38]. Technology adoption could be at the national level - that means a decision at a ministry to mandate or regulate the use of technology - but more generally, it is at the organizational level, which means that the decisions are made by the upper management in organizations as per a company's strategy. The choice will therefore be imposed or desired, which results in varied pressure or calendar constraints. Regardless of what the scenario is, factors that affect the success of a project are called the **critical success factor (CSF)**, **key success factors (KSF)**, or at the startup, **factors of technology acceptance**; these must be studied and will be useful. They usually relate to an organization, technology or individuals. The industrial context, the typology of the businesses, the size of the projects contained in the available case studies and scientific work are often different from the scope of this paper, but for the remainder of the work, it is important to know which factors influence the chances of success and the choice to adopt such an Information System. According to Takim *et al.*, these factors can be categorized into, and participate in the implementation process, in five stages. This author highlights the prevalence of **preuse preparation**, for which its justification is emphasized in the next section, and last in the MM proposed, the importance of the **initiating (starting) process** is covered [38].

Most of the results found during this research that concern these major implementation factors are presented in Table 2. No study that specifically addresses this subject in renovation has been found. **In addition to** the work of Takim *et al.*, **the second** relevant study that caught our attention results from observations and a survey conducted in Finland that drew a Roadmap for the implementation of BIM in the UK construction industry [32]. As per the author, before 2012, Finland had a clear vision of BIM implementation at both the governmental and operational levels, and it also demonstrated examples of best practices of the BIM approach. In conclusion, the authors stressed, among other things, that the leverage consists of changing the existing workflows to Lean-oriented processes. The study of this relationship is not new, and the possible interference between BIM and Lean were studied from a theoretical point of view as early as 2010 by Sacks *et al.* [59]. Partial elements of this conclusion also appear in the works of Owen *et al.*, which present drivers for change and stress the importance of approaches such as Lean construction and

Integrated Project Delivery [37]. This study is **the third** publication considered in this review. **Other studies** from Mahamadu *et al.* are focused on the key determinants that are considered to be a prerequisite for key success factors (there can be no success without acceptance) [60], and the criteria and drivers that must be considered can be studied through the Retrospectives of a large group: Wates Construction [39]. In their Model, Morlhon *et al.* present CSF for a BIM implementation project, with additional impacts on utilization [61]. This study was inspired by essential CSF facilitating an ERP (Enterprise Resource Planning) adoption project [62]. **These two studies** prompt reflection and bring about a rather complementary vision based on a project management approach. Even though the contexts or case studies diverge from the present scope, many similarities in the results can be emphasized. **Finally**, in a Taiwan study from Tsai *et al.*, 123 IFs (Influencing Factors) were selected, and a ranking was established owing to a survey conducted among local AEC industry stakeholders who had experience with CAD and were in the process of switching to BIM technology [63]. When accounting for the 75 more important IFs of this latter study, rounded out by an analysis of seven other publications quoted previously, a "raw" list of more than 110 key success factors were extracted. After merging closely related factors and eliminating those that are not appropriate or irrelevant for this paper, a synthesis is provided in Table 2. These factors are sometimes grouped by "family" to highlight the principles that are mentioned or presented later in the study. This grouping aims to definitively underline the relevance of more general concepts that constitute the levers of success that we will aim to exploit; namely, the BIM Execution Plan (BEP), the initiating process in a project, and the Lean and Integrated Project Delivery (IPD) approaches [42].

To conclude this section and to further introduce the intentions to follow, the observations made by Tsai *et al.* can summarize our feelings [63]. They argued that many guidelines and protocols, frameworks, standards, and evaluation tools for facilitating BIM adoption exist, but their constructions do not appear to be sufficiently related to the many CSFs that studies, of which those previously cited, reveal. Therefore, such statements justify studying the current maturity model and the content of the BEP later. **Moreover, to be as efficient as possible and to question industrials, the model proposed in Section 4 will account for and make use of a number of these factors, in particular, those most frequently cited in Table 2.**



Table 2: Major critical success factor of BIM implementation to consider:

CSF N°	Critical success factor description	Tsai <i>et al.</i>	Khosrowshahi <i>et al.</i>	Takim <i>et al.</i>	Owen <i>et al.</i>	Mahamadu <i>et al.</i>	Morlhon <i>et al.</i>	Folorunso <i>et al.</i>	Françoise <i>et al.</i>
Initiating Process	1 Do not start the transition prematurely, overcoming the resistance to change, and getting people to understand the potential and the value of BIM		x	x					x
	2 Need for organizational changes and anticipation of issues such as business processes, organizational typology, structure, systems, corporate culture (roadmap and clear guidelines possibly drawn by consulting or audit firms)	x	x				x		x
	3 Ensure that the processes are in a logical order, have reliability (robustness) and scalability and are not too bureaucratic	x			x	x			
	4 Long-term vision of costs: initial investment, maintenance and upgrade costs (software, hardware, training) or relationship with providers (vendors/suppliers)	x			x	x			x
	5 Define the project goals, team members' roles and responsibilities for BIM projects (project phases and BIM deliverables) before starting and training	x	x						x
	6 Need for change, project and knowledge management expertise of top management	x							x
LEAN	7 Adapting existing workflows to lean-oriented processes, introduction of <i>Lean Construction</i> processes (Team-based decision-making for value-added or benefits to project and team)		x		x				x
	8 A bottom-up approach							x	x
	9 Organizational learning capability, monitoring, evaluation of performance and continuous improvement (Set up a feedback loop for process improvement, feedback of good practice, indicators)	x		x					x
	10 Need for training, some positions can require that post holders gain certified standards of education and training (learning by doing), and all affected people require up-skilling (Improving Evidence Base)	x	x	x	x	x	x	x	x
	11 Perceive and communicate benefits from the implementation	x		x					x
	12 Obtain the support of mid-level managers and opinion leaders (acceptance)		x				x		x
	13 Support from top management	x		x		x		x	x
Integrated Project Delivery (IPD)	14 Consolidate Individual and group motivation and involvement for BIM adoption, prequalification of team members	x		x					x
	15 Supply chain competence and capacity					x			
	16 IPD Approach	x			x				
	17 Early involvement of project teams (owners, managers, architects, engineers, contractors, subcontractors)	x					x		x
	18 Coordination collaboration and integration among the professions	x	x						
	19 3D modeling by all stakeholders (i.e., architectural, structural, MEP, fire protection), design coordination to ensure various elements of design fitting together	x	x						
	20 Design validation or virtual design review of the design conflicts between professions or disciplines (i.e., clash detection, detailed clash detection integrating shop drawings)	x							
	21 Identify owner-defined BIM requirement (application) during design, construction and postconstruction	x							
	22 Selection of project delivery methods (design-build, design-bid-build, construction management)	x							
	23 Issue BIM models for submittals and approvals, information sharing and knowledge management	x							
	24 Interoperability (data exchange formats)	x	x				x		
	BEP	25 Integration capability (delivering information, flow efficiency and effectiveness, transparency, visibility and collaboration), adopt of adequate and effectiveness Information sharing/communication protocol among team members	x	x			x	x	
26 Document BIM execution plan, including but not limited to project information, project organizational chart, project schedule, BIM processes, contract and standards, codes, rules and regulations,		x	x			x	x		
27 Identify the risks, define mitigation plans, share rewards among team members who are tied to project success		x							x
28 Definition of the contracting/contract arrangement (Legal and Data Ownership)		x				x			
29 Determine model content requirements (data exchanges, information exchanges, reference information) for each level of development (LOD)		x	x						
30 Understanding functionalities (completeness, specific needs) of the required software or hardware resources, and collaborative environment (networking facilities) to run BIM and appropriate tools to perform the applications (thoroughly investigate expectations upstream)		x	x				x		
31 Construction coordination and tracking (real-time site coordination), site layout planning and site safety / site logistics (4D)		x							
32 Security and Privacy protection						x			
33 Technical support from suppliers (appropriate tools) and training		x	x	x		x			
34 Government / Client demands					x			x	
35 Being aware of market opportunities for differentiation / focus / niche in market (unique products or services in a narrow market)	x			x					
36 Being aware of market threats from competition synonym of Innovation Imperatives				x	x				
37 Education to information management (awareness and education of the internal members of the organization to information management practices and philosophy)		x				x			
38 Trust, respect and ethical behavior among project teams	x					x			
39 Choose good resources (Innovation capability, if possible BIM project experiences, technical competence of staff)	x								
40 Research and development capability of organization	x								
41 Quantity takeoff and cost estimation (5D)	x								

### 3.2 Project Management Process

250 In their work, Mlecnik *et al.* present the lack of knowledge and lack of project management in SMEs as important barriers to advancing the energy renovation of single-family housing [64]. More generally, to compensate for the fact that in this type of

company, the processes are less identified or sometimes absent versus in large groups, and thus, the BIM introduction process will rely on a project approach. Some project management fundamentals must be at the heart of this process and then of the BIM exploitation process itself during collaborations. This necessary succession of phases will be subject to certain identified rules and steps: for example, in industrial standards such as the PMBOK (®) Guide [65]. The generic scheme proposed on page 50 of this guide (Figure 3-1. Project Management Process Groups) presents the sequence of processes for any structured project, which will serve as a reference for the recommendations and discussions to follow.

The BiM<sup>2</sup>FR developed in this article, which is intended to support companies during a BIM introduction, must therefore reflect and emphasize these processes. Particular care must be taken with the content of the Initiating process (IPro) of a BIM introduction project before even talking about a collaborative project with other partners. According to PMBOK (®) “*IPro Group consists of those processes performed to define a new project... Within IPro, the initial scope is defined and initial financial resources are committed. Internal and external stakeholders who will interact and influence the overall outcome of the project are identified. If not already assigned, the project manager will be selected.... Performing the IPro at the start of each phase helps to keep the project focused on the business need that the project was undertaken to address. The success criteria are verified, and the influence, drivers and objectives of the project stakeholders are reviewed*”. These elements first highlight the need to master the processes of the company upstream and to set and follow the objectives, which is synonymous with setting up indicators, a vision, strategy and means. **Deployments and effort cannot be made randomly; these questions must be addressed first. To enhance the chances of success, the BiM<sup>2</sup>FR's originality will consist in highlighting this essential fact and this reflection, as presented in Section 4.**

This PMBOK (®) also advises on another fundamental that is of interest because it justifies other concepts that end up being present and are certainly essential, at this time, for the solid progress of a project executed in BIM. To ensure the success of a project, a “*well-defined project start, boundaries and a formal record*” of the project process are necessary inputs that must be defined, which require developing a Project Charter. Ultimately, this approach corresponds to the BIM Execution Plan (BEP), which is widely studied in the literature. As defined in the UK Standards PAS 1192-2 [66], BEP corresponds to a plan prepared by the suppliers to explain how the information modeling aspects of a project will be conducted. This tool is a valuable support tool when developing the “execution process” rules of a construction project. An analysis and understanding of all mechanisms that facilitate the introduction and use of BIM are driving forces of this study. Therefore, the next section is dedicated to examining the content of these BEPs.

