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Romain Morlhon
École Polytechnique de Montréal

Robert Pellerin
École Polytechnique de Montréal

Mario Bourgault
École Polytechnique de Montréal

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Defining Building Information Modeling implementation activities based on capability maturity evaluation: a theoretical model

Romain Morlhon
Jarislowsky/SNC-Lavalin Research Chair in the management of international projects and CIRRELT
Department of Mathematics and Industrial Engineering, École Polytechnique de Montréal
C.P. 6079, Succ. Centre-ville, Montréal, H3C 3A7, Canada
www.shortbio.net/rmorlhon@gmail.com

Robert Pellerin
Jarislowsky/SNC-Lavalin Research Chair in the management of international projects and CIRRELT
Department of mathematics and industrial engineering, École Polytechnique de Montréal
C.P. 6079, Succ. Centre-ville, Montréal, H3C 3A7, Canada
www.shortbio.net/robert.pellerin@polymtl.ca

Mario Bourgault
Department of mathematics and industrial engineering, École Polytechnique de Montréal
C.P. 6079, Succ. Centre-ville, Montréal, H3C 3A7, Canada
www.shortbio.net/mario.bourgault@polymtl.ca

Abstract:
Building Information Modeling (BIM) has become a widely accepted tool to overcome the many hurdles that currently face the Architecture, Engineering and Construction industries. However, implementing such a system is always complex and the recent introduction of BIM does not allow organizations to build their experience on acknowledged standards and procedures. Moreover, data on implementation projects is still disseminated and fragmentary. The objective of this study is to develop an assistance model for BIM implementation. Solutions that are proposed will help develop BIM that is better integrated and better used, and take into account the different maturity levels of each organization. Indeed, based on Critical Success Factors, concrete activities that help in implementation are identified and can be undertaken according to the previous maturity evaluation of an organization. The result of this research consists of a structured model linking maturity, success factors and actions, which operates on the following principle: once an organization has assessed its BIM maturity, it can identify various weaknesses and find relevant answers in the success factors and the associated actions.

Keywords:
Building Information System; project management; Critical Success Factors; information systems; maturity.

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1. Introduction

Integrated information management has increasingly become a matter of concern, despite the fact that ERP solutions have existed since the seventies. At the same time, numerous studies on 3D modeling have shown its benefits; these are especially noteworthy in the aircraft industry [1]. After a couple of decades of efforts focused on 2D-modeling from the Architecture, Engineering and Construction (AEC) industry, interest in a new way of leading projects finally grew in the late nineties. This led to the development of Building Information Modeling (BIM) systems. The initials "BIM" first appeared in 2004 in the normal AEC vocabulary [1].

Today, Building Information Modeling (BIM) is recognized as a form of software or a group of information systems that enable the digital representation of physical and functional characteristics of a facility. A BIM system allows the sharing of knowledge resources for information about a facility over its complete life-cycle. As such, BIM systems fall into the category of integrated collaborative tools that aim for data interoperability and life cycle management.

As indicated in its name, BIM implies modeling, and more specifically building models. 3D models can be particularly advantageous, as such models can be expanded with the use of parametric objects. Those objects do not have a fixed-geometry but rather are defined by sets of parameters and rules to determine their behavior and characteristics [1]. It is therefore possible to encapsulate more information in models, to have more dynamic representations of buildings and to conduct analysis from the models thanks to the use of parametric objects. Additional dimensions can also be introduced in the models: time is the usual fourth dimension, with scheduling becoming available in the building models, and cost estimation can also be cited as the traditional fifth. More than a mere technological evolution, BIM provides a powerful response in terms of information management, communication and coordination between stakeholders. Indeed, BIM enables "an accurate and more complete documentary record of building information throughout the building design and construction process" [2]. To do so, BIM integrates the documents and data produced by stakeholders during construction projects and is bound to become a trustworthy, authoritative and exhaustive source of information (as shown in Fig. 1). The use of BIM has shifted the construction industry's usual information platform from disconnected building models to a networked collaborative platform where business partners can "exchange valuable information throughout the lifecycle" [3].