### 3.3 BIM Execution Plan

BIM implementation within small organizations also requires making the operations, constraints and logic of SmEnt compatible with, among other things, the rigor of a BEP. The latter is often presented as indispensable in successful BIM use, and it is supposed to ensure that all parties are clearly aware of the opportunities and concerns associated with the incorporation of BIM into a project workflow. According to the CIC Research Group [67] “*It should define the appropriate uses for BIM on a project (e.g., design authoring, cost estimating, and design coordination), along with a detailed design and documentation of the process for executing BIM throughout a project's lifecycle*”. Consequently, most of the elements of this support document are a part of understanding the skills required by companies for BIM. According to BSI, a BEP should be developed by a supplier for the purpose of clarifying the assigned roles, responsibilities and authorities, standard methods and procedures in place, and so on [66]. Such a reference is justified in this study by the fact that this document corresponds to the reference source for the ISO 19650 standard being validated [68]. This step enables an approach and a vision to be disseminated that is in agreement with a document that the industrial bodies who are invested in the BIM will most likely also have to refer to in the coming years. To further underline the critical qualities of the BEP, it is possible to cite a work of Sackey *et al.*, which further justifies it as being mandatory via expert interviews [52]. It is necessary to have a vision for what is being done, and according to the authors, there is no universal support; regardless, an “*organization-specific BIM document must be developed to guide the development of people and processes, to mobilize existing technologies, to utilize team work and to provide access to a common data environment*”. Implementing BIM without this approach would be synonymous with failure.

For this reason, in this case, the development of a convention between stakeholders, a necessary step in decreasing the project planning time, must be one of the priorities of the companies. **The BiM<sup>2</sup>FR to follow will attempt to guide, more than the current MM, companies in this direction.** An “innovative” and well-designed MM could constitute an “informative” way to help, or better still, offer BEP writing assistance that can use, as a reference, a very comprehensive document edited by the CIC Research Group called the Execution Planning Guide 2.1 [67]. In the case of France, this document turned out to be one of the sources retained by Mediaconstruct to develop the first methodological guide for BEP editing, which was intended to assist and guide stakeholders in a Francophone context [69].

To conclude this analysis, in the same way as the PMBOK (®) specifies that it is essential to appoint a Project Manager, the presence of a BIM Champion is another aspect that is inseparable from BEP and must be considered to ensure the success of a BIM collaborative project [67]. The BIM Champion is the person who has the motivation and technical skills to guide the teams in improving their processes, pushing BIM utilization and managing resistance to change. Studies from major companies highlight that the presence of these Champions centralizing BIM knowledge and collaborating intensively convinces colleagues of

the benefits of BIM [22]. Clearly, a relationship between the BIM Champion's engagement in the BIM implementation process and the overall success of the project exists and must also be considered in the final model in Section 4.

### 310 3.4 Cooperative model

In the continuation of all these approaches, the "necessary opportunity" to work in a group setting, and cooperatively with BIM, is one of **the last important elements to introduce and highlight with this BIM maturity measurement tool**. BIM implementation improves the interorganizational collaboration capabilities of project participants, but this technological tool alone cannot address all collaboration problems [70].

315 BIM implementation is possible only by developing and imagining tools (such as BiM<sup>2</sup>FR, presented here) as well as other appropriate, original and simplified organizational models. Previous interviews and our own reflections have prompted us to believe that to be rapid and effective and to be able to integrate a continuous improvement process, it is necessary to cluster companies with common equipment and financial or human resources (HR). Such an association of companies specializing in renovation works, working concurrently and regularly together, could be a solution that "welds" together small companies whose  
320 scope, means and knowledge in new technologies are generally quite limited [9]. It could also allow for the reduction of siloing. In existing building refurbishment, contracts are considered to be the most important legal instruments in organizing projects or existing buildings, and they could be alleviated thanks to this collaborative approach inspired by the IPD principle [53]. A cooperative model of permanent entrepreneurship is very common in many other fields, such as agriculture. It has sometimes been mentioned during interviews and could be another key factor in pooling investments and limiting the effort required to  
325 achieve, for example, the establishment of BEP. Owing to a "quite permanent organization", some parts of BEP will not have to be reinvented or re-explained with each new project. An effective and sustained tracking of indicators, action plans, training, and so forth, could exist and be facilitated. Many benefits to this type of organization are present in the literature. Collaboration between firms could very well contribute to acquiring a "pool" of expertise and could help in sharing the cost of adoption [31]. Alliances and partnerships between various actors could lead to consistent information sharing and enhanced transparency, thus  
330 resulting in an increased understanding of, and insights into, other disciplines [51]. To ensure that more power is given to SMEs when confronting large organizations, this concept of Alliances in the Construction Sector is also discussed and defined as a type of virtual network of organizations that are grouping partners [71]. Thanks to ICT and the legal contractualization between actors, it allows for flexibility and innovation under the guise of an ethical and trust approach. For construction SMEs, economies of scale in the production of standardized processes can be achieved. The experts interviewed share our feelings on this matter,  
335 namely, that a permanent and stable alliance with well-known partners provides better chances in facing complex renovation projects. With such an organizational model, innovative and flexible SMEs can strengthen their competitive position against larger companies and build a reputation and a niche brand. This approach enables a more appropriate response to the client, who would become a full participant in the project and whose needs would be better understood due to the relationships established between all stakeholders. This approach is in line with studies that show that to counter the cost escalation due to the  
340 fragmentation of renovation projects, many companies are willing to collaborate for better customer satisfaction and expect their market share in this segment to grow [64] when sharing experiences and expertise [37,36]. The estimation phases, which are often very time-consuming and whose positive return rate does not exceed 50% according to our survey, could in the end be improved by a joint and more convincing proposal from the various stakeholders (thus participating in an IPD approach [42]).

### 3.5 Concept of maturity

#### 345 3.5.1 Terminology

Since this section is devoted to the study of BIM implementation and "facilitator levers", it is necessary to specify precisely what the concept of maturity corresponds to and can bring about. As previously explained, to characterize the introduction and usage of BIM, an analysis of the maturity of companies is often at the heart of scientific studies. To better understand this concept, it is once again <sup>2</sup>important to specify some vocabulary. One of the most recent standards on the subject, ISO/IEC 30105-  
350 3:2016 [72] defines the **maturity level** concept as *a point on an ordinal scale of organizational process maturity that characterizes the maturity of the organizational unit assessed in the scope of the maturity model used...maturity model derived from one or more specified process assessment model(s) that identifies the process sets associated with the levels in a specified scale of organizational process maturity*, and last, **organizational process maturity** is *the extent to which an organizational unit consistently implements processes within a defined scope that contributes to the achievement of its business needs (current or projected)*". Some normative changes and additions have been made with the introduction of this standard. Organizational maturity is now defined on a six point ordinal scale that enables the maturity to be assessed from **Level 0**: organization Immature to **Level 5**: organization Transformational, with the following maturity developments: **Level 1** for Basic; **Level 2** Managed activities; **Level 3** Managed organization and **Level 4** Strategic alignment. This arrangement differs slightly from previous approaches and standards often used in the BIM literature and relies on ISO/IEC 15504-7, which defined the last three levels as  
360 Established, Predictable and Innovating. The scale represents the extent to which the organization has explicitly and consistently performed, managed and established its processes with predicable performance and has demonstrated the ability to change and adapt the performance of the processes that are fundamental to achieving the organization's business goals. Most scientific papers

reveal the philosophical thinking that there should be no end to maturity; the last level is thus by no means the destination, but a higher level of BIM maturity [73].

365 Achieving this goal is also linked to the **capacity** concept. In the former ISO/IEC 15504-2:2003 standard, which is again often referenced and now in **ISO/IEC 33020**, the process capability is expressed in terms of process attributes grouped into capability levels. The process capability characterizes the ability of a process to meet current or projected business goals [74]. **Each level provides a major enhancement to the capability in the performance of a process.** Generally, but not systematically, the process capability is defined on a six point ordinal scale that enables the capability to be assessed from the bottom to the top of the scale (Incomplete, Performed, Managed, Established, Predictable, Innovating process). In this recent standard, the levels constitute a rational way of progressing through improvements in the capabilities of any process.

370 Maturity and Capability are therefore closely linked. In 2002, a study related to construction (Standardized Process Improvement for Construction Enterprises SPICE [75]) already specified the links between these two notions. They are helpful in regard to evoking process improvements and are complementary when they are not confused with one another. For example, ISO/IEC 33001:2015 is said to be the basis for the French BIM maturity repository BIMetric [76], which considers 6 maturity levels: 0:Absent; 1:Initial; 2:Defined; 3:Managed; 4:Integrated; and 5:Optimized, which correspond in reality to capabilities according to this standard. Succar's studies also contributed to spreading these notions for BIM purposes. They complement these findings and the relationships that could exist between these two concepts [77,78]. BIM Capability Stages (or BIM Stages) are defined in this study as the major milestones to be achieved by teams and organizations as they adopt BIM technologies and concepts. Thus, 380 BIM Stages correspond to a fixed starting point, as presented Figure 3. Pre-BIM represents the industry status prior to BIM implementation. Three fixed BIM stages are proposed as well as a variable ending point that allows for unforeseen future advancements in technology. This ultimate goal of implementing BIM corresponds to the IPD approach that was previously mentioned [42]. BIM Stages include technology, process and policy components and are defined by their minimum requirements.

385 To ease the passage between stages, four steps are defined (A to D), which are synonymous to incremental evolution.

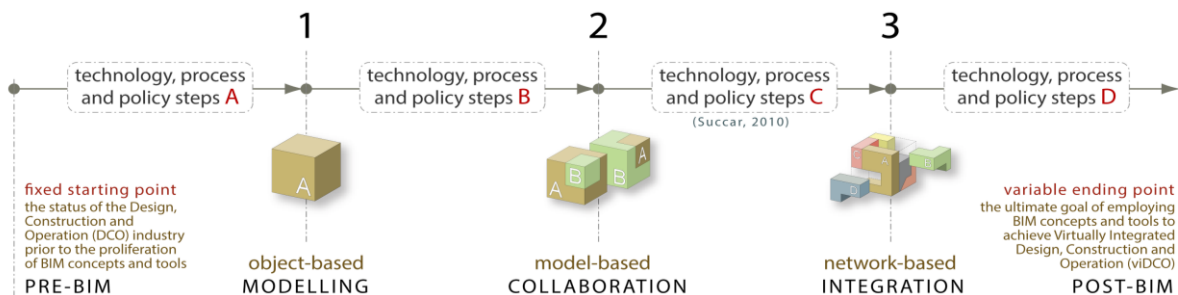


Figure 3: the steps and stages of evolution from the PRE-BIM to IPD approach, according to B. Succar [35]

However, once again, the evolutionary character of the concept can be stated, since in the first publications dating from 2008, three fixed BIM maturity stages were evoked [79] and then were refined and replaced, in subsequent work, by the concept of capacity.

390 Following this synthesis, the latest scientific vision of this author will finally be retained in the present study, namely, **Capability** “as the basic ability to perform a task, deliver a service or generate a product” and **Maturity** as “the degrees of excellence in performing a task”. This structuring approach appears to be accessible and useful to renovation companies. The following part is intended to confirm this impression by reviewing the various benefits expected from the use of MM.

### 3.5.2 Expected benefits from using a Maturity Model

395 Maturity can apply to many actors: a client, facility manager, building owners, architects, stakeholders, and so on; it can be the pretext to complete and complex analyses. According to the authors, the *raison d'être* of MM is that they are effective levers in introducing and improving BIM collaboration. In the same way that rather than talking about BIM, some refer to Virtual Design and Construction (VDC) [80], “BIM-Assessment Methods” concept (BIM-AMs) for AEC Operation is also used in addition to MM [41]. Among the arguments in their favor are measurement scales that can help project stakeholders’ reports and compare BIM capability and maturity of their actions, organizations and markets within the meaning of the standard [41,81]. Many argue that without internal metrics and evaluations (individuals, teams, projects) and sometimes even external ones (for evaluating stakeholders), actors are unable to consistently measure current successes, failures strengths or weaknesses and are unable to be effective in investing. This approach is an indispensable basis for the process of continuous improvement and to provide a management tool in terms of risk [82,77]. A valid set of BIM metrics can lay the foundation for a formal certification system that could be employed by industry leaders, governmental authorities and large facility owners/procurers to preselect BIM service 405 providers and to attest to the quality of their deliverables [77]. For decision makers, the results of BIM-AMs provide and help

companies to optimize their staff performance and influence individuals to improve their implementation of BIM (including training and education) and could result in a gain in market recognition [82,77]. They can help to develop a roadmap for stakeholders, help to identify goals for future plans and offer improvement opportunities by identifying susceptible areas for the AEC industry to assess their readiness practices when implementing BIM [82].

Without giving a universal answer, previous arguments that concern the objectives of MM suggest that such a tool is in and of itself an interesting response to the expectations of small companies in renovation and helps to support our recommendation to establish a specific MM. The current BIM Maturity Model For Renovation (BiM<sup>2</sup>FR) aims to perform a digital transition from the current, rather "artisanal" context, toward a more structured and digital future. To accomplish this goal, many models must be accounted for, even if, for the renovation sector, specific arrangements and innovations must be made, as presented below.

### 3.5.3 Influential factors

The scientific backing, the clarity of statements made and the expert validation processes have all been considered in selecting 7 MM. Deliberation and choices have been made; indeed, there has been a comprehensive study from 2016 counts and analysis of 16 BIM-AMs [82]. Our study will focus on only 7 models, 6 of which were also contained in this review. They were considered to be the most relevant and exploitable with regard to the context of this paper.

- To start, our attention focused on the Capability Maturity Model of the National BIM Standard-United States® [83], as recommended for users at an infancy stage by Wu et al. [81]. It is indeed easy to use, and enables basic BIM functions to be evaluated and provides necessary processes to initiate BIM. In 2007, the first version of the CMM appeared and is still present in this third interactive version released in 2015, **with however a very limited number of measured elements** (11 areas of interest and 10 levels of Maturity).
- In addition to the order of maturity levels and indicating the step-by-step stages toward maturity, it is important to add and develop a suitable scoring system for measuring teams and organizations. That is what is proposed in BIM<sup>3</sup>. In addition to a positioning across the maturity matrix, a maturity score is compiled related to 12 positions inside the matrix, grouped into 5 areas of concern: *Technology, Process, Policy, Maturity inside the Capability Stage*; and finally, *the Maturity relating to the BIM Organizational Scales* are selected. Finally, a score out of 50 is proposed to reflect the maturity of the company [78]. **However, most concepts used are beyond the reach of a craftsman and μEnt.** For example, the complexity of some metrics used added to concepts such as *Competencies, Organizational Scales* and *Granularity Levels* appear to be manageable and correspond only to significant-sized organizations [78]. The same applies to the advice provided in this work: *"Identify the best person...with significant experience in BIM tools, workflows and protocol...to conduct this assessment...through...workshop with 3-8 individuals representing different roles, disciplines and seniority levels"*
- A "multifunctional BIM Maturity Model", proposed by Cong Liang et al., who tried to simplify the approach, is also studied [73]. For this step, a panel of nine Chinese experts was selected, with four experts from the public sector, four from the private sector, and one from an academic institute. This MM is focused on the different stages of BIM development in three key areas: *Technologies, Processes, and Protocols*. **However, the vocabulary is not adapted to our target, and the low number of maturity levels degrades the vision of incremental progress required on the BIM path.**
- As explained in the introduction, MM can also be materialized by a succession of questions, such as those for the VDC Scorecard [80]. It results in a score and a breakdown across a percent tile scoring system broken into five tiers: conventional practice (0–25%), typical practice (25–50%), advanced practice (50–75%), best practice (75–90%), and innovative practice (90–100%). The tiers allow companies and researchers to see where a project stands relative to the remainder of the AEC industry. **The number of measurement points (60 questions) is too high here for our target.**
- With "BIM Assessment Profile", Maturity is measured through 20 "Planning Elements" divided into 6 themes: *Strategy, BIM Uses, Process, Information, Infrastructure and Personnel, Companies* [84]. Users must select one out of six maturity measures that range from 0: Non-Existent (no BIM vision of objectives defined) to 5: Optimizing. **This model, however, appeared to be too little outward-looking and not enough concerned by the BEP or data exchanges issue.**
- A collaboration between Pennsylvania State University and ARUP provided a free tool named the "BIM maturity measure" tool [85]. It offers 6 levels of maturity and is built in support of the BIM Project Execution Planning Guide by CIC. Owing to the questioning of the various actors of the project through at most 22 measurements, it provides the global maturity of the project, synthesized, among other factors, by radar charts outputs, to be defined. Despite this approach, the MM integrates a menu for **Renovation**; regrettably, it is split among 30 fields, such as **Bridges, Tunnels, Highways, Marine Constructions**. Such a situation might not be clear and engaging enough for an already unconvinced community that is likely to be resistant to change.
- Finally, Vicosoftware's proposal caught our attention [86]: it offers a special BIM Scorecard that allows companies to evaluate a firm's current solutions to help in clash detection, scheduling, and estimating in terms of three aspects: *Functionality/Capability, Best Practices, and Enterprise Integration*. The web evaluation is based on 27 questions, **but it offers mainly paying support services.**

### 3.6 Literature review synthesis

This state of the art has brought to light numerous approaches for enhancing the chances of success when implementing BIM. MM is the first of them. The diversity of the concepts and the necessary reflection to use them can be complex for the small companies that we are interested in. This trend will be even truer for the renovation sector since, as the present literature review has shown, none have been developed for this purpose. As highlighted by Wu *et al.* “*there is no universal applicable tool...each one has unique emphasis, strengths and weaknesses, matching different users...*” [81]. Nevertheless, these models provide an implementation process for BIM and enable users to identify skills required when introducing BIM. It is thus the format that will be used in our future work. Inspired by the 7 models presented, these developments should better fit the majority of the scenarios observed in the field. Moreover, this section has shown that **many FCS, including the development of a cooperative approach, the LC, the integrated and structured project approach, and the deployment of BEP are other levers that are useful for companies wishing to implement BIM.** These elements that are synonymous with success must be integrated into the strategies deployed by the companies, and they should be borne in mind. **For this reason, more than each existing MM taken separately, our MM will question more precisely companies on all of these approaches.**

That vision has made it possible to draw up an MM that is adapted to the renovation sector and its actors. The BiM<sup>2</sup>FR proposal is detailed in the next section.

## 4 Research proposal

The purpose of this model is for it to be adapted in small businesses that have fewer resources. It was intended to be relatively simple so that it could be effectively used by a large number of businesses without exceptional ICT knowledge or 3D skills. Any type of renovation actor could find an interest in this proposal, not limited to within the context of energy renovation. The preparatory analysis work and synthesis efforts presented enable the proposal of a more relevant, targeted MM for the renovation sector. This BiM<sup>2</sup>FR is composed of 28 measures that account for the major elements that facilitate a BIM implementation, as previously presented. For restitution, a normalized final kiviati diagram will be suggested to restore at time “*t*” the enterprise maturity felt in relation to 10 measures of maturity (examples available in Figure 5 to Figure 7). The model considers the company’s overall uses and not a particular project. This section aims to present the chosen themes of maturity, the questions and the calculation methods proposed.

### 4.1 Focus

According to previous data, and a result of the capabilities or needs revealed in an initial survey, companies that were prioritized in this BiM<sup>2</sup>FR are SmEnts [9]. Those that will be quickly impacted by BIM have the following qualities:

- Have between 5 and 50 employees
- Perform (though not exclusively) renovation work
- Take part in few public procurement processes
- Are sometimes in contact with professions whose primary missions are to advise and organize projects (Architects, Project Managers, Construction Consultants and Designers, Commercial and Residential Landlords, and so on)

Of course, companies with fewer than 5 employees can consider and use this model, but they do not constitute the target users. The hierarchical models of companies that we are interested in are usually very simple, with management, team leaders and operators. The present tool and the terms used within it are deliberately simplified to attempt to match this reality. For these reasons, we sought to remove from the literature and from the 7 MM that were selected some or all of the elements that were intended for organizations and operations that are industrial and already very structured (i.e., the existence of a BIM Planning Committee, Senior Leadership, and so on).

To “challenge” and convince the target audience, it is important to share Azzouz *et al.*’s vision, namely, “*simplicity might be found in ‘complex’ AMs, with clear language, a description of the measures and a structured framework with direct guidelines on how to use it*” [82]. This approach is an additional key to success and a central motive behind this proposal.

### 4.2 Adaptation and innovation

The procedure used to extract and retain the best of the 7 MM was to list all of the questions and approaches proposed (plus some related or personal ideas). From this step, it was possible to build a first database **of more than 160 questions that lead to approximately 800 possible answers.** It was then necessary to make groupings by themes. A number of redundancies then appeared. For maximum efficiency, it appears to be fair to dedicate a tool for craftsmen or the micro and small enterprises sector. In doing so, it is important to consider (and sometimes try to counter) most of the advantages (or deficiencies) found in the literature or evoked during interviews:

- Simple scales or multiple-choice questionnaires used in many models are easy to employ, but they are sometimes considered to be too subjective for solutions [81]. On the other hand, an unaccompanied BIM infant discovering the problems of BIM cannot use complex tools to produce correct outcomes. This situation usually incurs significant expenses related to training and the hiring of consultants. Aware of the shortcomings that some choices in BiM<sup>2</sup>FR could entail, we have moved toward a model and a set of relatively simple questions. This step does not prevent the near necessity of external expertise (Question number 12, Appendix A).
- Convinced that developing a BIM Assessment Profile that specifies the transitional stages, goals and milestones eases users into developing a clear roadmap for BIM implementations [81]. The proposed model has been inspired as much as possible by the relevant questions contained in MM, such as the NBIMS Capability Model with an important number (10) of maturity levels.
- **BiM<sup>2</sup>FR will take the form of a succession of classical or innovative questions and themes that were already present in the literature or inspired by potential users and that were met for that reason. For example, a reflection on a collaborative mindset** (also described as a potential for SME Alliances [71] or an interorganizational collaboration process [70]) could ease some of the aims of BIM [31]. It is the same for the primary place of estimates before individual renovation projects are achieved. **This step is not addressed in the current MM, and it is considered in the final proposal.**
- It also appears to be important to make the model free and accessible to most, to avoid obstacles that are sometimes encountered with “expensive” MM [41].
- Finally, to mention another weakness that studies highlight, at a low maturity level or at the “lonely BIM” stage, there is a lack of coordination and collaboration with other BIM users and clients [87]. The client must have a predominant role in the choice and implementation of a cooperative model. Crucial elements such as client Employer Information Requirements are contained within BEP (and many other important skills); an effort is thus made to highlight BEP in the model. Consequently, among the measured maturities, one will be devoted to it through the “*BEP Maturity Index*”.