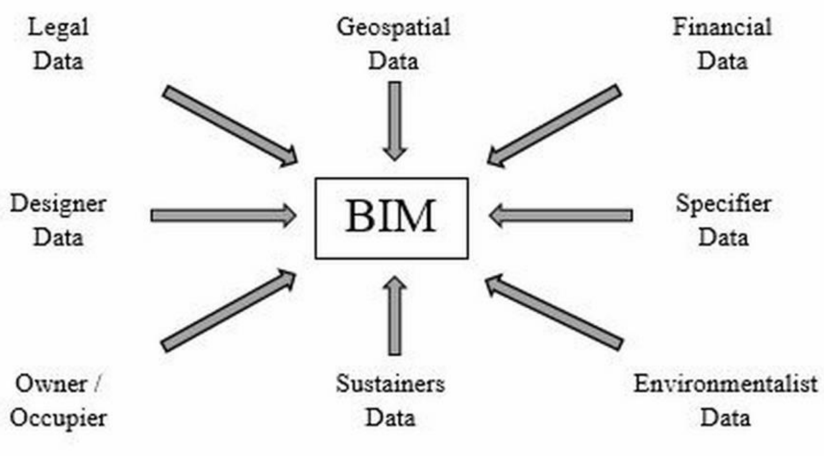

Fig. 1. BIM models integrating documents in order to communicate and collaborate (adapted from [4])

The AEC has seen its productivity stagnate and even shrink a little from 1964 to now, whereas other industries have performed much better [5]. Explanations for this can be found in the high amount of small firms in this sector that are unable to invest to improve their practices, or in the complexity of setting up an appropriate environment for numerous stakeholders to work together. The AEC industry still needs to find a way to raise productivity, efficiency, quality and sustainability and lower lifecycle costs, lead times and duplication [6]. BIM has proven its potential in terms of solving some of these major problems that are encountered in the AEC industry, but is still in the early phase of adoption. By reengineering their business processes by adopting BIM solutions and practices, firms can save time and money, produce more accurate and exhaustive building models and keep track of the information created during projects. BIM allows real-time communication based on the multidimensional models that have been introduced before and permits some additional analysis such as quantity takeoffs or clash detection [1],[7]-[9].

Despite this promising progress, BIM tools have not yet fully delivered their capabilities to professionals in this sector. The explanation for this limited introduction can be found in several factors, such as stubbornness of some firms about keeping the old CAD ways of working alive [10], change management [6],[11] or the need to adapt existing workflows in a lean oriented manner [6]. Consequently, a transition, as well as technical mindset, is compulsory to achieve the benefits of BIM. Another barrier to its widespread use in the AEC industry is the lack of guidance for this transition and the poor amount of studies that are rooted in reality to support firms in its adoption [6]. The most successful companies in this kind of project are the ones that had a clear deployment strategy [2]. By extension, implementation and adoption projects are smoother when ruled by a detailed plan and well-defined objectives, and progress needs to be made on that [12]. Thus, researchers can take part in a common trend towards the establishment of industry standards and best practices in that context and bring their support toward better integration of BIM in the industry.

Recognizing this need, the objective of this paper is to propose a support model for the adoption of BIM based on the BIM maturity of a company. The remainder of this article is organized as follows. Section 2 presents a brief review of the studies on the existing implementation procedures and how it can be assisted. Section 3 describes the model; the three different elements in the model and the linkages between them are depicted. After some consideration about how the model will be validated, we conclude with limitations and improvements that could be made.

2. Background work

As successful implementation needs to be framed by a well thought-out strategy, it is of interest to look into the literature to find out which studies have been realized in order to assist the implementation projects of integrated systems. Indeed, BIM integration is a complex objective to achieve and involves multiple issues that have to be taken into account differently according to the context of each organization.

BIM implementation can be seen from several points of view, depending on what the project owner’s aim is [11]. Technological issues can be the main concern [6],[14]-[16], as well as the new functionalities allowed by the implementation [14],[15] or its maturity [16]. Hartmann and al. [13] also note that the industry suffers from a poor amount of practical experiments led on a theoretical basis and insist above all on the need to adapt BIM to the company’s requirements, and not the other way around, in order to trigger the least possible resistance to change, and to disrupt the existing workflows as little as possible [18]. It also implies that studies often focus only on very aggregate levels and that firms lose from the lack of concrete advice. This point is reinforced by Davies and Harty [19] and their approach toward on-site implementation.

In addition to the definition of the expectations for BIM use, it is also relevant to assess its maturity in the organization with levels depicted in [10],[17]: object-based modelling, model-based collaboration and network-based integration. This evaluation can be used to enlighten firms about their current situation so they can prioritize the jobs to be done. This is indeed a central aspect in order to evolve towards the wider integration of BIM in the industry, as demonstrated by [2] with a description of the *Capability Maturity Model* (CMM). This tool has been developed by the *National Building Information Modeling Standard* (NBIMS), which adapted the Carnegie Mellon University original CMM® (CMM is registered in the U.S. Patent and Trademark Office by Carnegie Mellon University). It provides a maturity index through an organized assessment of BIM use and business processes happening in a company. The final mark obtained with the CMM is built from several criteria about the main issues of BIM.