### 4.3 Maturity representation

As explained previously, the first maturity characterized will correspond to a Maturity Index relative to the development of the BEP (*BEP Maturity Index*). Since the tool developed aims to be a decision-making accelerator, the nine other maturities will correspond to topics that the NBS relies on when implementing the BIM: *Strategy, Foundations, Collaboration, Process, People, Technology, Standards, Enabling Tools* and *Resources* [88]. They are presented as themes that cannot be neglected, to ensure successful BIM implementation. It is of interest to take back these themes inspired by the experience of this entity that correspond to the commercial part of RIBA Enterprises Ltd. However, some divergences could exist with regard to a few of the points raised in the NBS proposal. For example, in the MM proposed, the issue about training staff will have an impact on the themes of *People, Strategy* and *Foundations* rather than *Technology* alone, as proposed by the NBS. In addition, we chose to exclude from our proposal a tenth theme that was proposed in this visual, namely, the "Digital Plan Of Work", by considering, for simplicity, that it was included in the *BEP Maturity Index*. The latter was also redundant since it is present in the *Process* list, contained in the *Periodic Table of BIM* [88]. Upon reflection, the same question will impact up to 4 themes depending on the issues and points that it raises. The data exchange issue addressed in Question 17 will be used, for example, to calculate the *Collaboration, People,* and *Process* maturities.

Questions (1 to 28 proposed in Table 4 and Appendices A and B), which were selected or made and supported by previous analysis, the reasoning behind them and the associated maturities can be used to compose a table that contains various information, as explained in Table 3. In this last step, the Critical Success Factor (CSF) that they refer to corresponds to the scientific elements synthesized in Table 2. The sources for the questioning are those cited above or, when the question follows our survey or our personal reflection, are titled PA for "Personal Analysis".

Q N°	Φ: NBS grouping to which the question refers?	BEP: yes <input type="checkbox"/> or no <input type="checkbox"/>	CSF: In relation to which KSF, CSF or factor of technology acceptance? "Scientific" concepts underlined?
Questioning relating to?			Source:?

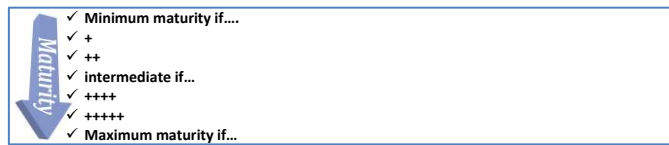





Table 3: Purpose and content of the questions.

Concerning the maturity levels, previous studies have revealed that the number of levels varied from 3 to 10. So as not to restrict the approach with a fixed number of levels of maturity, the choice was made to consider the level of maturity as evolving linearly between a **minimum (0%) and a maximum (100%)** according to the relevance of the proposals found in the literature and the incremental vision that we have of the issue. Once proven possible, the choice was made to propose a large number of positions/significant increments (similar to in NBIMS), thus highlighting the long path that is sometimes necessary when increasing the domain maturity of a company. A significant number of levels, for example, for the first question presented in Table 4 relating to “change management”, or for “the quantity and type of indicator to be deployed” to manage a project (question 25 presented in Appendix A), are indications that could be useful in highlighting the need for a continuous improvement process that companies are bound to engage in.

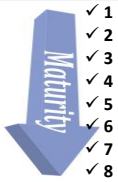
#### 4.4 Specified input

A diagnosis of the company will therefore be made by successively proposing 28 questions and the associated answers, with each response revealing a certain level of maturity.

The first block of 5 questions concerns the fundamentals and basics of project management, as presented in Table 4.

Q 1	✦ Strategy, People, Foundations	BEP: yes <input type="checkbox"/> no <input checked="" type="checkbox"/>	CSF: IPro
 How are you preparing for Change Management?		Source: NBIMS	
<ul style="list-style-type: none"> <li>✓ No change management process awareness is evident nor has been implemented in the organization</li> <li>✓ There is an early awareness of the need for business process definition and change management in the organization although implementation is not yet initiated</li> <li>✓ Early implementation of business process definition is underway and there is an early awareness of the need for business process definition and there is an awareness of change management and the need for root cause analysis in the organization</li> <li>✓ Business processes are in place and there is an understanding of the full change management requirement to include root cause analysis and implementation of a feedback loop</li> <li>✓ Business processes are in place and the organization has begun implementing change management procedures</li> <li>✓ Business processes are in place and early change management processes are identifying changes, but no process is in place to make changes</li> <li>✓ Early implementation of change management is in place and some processes are being maintained through a root cause analysis process</li> <li>✓ Implementation of a change management process is in place and is beginning to be exercised, but is not fully endorsed by all participants</li> <li>✓ The change management processes are in place, but is not an efficient process and changes typically take more than 48 hours</li> <li>✓ A mature and fully operational change management process is in place and processes changes are implemented within 48 hours</li> </ul>			
Q 2	✦ Strategy, People, Foundations	BEP: yes <input type="checkbox"/> no <input checked="" type="checkbox"/>	CSF: IPro
 What is your BIM Change Readiness?		Source: BIM Assessment Profile	
<ul style="list-style-type: none"> <li>✓ No Change Readiness Awareness</li> <li>✓ Established need for BIM</li> <li>✓ Upper management buy-in</li> <li>✓ Operating unit buy-in</li> <li>✓ All individuals buy-in</li> <li>✓ Willingness to change is part of the culture of the organization</li> </ul>			
Q 3	✦ Strategy, People	BEP: yes <input type="checkbox"/> no <input checked="" type="checkbox"/>	CSF: IPro and N°40
 What is your BIM Vision?		Source: BIM Assessment Profile	
<ul style="list-style-type: none"> <li>✓ No BIM vision or objectives defined</li> <li>✓ Basic BIM vision is established. BIM implementation strategy lacks actionable details. Business opportunities arising from BIM are identified but not exploited</li> <li>✓ The vision to implement BIM is communicated and understood by most staff. BIM implementation strategy is coupled with detailed action plans and a monitoring regime. BIM is acknowledged as a series of technology, process and policy changes which need to be managed without hampering innovation. Business opportunities arising from BIM are acknowledged and used in marketing efforts</li> <li>✓ Business opportunities arising from BIM are part of team, organization or project-team's competitive advantage and are used to attract and keep clients</li> <li>✓ Stakeholders have internalized the BIM vision and are actively achieving it. BIM implementation strategy and its effects on organizational models are continuously revisited and realigned with other strategies</li> </ul>			
Q 4	✦ Strategy, People, Foundations	BEP: yes <input type="checkbox"/> no <input checked="" type="checkbox"/>	CSF: IPro and LEAN Adapt BIM functionalities and HR skills (CSF N°10 and 30)
What is your position on the topic of training?		Source: Succar	





Examples of resources: Surveys and Reports; Videos; Events; Forums and user groups; Social media; Blog posts; Books...

Table 4: Example of the first 5 questions that were retained.

620 The second includes 20 questions with issues that correspond to sensitive points that are usually addressed and covered in the BEP, a document that is shared among companies working on the same project. These elements are presented in Appendix A, and they provide input, among others, to the *BEP Maturity Index*.

625 Last, in the course of the encounters, in view of the current projects and studies within the profession [89,90], or within the bibliographical analysis that has been presented, it is of interest to ask open questions that consider other value-added approaches such as Lean Construction, a BIM certification or an ethical charter (as proposed in Appendix B).

Some of the questions are derived from questions already tested and proposed in the selected 7 MM. Six are totally original and specific to our area of concern. For Questions 7, 8, 9, 18 and 19, the maturity levels proposed by ARUP have been reconducted. It has been taken into consideration that an important gap sometimes exists between different practices. Consequently, the scale chosen was nonlinear, and this vision is transposed in BiM<sup>2</sup>FR. For this reason, certain maturity levels between 0 and 100% **are**

630 **impossible**, which explains the use of the symbol  $\Phi$  in the Tables. The Periodic Table of BIM, proposed by NBS, raises questions on the sources of information that allow companies to open up critical thinking (as soon as possible) and to complete the training.

Questions related to these sources of information have therefore been posed that make it possible to identify the maturity of the business in proportion to the number of resources used (Question number 5). Given previous observations, it is clear that for the companies and the sector that we are interested in, the current habits are far from the stage where BIM processes can be

635 implemented and upheld. Therefore, most companies will have to be mentored in the process. **This observation explains the specific point concerning support and the gradual acquisition of autonomy added to existing models in Question 10.** We assume here that BIM competency will be, at first glance, external (but could be internal to the company) and that autonomy, synonymous with maturity, will gradually grow within the companies. In addition, as was highlighted in the state of the art, it appears to be necessary to incite companies to produce more cooperative work and to create various formulae of alliances

640 between them. This idealistic vision is an organizational model that we believe in. This approach is the perspective that Questions number 6, 12 and 13 (Appendix A) aim to highlight. The ultimate maturity level proposed in Question 12, for estimation phases, is a process wherein a member of the group would be in charge of gathering a set of digital data that is used to transcribe the existing building and the needs of the client. In this scenario, each participant of the project would be able to constitute synchronously in BIM their own contribution and proposal related to their activity. Additions have also been proposed to the

645 positions suggested by Succar (Question number 13) to accentuate this cooperative model vision.

The maturities returned to the company seeking to position themselves within this framework of study are obtained according to the methods of calculation proposed in the following section.

#### 650 4.5 Specified output

The proposed synthesis in Figure 4 highlights how maturities are addressed via the 28 questions of the MM.

Each question can therefore influence up to 4 maturities depending on the meaning and interests targeted by it.

- The first 5 questions address important points that should be mastered from the start of a BIM implementation project. For average calculations and to accentuate the scope of the model, a minimal maturity obtained in one question of this **IPro block** will be transformed into a null value in the grouping restitution. A strong signal can then be sent to the companies concerned. These essential elements of the **Initiating Process** therefore strongly condition the maturities of the **Strategy, Foundations, People, Collaboration** and **Resources** themes. Because of this arrangement, the bases will have to be consolidated above all else.
- The need to develop and dispose of a BIM Execution Plan between an entire project's stakeholders has been previously reviewed and demonstrated. MM also addresses some of the BEP's foundational themes. For this reason, it was decided to develop a complementary, specific information indicator related to this concern, namely, the **BEP Maturity Index**. This decision could highlight some deficiencies and could account for the compatibility between the current "measured" situation of the company and the level that it must have to participate in the implementation of BEP between various actors. To accomplish this goal, an average score of all values obtained by the topics contained in BEP will be put forth. The originality of this **BEP Maturity Index** is that the average will be obtained through a geometric mean:

$$\text{BEP Maturity Index} = \sqrt[n]{x_1 * x_2 * \dots * x_n}$$

Merely proposing this index reflects the value of this "contracting" document. This approach concerns the 20 questions, from 6 to 25, proposed in Appendix A. Any untreated question will return a null value. This procedure will reveal insufficiencies found within a company before starting a collaborative work BIM. Examples are presented in Section 5.

- More generally with regard to other maturities, an arithmetic average of the answers obtained (between 0 and 100%) to the questions relating to this maturity is proposed.

In conclusion, the 40 FCS that are most present in the literature (Table 2) are addressed throughout the selected questions presented in Table 4 and Appendices A and B. All of the levers revealed by the state of the art that can increase the chances of success or facilitate the implementation of BIM form the backbone of the proposed MM.

## 5 Validation and assessment

Three case studies that are fairly representative of the situations encountered during our interviews are described in this section. This panel was used to verify that the proposed model and output data are relevant, exploitable, and informative for the concerned companies. To highlight the interest in and the pertinence of the model, a first case study is proposed in Figure 5. This report summarizes the information obtained from Company X during the initial survey. It corresponds to a very traditional company with two people that is focused on renovation work (roofing and roof insulation). No specific digital competence is available, and workers sometimes use 2D drawings. The company does not yet intend to implement BIM.

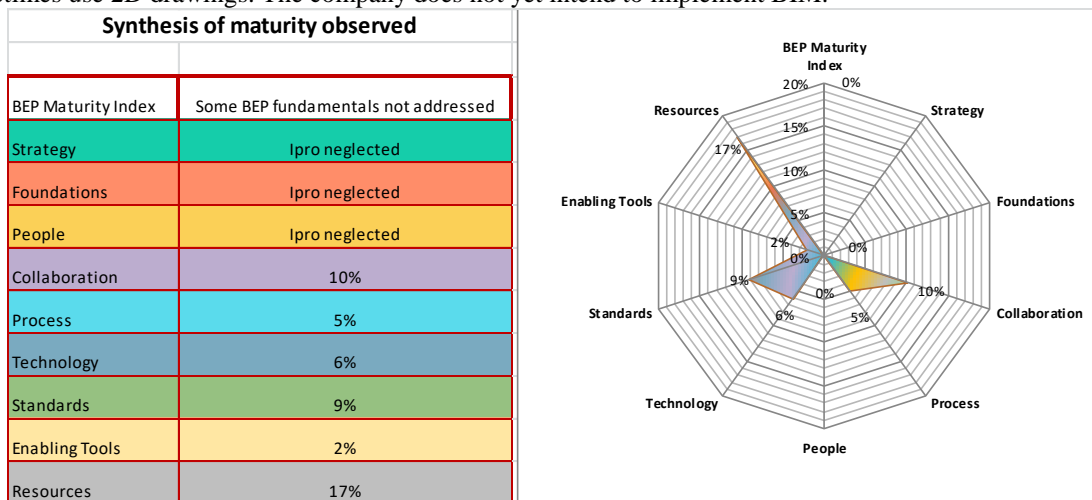


Figure 5: Company X: traditional, without specific digital knowledge and not yet intending to implement BIM.

The second company (Y) of 18 people corresponds to a case that is both relevant and of interest to the remainder of our work. It is a roofing, carpentry and timber frame construction company. It used to work with 3D software. The company has Computer Numeric Controlled machines, and managers have been aware of the need to introduce and work on BIM for approximately three years. The summary illustrated in Figure 6 shows that the company is currently not able to integrate a collaborative BIM process and is still far from mastering all of the content of BEP. Special effort and attention should be given to the initiation phases, and

especially to the problem of change management (Questions 1 to 5). The project and the vision of the company are not yet mature enough. Too little process has been identified as of yet, as revealed by the model and the radar output.

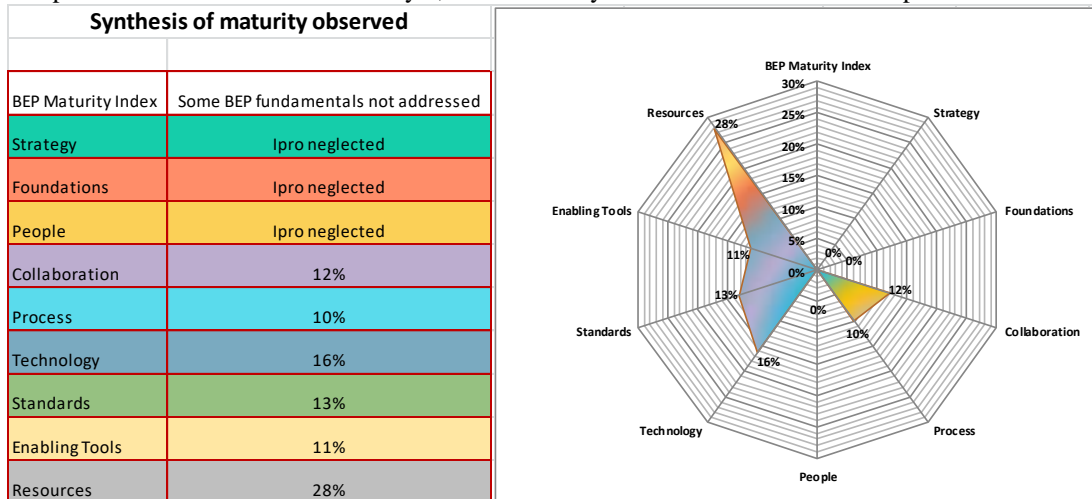


Figure 6: Company Y, a carpentry and timber frame construction company that plans to implement BIM

The final case study corresponds to the skills and functions observed within an engineering and consulting company that consists of four people working exclusively in BIM and whose roles are to assist renovation or demolition companies. As shown in Figure 7, the BIM collaborative process is completely mastered. For this company, the maturity is close to 100% for most of the 10 proposed groupings.

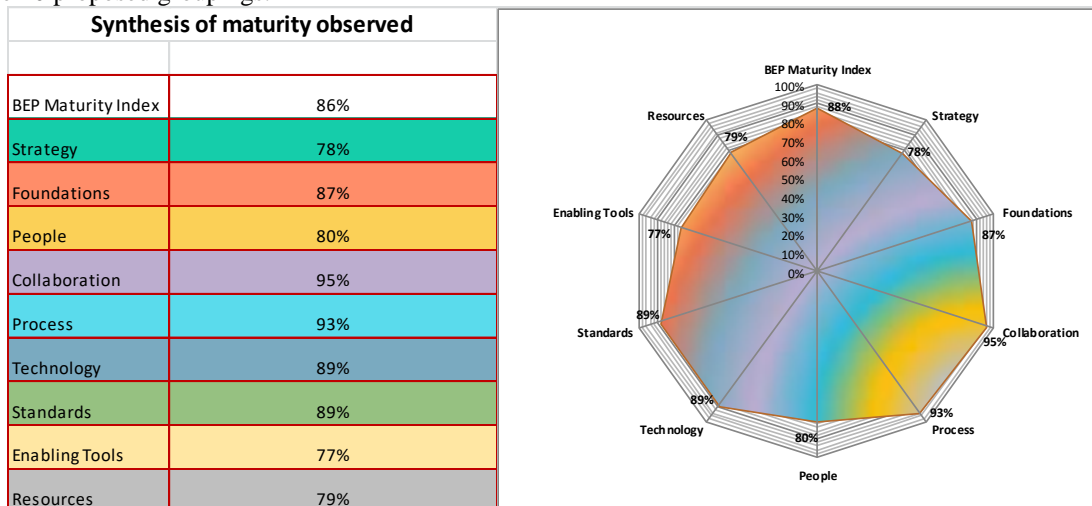


Figure 7: Company Z, a mature company that specializes in BIM renovation and demolition projects

## 6 Conclusions and further perspectives

A novel reflection of the construction of a BIM MM specific to the renovation sector has been substantiated by this work, foremost by the major interest that this sector represents in terms of employment and its impact on the economies of countries and households. Despite the size of this market, few studies on the subject have been performed thus far. In recent years, only the energy renovation sector has been at the center of the scientific or industrial studies relating to BIM. Our work is concerned with this sector, but it is not the only beneficiary of our reflection, which is intended to be as wide as possible and open to all professions and renovation actors. Moreover, as shown, SmEnts working on renovation will be prompted to move toward a more widespread adoption of BIM. For this step to occur, companies must be convinced and assisted, and in addition, profound changes and a long-term vision must be adopted. Consequently, companies must position themselves in a repository in such a way that they can then define realistic development targets. Companies are aided in this by an MM, and additionally, as demonstrated, current MMs are not relevant in characterizing their situations and uses. The response proposed here has been inspired by the best references found to address this concern. A **free questionnaire has been proposed** to help renovation actors determine their BIM

maturity level. The selected format and the simplicity of the questions should enable SmEnts maturities to be characterized and to emphasize their weak and strong points. Questions also draw the outline of individual and appropriate action plans.

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The proposal made is an innovative answer to the needs of these companies **in the sense that, unlike existing models, we have the following:**

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- Its specific, dedicated side will be reassuring and will be able to play the role of analyzing, diagnosing or monitoring the company's evolution throughout the implementation process of the BIM. This point is accentuated by the fact that the vocabulary has been streamlined to be suitable for organizations that are usually small and highly technical but not very robust from an administrative and organizational point of view.
- It not only encourages companies to appropriately prepare but also aims to provoke a reaction on their part since, without proper upstream preparation, certain maturities will not be calculated (IPro Block).
- The model accounts for the specifics of the sector by integrating the problems posed by quotations before any work is performed, as well as the organizational structure of small businesses, which no other MM evokes.
- It raises the issue of the development and use of the essential BEP between the various actors and contributes to a homogenization of the practices and content of the latter (the substance in Questions 6 to 25). BiM<sup>2</sup>FR incidentally provides assistance in BEP drafting.
- **It encourages reflection on many different notions or principles that value the most important FCS found in the scientific literature** and that are essential for the deployment of BIM. This status is only partially verified by the MMs that are most widely disseminated to date. **Due to our work, the best of these latter take the form of a unique model. The CSF studied and presented within the BiM<sup>2</sup>FR** are the markers and pledges of success that will enable companies to progress in their BIM implementation for renovation purposes and thereby remain visible and consistent as markets evolve.
- It insists on the IPD approach by sensitizing Project Management to the roles that customers and all stakeholders must play early on in renovation projects. More than other MMs, **it provides advice about innovative organizational choices, such as Lean Construction, certification or the existence of an ethical charter.**
- **Finally, this MM encourages companies to cooperate and create long-term alliances between complementary partners, to set up and monitor indicators or to develop a process approach, and so forth.**

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These points have been demonstrated through a case study of three different companies. This work supports a first proposal, which responds to and leans on observations, and a relatively wide literature review. Among the contributions to this model, it enables a response to items widely felt but sometimes not expressed, and it outlines a roadmap for gaining autonomy, maturity and performance.