Moreover, significant challenges can be clearly isolated, which can contribute to better preparation for the implementation if they are known in advance. Organizational culture, education and training, and information management seem to be three essential factors [10]. A comprehensive roadmap should integrate these issues in the implementation plan. In a similar manner, information management is often stated as a complex matter that has to be taken with much care, notably with the concepts of information stewardship, data responsibility and data accuracy [2]. The importance of the external stakeholders in the BIM leap forward [1],[2] can also be cited.

Within the context of implementation procedures and recommended practices, Arayici and al., [3] propose an iterative model for adoption used in a case study and by mimicking the lean principle of Plan, Do, Check, Act. This strategy is, however, restrained to a single case and does not exhaustively describe the steps to follow. It has also been applied in the specific situation of an implementation for remote projects [3]. Migilinskas and al. [7] prefer to focus their research on the identification of benefits, obstacles and challenges of an implementation, through different case studies. On the other hand, the well-known Autodesk Inc. company produced a BIM deployment plan [20]. This plan tackles multiple issues of a BIM implementation project, even though some other issues like change management are completely left aside. Therefore, this proposal has the major drawback of being one-sided and Autodesk-centered. Another interesting approach constructs a BIM adoption framework, which integrates challenges that were pointed out by professionals in specific interviews [16]. Furthermore, recent research conducted by Forgues and Staub-French [21] proves to be extremely relevant and can be compared to the previous deployment plan. The two authors provide a general overview of the benefits, challenges and hurdles encountered during a BIM adoption, based on three Canadian case studies, and continue with a proposal for a precise implementation guide, built upon the lessons learnt from those three experiences. Presented as a cycle, the result is an 8-step procedure, including practical activities, and is meant to cover the whole process of implementation. Its main weaknesses, however, lie in the choice of taking into account only Canadian small and medium enterprises, which directly restricts the study’s impact both with regards to country and the size of the companies that are likely to use the guide. Still, this research illustrates the efforts that need to be invested to properly describe the implementation issues and provide appropriate answers.

In light of the above research, it is important to mention how a methodology can rigorously be defined. Braun et al. [22] exhibit several constitutive elements necessary to wholly describe a methodology, four of which are activities included in a given procedure, the associated roles needed to perform them, deliverables produced by them and techniques to assist in their realization. Winter and Schelp [23] corroborate those elements and also add the flexibility and adaptability to any environment as criteria to obtain an exhaustive method. In comparison with what can be found in the literature about BIM, which was concisely explained in the previous review, there is obviously a gap to clear before having exhaustive implementation methodologies.

Instead of trying to treat the matter of implementation fully, some authors stay centered on a particular problem so they can examine it in more depth. Selecting the right BIM tool that fits with the company expectations [6], change management during an implementation project [11] or workflow reengineering [18] are examples. Information management and the associated corporate culture also seem to play a preponderant role and are investigated in depth in Smith and Tardif’s book [2].

With regard to that article and its motivations, it is also relevant to investigate which factors could influence how well a BIM implementation will go. Due to the similarities between BIM, PLM and ERP software, a close look at the dedicated literature is important. Many research projects have been carried out on the Critical Success Factors (CSF), which are elements that are seen as essential and that facilitate achievement related to an ERP adoption project [24]-[28]. Business process reengineering [24],[27],[28], change management [25],[27],[28] as well as end-user involvement [28] are three examples of those factors, that have to be taken into account to maximize the likelihood of success of the implementation projects. As far as BIM is concerned, studies have been conducted with a similar objective but no broad consensus has been reached. Analysis on which points gave an edge to acknowledged projects [29], driving factors [14] or key issues [2],[16] tend to be spread.