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In agreement with the work presented by De Bruin *et al.*, reproduced on Figure 8, this BiM<sup>2</sup>FR will next be tested at a larger scale as a way to adjust the first version [91].



Figure 8: Main phases of developing a maturity assessment model according to De Bruin *et al.*

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This proposal is based on state-of-the-art studies and the experience feedback that has occurred in several countries: Taiwan, Finland, UK, France, and others. This article has highlighted the research approach that was conducted to scientifically develop an appropriate and original MM. From this point, a long task of information collection and analysis will be required. The first returns of this work will be obtained due to a BiM<sup>2</sup>FR web tool that implements the questionnaire and MM. The data collected will help to better understand the specificities of countries, their cultural BIM implantation approach, the typical features of BIM pioneers and more. For this reason, an interface and a web version were developed, and a prototype version is available **in French and in English** at [www.BiM2FR.eu](http://www.BiM2FR.eu). The first tests are now being conducted with selected members of the French Building Federation in Burgundy and privileged partners, which will likely result in some refinements. All of these developments will also accelerate the dissemination of this proposal, as well as help to judge its implementation and instantiation. For the time being, feedback on BiM<sup>2</sup>FR is still premature given, for example, the time required to collect and analyze the data, and the time needed to formulate new hypotheses and update a second version. This work is necessary and must be performed relatively quickly to be able to accompany a sector that is itself in full and rapid evolution.

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Similar to the way in which the model developed by the VDC Scorecard research team in 2009 has progressively moved from version 1 to 8, we are aware that developments are expected before a referential can be mutually agreed upon. It is likely that we are only at the beginning of a long and difficult process, as observed during recent interviews, and in accordance with past studies [32].

In more general terms, the required BiM<sup>2</sup>FR adjustments can be noted because of the users themselves. Since small structures with mainly strong technical skills are the target, the model might first be adapted from a linguistic point of view for ease of use. Other input data could lead to changes such as local and legislative constraints, such as digital building or rehabilitation permits, necessary BIM models for costly works, the replacement of major building services every 30 years such as plumbing systems (for example, in Finland), and other country-specific factors. Finally, additional elements of interest that were raised in the literature and were only partially addressed here could be approached in later work to increase the digitization of renovation projects and to round out this work. Indeed, we have the following:

- We are considering developing an “intelligent” questioning interface that will limit, in some cases, the number of questions to be asked (approximately 20 topics for more involvement and efficiency appears to be a good compromise). Unnecessary questions in light of earlier answers obtained can then be eliminated. This approach could bring about a potential risk of loss of information. However, it is anecdotal to question specific points related to BIM if, for example, the fundamentals (i.e., general organization, project management) are not acquired.
- For output data, in addition to the Kiviat visualization, positioning in an ISO repository can also be proposed. Standards and normative documents could be additional ways that could help companies to identify and chart a path. This approach might be made through the model proposed by Succar [77], and whose capacity levels correspond to those proposed in BSI [66] (itself referential of the future ISO 19650 [68]), as indicated previously. Due to the topics addressed through the BiM<sup>2</sup>FR questions, it appears to be simple to automatically position a company inside a set of competencies selected by this author and by extension within ISO 19650.
- The final challenge that is presented in parallel with this MM development is to respond to the need for automated data capture: the initial stage of BIM model creation. The challenge is to limit certain errors and reduce time-consuming steps and increase accessibility for any company or any type and size of renovation project [53]. When bringing about solutions such as these to companies, the spread of BIM within the renovation sector could accelerate.

In addition to its primary function of supporting companies, this research and its perspectives are offered as first proposals for BiM<sup>2</sup>FR.

## 7 References

- [1] P. Gerbert, S. Castagnino, C. Rothballer, A. Renz, R. Filitz, The Transformative Power of Building Information Modeling, The Boston Consulting Group (BCG). (2016). <https://www.bcg.com/publications/2016/engineered-products-infrastructure-digital-transformative-power-building-information-modeling.aspx> (accessed December 28, 2018).
- [2] K. Barlish, K. Sullivan, How to measure the benefits of BIM — A case study approach, *Automation in Construction*. 24 (2012) 149–159. doi:10.1016/j.autcon.2012.02.008.
- [3] BuildingSMART, What is a BIM?, BuildingSMART. (2017). <http://www.buildingsmart.org/standards/technical-vision/> (accessed December 12, 2018).
- [4] L. Joblot, T. Paviot, D. Deneux, S. Lamouri, Literature review of Building Information Modeling (BIM) intended for the purpose of renovation projects, *IFAC-PapersOnLine*. 50 (2017) 10518–10525. doi:10.1016/j.ifacol.2017.08.1298.
- [5] HIA, Australia’s \$31.4 Billion Home Renovations Market, (2016). [https://hia.com.au/-/media/HIA-Website/Files/Media-Centre/Media-Releases/2016/national/Australia-\\$31-Billion-Home-Renovations-Market.ashx](https://hia.com.au/-/media/HIA-Website/Files/Media-Centre/Media-Releases/2016/national/Australia-$31-Billion-Home-Renovations-Market.ashx) (accessed December 28, 2018).
- [6] Harvard University, Renovation Spending Continues to Grow, But More Slowly (Press release from the Joint Center for Housing Studies, Harvard University), (2017). <http://www.jchs.harvard.edu/renovation-spending-continues-grow-more-slowly> (accessed December 12, 2018).
- [7] CAPEB, Les chiffres de l’Artisanat, (2016). <http://www.capeb.fr/les-chiffres-de-lartisanat> (accessed December 28, 2018).
- [8] N.H. Sandberg, I. Sartori, O. Heidrich, R. Dawson, E. Dascalaki, S. Dimitriou, T. Vimm-r, F. Filippidou, G. Stegnar, M.Š. Zavrl, Dynamic building stock modelling: Application to 11 European countries to support the energy efficiency and retrofit ambitions of the EU, *Energy and Buildings*. 132 (2016) 26–38. doi:10.1016/j.enbuild.2016.05.100.
- [9] L. Joblot, D. Deneux, T. Paviot, S. Lamouri, Survey of the Renovation Sector in France: A Necessary Step Towards Implementing BIM in Microenterprises, in: *IESM 2017 - International Conference on Industrial Engineering and Systems Management*, Saarbrücken, Germany, 2017. <https://hal.archives-ouvertes.fr/hal-01666318> (accessed December 28, 2018).
- [10] R. Miettinen, S. Paavola, Beyond the BIM utopia: Approaches to the development and implementation of building information modeling, *Automation in Construction*. 43 (2014) 84–91. doi:10.1016/j.autcon.2014.03.009.
- [11] Commission européenne, Statistiques structurelles sur les entreprises – vue d’ensemble - Statistics Explained, (2017). [https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Structural\\_business\\_statistics\\_overview/fr](https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Archive:Structural_business_statistics_overview/fr) (accessed December 12, 2018).

- 770 [12] European commission, Micro-, small- and medium-sized enterprises: definition and scope, (2003). <http://eur-lex.europa.eu/eli/reco/2003/361/oj> (accessed December 12, 2018).
- [13] A. Owen, The challenges of implementing low carbon retrofit in existing buildings—attending to installers and micro-enterprises, in: *Sustainable Ecological Engineering Design for Society (SEEDS) Conference 2015: Conference Proceedings*, LSI Publishing, 2016: pp. 55–66 (ISBN 978-0-9955690-0-3).
- 775 [14] Office for National Statistics, UKBC Enterprise/local units by Industry, Employment size band and Legal status, (2016). <https://www.ons.gov.uk/businessindustryandtrade/business/activitysizeandlocation/adhocs/006961analysisoflocalunitsandenterprisesintheunitedkingdombyuksicsectionandemploymentsizeband2016> (accessed December 12, 2018).
- [15] H. Kagermann, J. Helbig, A. Hellinger, W. Wahlster, Recommendations for Implementing the strategic initiative INDUSTRIE 4.0 : Securing the future of German manufacturing industry; final report of the Industrie 4.0 Working Group, Forschungsunion, 2013. [http://www.forschungsunion.de/pdf/industrie\\_4\\_0\\_final\\_report.pdf](http://www.forschungsunion.de/pdf/industrie_4_0_final_report.pdf) (accessed December 17, 2018).
- 780 [16] A. Moeuf, R. Pellerin, S. Lamouri, S. Tamayo-Giraldo, R. Barbaray, The industrial management of SMEs in the era of Industry 4.0, *International Journal of Production Research*. 56 (2018) 1118–1136. doi:10.1080/00207543.2017.1372647.
- [17] O. Torrès, *les PME*, Flammarion Paris. (1999) (ISBN-13: 978-2080355959).
- [18] C. Wang, E. Walker, J. Redmond, Explaining the lack of strategic planning in SMEs: The importance of owner motivation, in: *International Journal of Organisational Behaviour*, 2007: pp. 1–16 (ISSN 1440-5377). <https://www.researchgate.net/publication/49277688> (accessed December 12, 2018).
- 785 [19] J. Jansson, J. Nilsson, F. Modig, G. Hed Vall, Commitment to sustainability in small and medium-sized enterprises: The influence of strategic orientations and management values, *Business Strategy and the Environment*. 26 (2017) 69–83. doi:10.1002/bse.1901.
- 790 [20] D. Souder, G. Reilly, R. Ranucci, Bringing Long-Term Thinking into Business, Network for Business Sustainability. (2015). <https://nbs.net/p/bringing-long-term-thinking-into-business-377e84dd-8234-4488-8c6d-f7b91e2add33> (accessed December 27, 2018).
- [21] T. Kouider, G.J. Paterson, Architectural technology and the BIM acronym: critical perspectives of evangelical and evolutionary paradigms for technical design., in: *Architectural Technology: The Defining Features. Proceedings of the 4th International Congress of Architectural Technology*, 2013: pp. 122–141. <https://openair.rgu.ac.uk/handle/10059/1162> (accessed December 12, 2018).
- 795 [22] A. Ghaffarianhoseini, D.T. Doan, T. Zhang, A. Ghaffarianhoseini, N. Naismith, J. Tookey, A BIM Readiness & Implementation Strategy for SME Construction Companies in the UK, Proceedings of the 33rd International Conference of CIB W78., (2016). <http://itc.scix.net/data/works/att/w78-2016-paper-008.pdf> (accessed December 28, 2018).
- 800 [23] D. Ilter, E. Ergen, BIM for building refurbishment and maintenance: current status and research directions, *Structural Survey*. 33 (2015) 228–256. doi:10.1108/SS-02-2015-0008.
- [24] R. Santos, A.A. Costa, A. Grilo, Bibliometric analysis and review of Building Information Modelling literature published between 2005 and 2015, *Automation in Construction*. 80 (2017) 118–136. doi:10.1016/j.autcon.2017.03.005.
- [25] T. Hartmann, H. van Meerveld, N. Vosseveld, A. Adriaanse, Aligning building information model tools and construction management methods, *Automation in Construction*. 22 (2012) 605–613. doi:10.1016/j.autcon.2011.12.011.
- 805 [26] M. Giroud, *Baromètre des entreprises du bâtiment*, KPMG. (2017). <https://assets.kpmg.com/content/dam/kpmg/fr/pdf/2017/01/fr-barometre-entreprises-batiment-2016.pdf> (accessed December 5, 2018).
- [27] B. McAuley, A. Hore, R. West, BICP Global BIM Study-Lessons for Ireland’s BIM Programme, (2017). doi:10.21427/D7M049.
- 810 [28] D. Proença, J. Borbinha, Maturity Models for Information Systems - A State of the Art, *Procedia Computer Science*. 100 (2016) 1042–1049. doi:10.1016/j.procs.2016.09.279.
- [29] M.H. Zack, Developing a knowledge strategy, *California Management Review*. 41 (1999) 125–145. doi:10.2307/41166000.
- [30] D. Helander, V. Singh, BIM in building renovation projects: what is the useful minimum information requirement?, *International Journal of Product Lifecycle Management*. 9 (2016) 65–86. doi:10.1504/IJPLM.2016.078863.
- 815 [31] S. Mellon, T. Kouider, SMEs and BIM in preparation for 2016: a case study., in: *Architectural Technology, Towards Innovative Professional Practice: Conference Proceedings of the 5th International Congress of Architectural Technology*, Aberdeen 2014, Robert Gordon University, 2014. <http://openair.rgu.ac.uk/handle/10059/1151> (accessed December 5, 2018).
- [32] F. Khosrowshahi, Y. Arayici, Roadmap for implementation of BIM in the UK construction industry, *Engineering, Construction and Architectural Management*. 19 (2012) 610–635. doi:10.1108/09699981211277531.
- 820 [33] A. Ghaffarianhoseini, J. Tookey, A. Ghaffarianhoseini, N. Naismith, S. Azhar, O. Efimova, K. Raahemifar, Building Information Modelling (BIM) uptake: Clear benefits, understanding its implementation, risks and challenges, *Renewable and Sustainable Energy Reviews*. 75 (2017) 1046–1053. doi:10.1016/j.rser.2016.11.083.
- [34] E.A. Pärn, D.J. Edwards, M.C.P. Sing, The building information modelling trajectory in facilities management: A review, *Automation in Construction*. 75 (2017) 45–55. doi:10.1016/j.autcon.2016.12.003.
- 825