In conclusion, previous BIM related studies do not provide complete and concrete answers to the issues raised by the adoption and utilization of BIM. On the one hand, exhaustive implementation procedures are relatively non-existent and case studies are, conversely, not general enough. On the other hand, critical success factors of those kinds of projects are poorly documented. In order to comprehensively understand what the main issues of a BIM implementation are and how it is possible to assist in such a process, the objectives of this research are the following:

- Rationalize the scattered information about BIM found in the scientific literature around a structured and formalized model
- Assist the AEC industry in becoming more familiar with the BIM implementation issues and adopting BIM
- Establish a list of Critical Success Factors for a BIM implementation project
- Establish a list of practical actions derived from the literature, cases studies or experts' suggestions that are likely to be put in place in a BIM implementation project
- Build an assistance model for BIM implementation, including maturity assessment, CSFs and actions.

The construction of the assistance model will be carried out inspired by the Françoise et al. model [28], as they described connections between success factors for ERP implementation projects and concrete actions. With the significant role that maturity has to play in the ways to properly lead implementation, the model will also take root in a BIM maturity evaluation in the user company.

3. Model

3.1 Literature review strategy

The approach used to perform the literature review involves several steps. At first, in order to look at the problem as a whole, research was centered on works related to BIM implementation and not only BIM implementation methodologies. As the results highlighted the weakness of representation of adoption procedures, the focus has progressively shifted to this particular matter as well as on how to help the industry integrate BIM into their practices. The significant amount of data scattered in case studies has pointed out that efforts to rationalize it should be made. The objective of the literature study thus has become twofold. On the one hand, it is to clarify factors that have a strong influence on implementation projects. In fact, because research on how to adopt BIM in an organization was scarce, the reflection moved towards which issues are to be prioritized. On the other hand, the literature review also aims to identify concrete examples of BIM adoption, practices and practical advices that could lead to the achievement of critical success factors. As such, there is a need for practitioners to link concrete actions to the desired success factors, as stated by Françoise et al. [28].

Consequently, the literature exploration turned towards defining critical success factors for BIM adoption and collecting empirical studies or proposals for actions to be undertaken in such projects. However, the decision of staying focused on factors deeply influencing both implementation and utilization was made. Indeed, companies suffer from those two issues and it is wise to bring to the table solutions that can best bridge these gaps. The decision to add maturity in the model has also been taken; the assumption, which is revealed through the literature, is that it plays a determining role in implementation. The CMM tool previously presented was immediately a relevant answer because of its ability to assess maturity in an organization.

3.2 Capability Maturity Model

The BIM *Capability Maturity Model* was developed to assess building an information model and the processes associated with creating and maintaining it [2]. It originates from the *National Building Information Model Standard* (NBIMS), an American organization working for the adoption of standards and best practices among the AEC industry to make it more productive, and has proven its reliability in terms of variance of the results (study led by NBIMS Testing Team [2]). It is a measure of the quality of a BIM implementation and an indicator of how profound BIM implementation is in the industry [30]. It has been applied in different engineering domains before being adapted for construction. Though it is not really a model, it provides a maturity index through an organized assessment of BIM use and business processes that happen. This evaluation is distributed into eleven criteria, as presented in Table 1. Each criteria is marked from one to ten, each rank describing a particular condition of the company for the assessed criteria. Then, a global mark is obtained.

The organizations willing to use the CMM to get an overview of their use of BIM can therefore be aware of their global performance as well as their abilities in each of the issues, so they can react according to their weaknesses. In this regard, an analysis took several successful BIM implementation projects to see which criteria they were good or poor in [30]. For instance, it sheds light on the convincing performance of these companies in the Graphical Information criterion. The latter represents how well buildings are modelled, with respect to the available dimensions and analysis. The success of this criterion is also not a surprise, as building models are the primary source of attention when enterprises get in contact with BIM. A brief description of the ten levels included in the first category, Data Richness, is shown in Table 2.

3.3 Critical Success Factors

As explained above, the model developed is grounded in the research conducted by Françoise et al. [28] and on the relationship between success factors and actions that he imagined, with the difference that this is applied to BIM implementation projects, with an additional focus on factors that also have an impact only on utilization and that maturity is deliberately involved in it. Then, one first thing to obtain was a precise list of critical success factors. With the literature guiding the thinking process for this task, the set of CSFs retained is presented in Table 3.