- [35] B. Succar, W. Sher, A. Williams, An integrated approach to BIM competency assessment, acquisition and application, *Automation in Construction*. 35 (2013) 174–189. doi:10.1016/j.autcon.2013.05.016.
- [36] J. Harty, T. Kouider, G.J. Paterson, Challenges, risks and benefits for SMEs., Routledge, chapter 8 (ISBN 9781138843974), 2015. <https://openair.rgu.ac.uk/handle/10059/1843> (accessed December 28, 2018).
- 830 [37] R.L. Owen, R. Amor, J. Dickinson, M. Prins, A. Kiviniemi, Research roadmap report: Integrated Design and Delivery Solutions (IDDS), (2013) (ISBN 9789063630720) 39.
- [38] R. Takim, M. Harris, A.H. Nawawi, Building Information Modeling (BIM): A New Paradigm for Quality of Life Within Architectural, Engineering and Construction (AEC) Industry, *Procedia - Social and Behavioral Sciences*. 101 (2013) 23–32. doi:10.1016/j.sbspro.2013.07.175.
- 835 [39] T.A. Folorunso, T.A. Uthman, The Process of Implementing Building Information Modelling (BIM) in the UK: A Contractor’s Perspective, in: *The Nigerian Institute of Quantity Surveyors: 2nd Research Conference, 2015*: pp. 496-517 (ISBN 978 – 978 – 949 – 128 – 5).
- [40] T. Mäkeläinen, J. Hyvärinen, M. Rekola, Methodology for tracking BIM benefits on project level, in: *EWork and EBusiness in Architecture, Engineering and Construction 2016: Proceedings of the 11th European Conference on Product and Process Modelling*, Limassol, Cyprus, 7-9 September 2016, CRC Press, 2017: pp. 417-426 (ISBN 978-113803280-4).
- 840 [41] A.C. Badrinath, S.-H. Hsieh, N. Kumar, BIM performance assessments and its application in Indian AECO Industry - A case study, in: *Proceedings of the 16th International Conference on Construction Applications of Virtual Reality, 2016*: p. 13. <https://www.researchgate.net/publication/311575835> (accessed December 2, 2018).
- [42] The American Institute of Architects, *Integrated Project Delivery: A Guide*, (2007). <http://www.aia.org/contractdocs/AIAS077630> (accessed December 12, 2018).
- 845 [43] I. Motawa, A. Almarshad, A knowledge-based BIM system for building maintenance, *Automation in Construction*. 29 (2013) 173–182. doi:10.1016/j.autcon.2012.09.008.
- [44] E. Gholami, S. Sharples, S. Abrishami, T. Kucaturk, Exploiting BIM in energy efficient refurbishment: a paradigm of future opportunities, in: W. Lang (Ed.), *PLEA2013 (Passive and Low Energy Architecture)*, Fraunhofer IRB Verlag, Munich, Germany, 2013: pp. 1-6 (ISBN 978-3816790549).
- 850 [45] F. Khosrowshahi, A. Alani, Visualisation of impact of time on the internal lighting of a building, *Automation in Construction*. 20 (2011) 145–154. doi:10.1016/j.autcon.2010.09.012.
- [46] J. Won, J.C.P. Cheng, Identifying potential opportunities of building information modeling for construction and demolition waste management and minimization, *Automation in Construction*. 79 (2017) 3–18. doi:10.1016/j.autcon.2017.02.002.
- 855 [47] E.O. Ibem, S. Laryea, Survey of digital technologies in procurement of construction projects, *Automation in Construction*. 46 (2014) 11–21. doi:10.1016/j.autcon.2014.07.003.
- [48] J. Wang, S. Zhang, J. Teizer, Geotechnical and safety protective equipment planning using range point cloud data and rule checking in building information modeling, *Automation in Construction*. 49, Part B (2015) 250–261. doi:10.1016/j.autcon.2014.09.002.
- 860 [49] S. Ghosh, S. Negahban, Y.H. Kwak, M.J. Skibniewski, Impact of sustainability on integration and interoperability between BIM and ERP-A governance framework, in: *IEEE*, 2011: pp. 187–193. doi:10.1109/ITMC.2011.5995975.
- [50] E.A. Pärn, D. Edwards, Vision and advocacy of optoelectronic technology developments in the AECO sector, *Built Environment Project and Asset Management*. 7 (2017) 330–348. doi:10.1108/BEPAM-11-2016-0081.
- [51] E. Papadonikolaki, Alignment of Partnering with Construction IT, *A+BE | Architecture and the Built Environment*. 6 (2016) 1–328. doi:10.7480/abe.2017.19.
- 865 [52] E. Sackey, J. Akotia, Spanning the multilevel boundaries of construction organisations: towards the delivery of BIM-compliant projects, *Construction Innovation*. 17 (2017). <http://www.emeraldinsight.com/doi/abs/10.1108/CI-09-2016-0047>.
- [53] M. Khaddaj, I. Srour, Using BIM to Retrofit Existing Buildings, *Procedia Engineering*. 145 (2016) 1526–1533. doi:10.1016/j.proeng.2016.04.192.
- 870 [54] Cuš Babić, Danijel Rebolj, Culture change in construction industry: from 2D toward BIM based construction, in: *Journal of Information Technology in Construction*, 2016: pp. 86–99. <http://www.itcon.org/2016/6> (accessed December 12, 2018).
- [55] T. Beach, I. Petri, Y. Rezgui, O. Rana, Management of Collaborative BIM Data by Federating Distributed BIM Models, *Journal of Computing in Civil Engineering*. 31 (2017). doi:10.1061/(ASCE)CP.1943-5487.0000657.
- 875 [56] A. Noori, M. Saruwono, H. Adnan, I. Rahmat, Conflict, Complexity, and Uncertainty in Building Refurbishment Projects, in: M. Yusoff, N.H.A. Hamid, M.F. Arshad, A.K. Arshad, A.R.M. Ridzuan, H. Awang (Eds.), *InCIEC 2015*, Springer Singapore, 2016: pp. 251–258. doi:10.1007/978-981-10-0155-0\_24.
- [57] J. Redwood, S. Thelning, A. Elmualim, S. Pullen, The proliferation of ICT and digital technology systems and their influence on the dynamic capabilities of construction firms, *Procedia Engineering*. 180 (2017) 804–811. doi:10.1016/j.proeng.2017.04.241.
- 880 [58] C.D. Ramanayaka, S. Venkatachalam, Reflection on BIM Development Practices at the Pre-maturity, *Procedia Engineering*. 123 (2015) 462–470. doi:10.1016/j.proeng.2015.10.092.

- [59] R. Sacks, L. Koskela, B.A. Dave, R. Owen, Interaction of lean and building information modeling in construction, *Journal of Construction Engineering and Management*. 136 (2010) 968–980. doi:10.1061/(ASCE)CO.1943-7862.0000203.
- 885 [60] A.-M. Mahamadu, L. Mahdjoubi, C.A. Booth, Determinants of Building Information Modelling (BIM) acceptance for supplier integration: A conceptual model, in: *Proceedings 30th Annual Conference of the Association of Researchers in Construction Management*, 2014; pp. 723–732 (ISBN 978-0-9552390-8-3).
- [61] R. Morlhon, R. Pellerin, M. Bourgault, Defining Building Information Modeling implementation activities based on capability maturity evaluation: a theoretical model, *International Journal of Information Systems and Project Management*, 3( 1). (2015) 51–65. doi:10.12821/ijispm030103.
- 890 [62] O. Françoise, M. Bourgault, R. Pellerin, ERP implementation through critical success factors' management, *Business Process Management Journal*. 15 (2009) 371–394. doi:10.1108/14637150910960620.
- [63] M.-H. Tsai, M. Mom, S.-H. Hsieh, Developing critical success factors for the assessment of BIM technology adoption: part I. Methodology and survey, *Journal of the Chinese Institute of Engineers*. 37 (2014) 845–858. doi:10.1080/02533839.2014.888811.
- 895 [64] E. Mlecnik, I. Kondratenko, J. Cré, J. Vrijders, P. Degraeve, J.A. van der Have, T. Haavik, S.A. Aabrekk, M. Grøn, S. Hansen, Collaboration opportunities in advanced housing renovation, *Energy Procedia*. 30 (2012) 1380–1389. doi:10.1016/j.egypro.2012.11.152.
- [65] C.S. Snyder, *A Guide to the Project Management Body of Knowledge: PMBOK (®) Guide - Fifth edition.*, Project Management Institute, Inc. (2014) (SBN: 978-1-935589-67-9).
- 900 [66] British Standards Institution (BSI), PAS 1192-2:2013 Specification for information management for the capital/delivery phase of construction projects using building information modelling, (2013). <https://shop.bsigroup.com/Sandpit/PAS-old-forms/PAS-1192-2/> (accessed December 22, 2018).
- [67] CIC Research Group, *BIM Project Execution Planning Guide*, (2011). [http://bim.psu.edu/Project/resources/download\\_thank\\_you.aspx](http://bim.psu.edu/Project/resources/download_thank_you.aspx) (accessed June 25, 2018).
- 905 [68] International Organization for Standardization, ISO/DIS 19650-1 - Organisation des informations concernant les ouvrages de construction -- Gestion de l'information par la modélisation des informations de la construction -- Partie 1: Concepts et principes, (2018). <https://www.iso.org/standard/68078.html> (accessed December 12, 2018).
- [69] Mediaconstruct, *Guide méthodologique pour des conventions de projets en BIM*, (2016). <http://www.mediaconstruct.fr/boites-a-outils-bim/guide-de-convention-bim> (accessed December 29, 2018).
- 910 [70] D. Cao, H. Li, G. Wang, Impacts of building information modeling (BIM) implementation on design and construction performance: a resource dependence theory perspective, *Frontiers of Engineering Management*. 4 (2017) 20–34. doi:10.15302/J-FEM-2017010.
- [71] Y. Rezgui, J. Miles, Exploring the Potential of SME Alliances in the Construction Sector, *Journal of Construction Engineering and Management*. 136 (2010) 558–567. doi:10.1061/(ASCE)CO.1943-7862.0000150.
- 915 [72] International Organization for Standardization, ISO/IEC 30105-3:2016 - Information technology — IT Enabled Services-Business Process Outsourcing (ITES-BPO) lifecycle processes — Part 3: Measurement framework (MF) and organization maturity model (OMM), (2016). <https://www.iso.org/standard/62707.html> (accessed January 7, 2019).
- [73] Cong Liang, Weisheng Lu, Steve Rowlinson, Xiaoling Zhang, Development of a Multifunctional BIM Maturity Model, *Journal of Construction Engineering and Management*. 142 (2016). doi:10.1061/(ASCE)CO.1943-7862.0001186.
- 920 [74] International Organization for Standardization, ISO/IEC 33020:2015 - Information technology -- Process assessment -- Process measurement framework for assessment of process capability, (2015). <https://www.iso.org/standard/54195.html> (accessed January 7, 2019).
- [75] A. Hutchinson, M. Finnemore, Standardized process improvement for construction enterprises, *Total Quality Management*. 10 (1999) 576–583. doi:10.1080/0954412997550.
- 925 [76] BIMetric, *La méthode BIMetric*, (2016). <http://bimetric.list.lu/> (accessed December 12, 2018).
- [77] B. Succar, Building information modelling maturity matrix, *Handbook of Research on Building Information Modeling and Construction Informatics*, IGI Global. (2009) 65–103. doi:10.4018/978-1-60566-928-1.ch004.
- [78] B. Succar, W. Sher, A. Williams, Measuring BIM performance: Five metrics, *Architectural Engineering and Design Management*. 8 (2012) 120–142. doi:10.1080/17452007.2012.659506.
- 930 [79] B. Succar, Building information modelling framework: A research and delivery foundation for industry stakeholders, *Automation in Construction*. 18 (2009) 357–375. doi:10.1016/j.autcon.2008.10.003.
- [80] C. Kam, M.H. Song, D. Senaratna, VDC Scorecard: Formulation, Application, and Validation, *Journal of Construction Engineering and Management*. (2016) 04016100. doi:10.1061/(ASCE)CO.1943-7862.0001233.
- 935 [81] C. Wu, B. Xu, C. Mao, X. Li, Overview of BIM maturity measurement tools, in: *Journal of Information Technology in Construction*, 2017; pp. 34–62 (ISSN: 1874-4753). <http://itcon.org/paper/2017/3> (accessed December 12, 2018).
- [82] A. Azzouz, P. Shepherd, A. Copping, The emergence of Building Information Modelling Assessment Methods, *Integrated Design at 50: Building Our Future*. (2016). [http://opus.bath.ac.uk/52088/1/id50\\_preprint.pdf](http://opus.bath.ac.uk/52088/1/id50_preprint.pdf) (accessed December 12, 2018).



- [83] NBIMS-US, National BIM Standard-United States® Version 3 | National BIM Standard - United States, (2015). <https://www.nationalbimstandard.org/nbims-us> (accessed December 28, 2018).
- [84] CIC, BIM Planning Guide for Facility Owners, (2013). [https://www.bim.psu.edu/owners\\_guide/](https://www.bim.psu.edu/owners_guide/) (accessed December 12, 2018).
- 1020 [85] ARUP, BIM Maturity Model, (2015). <https://www.arup.com/perspectives/publications/research/section/bim-maturity-model> (accessed December 29, 2018).
- [86] Vicosoftware, Calculating Your BIM Score | BIM Scorecard | BIM Maturity, (2017). <http://support.vicosoftware.com/login.aspx?ReturnUrl=%2f> (accessed December 5, 2018).
- 1025 [87] A. Dakhil, J. Underwood, M. Al Shawi, BIM benefits-maturity relationship awareness among UK construction clients., in: Proceedings of the First International Conference of the BIM Academic Forum, Glasgow Caledonian University, 2016. (ISBN 9781905866816).
- [88] NBS-RIBA, Periodic Table of BIM, NBS. (2016). <https://www.thenbs.com/knowledge/periodic-table-of-bim> (accessed December 20, 2018).
- 1030 [89] Mediaconstruct, Code d'éthique BIM, (2017). <http://www.mediaconstruct.fr/boites-a-outils-bim/code-dethique-bim> (accessed December 15, 2018).
- [90] BuildingSMART, Professional Certification, BuildingSMART. (2017). <https://education.buildingsmart.org/> (accessed December 15, 2018).
- 1035 [91] T. De Bruin, R. Freeze, U. Kaulkarni, M. Rosemann, Understanding the Main Phases of Developing a Maturity Assessment Model, in: B. Campbell, J. Underwood, D. Bunker (Eds.), Australasian Conference on Information Systems (ACIS), Australia, New South Wales, Sydney, 2005: pp. 8-19 (ISBN 978-0-9758417-0-9).

## APPENDIX A: 20 Maturity issues also linked to BEP

Q 6	Strategy, Collaboration, Standards	BEP: yes <input checked="" type="checkbox"/> no <input type="checkbox"/>	CSF: IPD and Cooperative model
Which alliance or interorganizational dynamics is conceivable for you?		Sources: Succar and PA	
1040	 <ul style="list-style-type: none"> <li>✓ Each project is run independently. There is no agreement between stakeholders to collaborate beyond their current common project</li> <li>✓ Stakeholders think beyond a single project. Collaboration protocols between project stakeholders are defined and documented</li> <li>✓ Collaboration between multiple organizations over several projects is managed through temporary alliances between stakeholders</li> <li>✓ Collaborative projects are undertaken by interdisciplinary organizations or multidisciplinary project teams; an alliance of many key stakeholders</li> <li>✓ Collaborative projects are undertaken by self-optimizing interdisciplinary project teams which include most stakeholders</li> </ul>		
Q 7	Foundations, Process, Standards	BEP: yes <input checked="" type="checkbox"/> no <input type="checkbox"/>	CSF: IPD and N°34
How BIM client's needs are taken into account?		Source: ARUP	
1040	 <ul style="list-style-type: none"> <li>✓ No known client BIM-specific information requirements</li> <li>✓ Client BIM-specific information requirements discussed with the client but not resolved</li> <li>✓ <math>\Phi</math></li> <li>✓ Complete client BIM-specific information requirements received and comments returned</li> <li>✓ Complete client BIM-specific information requirements received and implemented before contractor procurement</li> <li>✓ Complete client BIM-specific information requirements received and reviewed regularly</li> </ul>		
Q 8	Process, Standards, Collaboration	BEP: yes <input checked="" type="checkbox"/> no <input type="checkbox"/>	CSF: IPD and N°37
What is your data review's maturity?		Source: ARUP	
1040	 <ul style="list-style-type: none"> <li>✓ No Design Data Review, pre or post award</li> <li>✓ Post-award BIM Design Data review (acceptance of the final estimate) held</li> <li>✓ <math>\Phi</math></li> <li>✓ BIM Design Data reviewed against the BEP as part of the Design Review process</li> <li>✓ <math>\Phi</math></li> <li>✓ BIM Design Data reviewed against the BEP as part of the Delivery process</li> </ul>		
Q 9	Process, Standards, Collaboration	BEP: yes <input checked="" type="checkbox"/> no <input type="checkbox"/>	CSF: IPD
Are your models developed to support the Operations and Facility Management phase?		Source: ARUP	

1045



- ✓ None considered
- ✓ Client requirements not implemented
- ✓ ∅
- ✓ Client requirements implemented but Model not used for FM
- ✓ ∅
- ✓ Model progressively matured with embedded attributed information suitable for Client handover for use in O&M

Maturity

- ✓ Usage of software applications is unmonitored and unregulated. 3D Models are relied on to mainly generate accurate 2D representations/deliverables. Data usage, storage and exchanges are not defined within organizations or project teams. Exchanges suffer from a severe lack of interoperability
- ✓ Software usage/introduction is unified within an organization or project teams (multiple organizations). 3D Models are relied upon to generate 2D as well as 3D deliverables. Data usage, storage and exchange are well defined within organizations and project teams. Interoperable data exchanges are defined and prioritized
- ✓ Software selection and usage is controlled and managed according to defined deliverables. Models are the basis for 3D views, 2D representations, quantification, specification and analytical studies. Data usage, storage and exchanges are monitored and controlled. Data flow is documented and well-managed. Interoperable data exchanges are mandated and closely monitored
- ✓ Software selection and deployment follows strategic objectives, not just operational requirements. Modeling deliverables are well synchronized across projects and tightly integrated with business processes. Interoperable data usage, storage and exchange are regulated and performed as part of an overall organizational or project-team strategy
- ✓ Selection/use of software tools is continuously revisited to enhance productivity and align with strategic objectives. Modeling deliverables are cyclically being revised/ optimized to benefit from new software functionalities and available extensions. All matters related to interoperable data usage storage and exchange are documented, controlled, reflected upon and proactively enhanced

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- ✓ No data security and saving requirement
- ✓ Data security and saving requirements are established within the BIM department or BIM group
- ✓ Data security and saving requirements are established within the organization
- ✓ Data security and saving requirements are established within the industry



- ✓ No intention or knowledge about BIM certification
- ✓ Aware of the importance of having certified partners
- ✓ Aware of the importance of having in-house certified partners
- ✓ All members of the company is certified
- ✓ Tracking certificate updates, and certification required to work with a third party

Q 28	Strategy, Foundations, Collaboration	BEP: yes <input type="checkbox"/> no <input checked="" type="checkbox"/>	Cooperative model and N°38
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What is your position about a BIM Ethical Code?	Source: PA
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- ✓ No intention or knowledge about this code if it exists in the country
- ✓ A reference member of the company intends to sign it
- ✓ A reference member of the company signed it
- ✓ All members of the company signed it
- ✓ Follow up on this code update and necessary condition to work with a third party

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