Table 1. Capability Maturity Model categories (Taken from [2]. As descriptions were very accurate, they were inserted as found in [2]. All credits for the formulations are given to Smith and Tardif and NBIMS)

CMM categories	**Description**
Data Richness	Refers to the degree to which a building information model encompasses the available information about a building.
Life Cycle Views	Refers to the degree to which a building information model can be viewed (and used) appropriately by any players throughout the building life cycle who may have need of the data to execute their responsibilities.
Roles or Disciplines	Refers to the number of building - related roles or disciplines that are accommodated in the modeling environment, and thus is a measure of how well information can flow from one role or discipline to another.
Change Management	Refers to the degree to which an organization has developed a documented methodology for changing its business processes.
Business process	Refers to the degree to which business processes are designed and implemented to capture information routinely in the building information model as an integral part of each business process.
Timeliness/Response	Measures the degree to which BIM information is sufficiently complete, up-to-date, and accessible to users throughout the life cycle.
Delivery Method	Refers to the robustness of the IT environment to support data exchange and information assurance.
Graphical Information	Refers to the degree of sophistication or embodied intelligence of graphical information.
Spatial Capability	Refers to the degree to which the building information model is spatially located in the real world according to Geographic Information Systems (GIS) standards.
Information Accuracy	Measures the degree to which information reflects real-world conditions.
Interoperability/IFC Support	Measures the degree to which data can be reliably exchanged among software applications using the open-standard Industry Foundation Classes.

Table 2. Description of the CMM criteria: Data Richness (adapted from [2],[31])

Data Richness Maturity Level	Description
1	Basic Core Data: BIM has been introduced in the company but there is no data or little basic data to load.
2	Expanded Data Set: Some more data can be entered, but it is still early in the maturity.
3	Enhanced Data Set: The model is reliable for basic data.
4	Data Plus Some Information: Data becomes information.
5	Data Plus Expanded Information: Data begins to be authoritative and the primary source.
6	Data with Limited Authoritative Information: Metadata is introduced, so information is the best available.
7	Data with Mostly Authoritative Information: Data is seen as reliable and authoritative, data checking progressively becomes useless.
8	Completely Authoritative Information: Metadata is entirely linked to the information, which is the authoritative source.
9	Limited Knowledge Management: Knowledge Management strategies are set up and information is beginning to be linked.
10	Full Knowledge Management: Authoritative information is completely linked to Knowledge Management strategies.

As the literature study was going on, several other success factors were identified, such as the essential need for a clear strategic vision to achieve BIM benefits [1],[9],[19],[23],[24],[27]. However, it did not appear as though those factors had any clear effect on the utilization of BIM, whereas the model was intended to include this aspect. Further examination with CSFs correlated to CMM would bring about more clarification.

Table 3. Critical Success Factors for a BIM implementation project, with additional impacts on utilization

CSFs list	Description	Literature references
Business Process Reengineering	Efforts invested to deeply review the current processes and reorganize workflows and ways of doing things in a BIM oriented manner.	[1],[2],[10],[16],[18],[28]
Standardization	Introduction of standards and metadata to better handle information and to tend towards an industry wide paradigm about BIM use.	[1],[2],[16],[20]
External stakeholders involvement	Ability to involve every business partner in the BIM dynamic and get them to facilitate the transition.	[1],[2]
Education to Information Management	Awareness and education of the internal members of the organization to information management practices and philosophy.	[2],[10]
Technical Education	Formation and education of the internal members on the use of the different tools composing the BIM and on the new processes.	[10],[20],[25]
System selection process	Proper selection of BIM tools fitting adequately the needs of the organization.	[1],[10],[20],[24],[25]

3.4 Connections between CMM, CSF and actions

Three entities constitute the model: the CMM, a CSF list and actions. CMM categories can be seen as some of the driving factors for using BIM successfully. However, because it has been designed to assess maturity and because the intention for the model was to generally tackle the hurdles the industry faced when adopting BIM, those categories have been transcribed into CSFs, which form the first relationship between the three parts. As a result, each CMM criterion is associated with one or several CSF(s), meaning that those CSFs can be used as levers to progress in the criterion in question. It is also relevant to note that one CMM criterion can be linked to several CSFs, which shows that multiple issues are included in each category of the formatted CMM tool and justify the linkage. Furthermore, this connection permits the amount of CSFs in the list to be lowered, some of them with only very limited influence, and in the meantime to highlight the significant ones. To return to the preceding example, no clear causal bond can be seen between having a precise strategic vision for BIM utilization and performing better in any CMM category. Nevertheless, it does not imply either that this particular issue has no business enhancing BIM implementation and use, but the link seemed too indirect to include the factor. Following this logic, Table 4 exhibits the connections established between CMM and CSFs for the model.

Table 4. Connections between CMM and CSFs

CMM categories	Linked CSFs in the assistance model for BIM implementation
Data Richness	▪ Business Process Reengineering ▪ External stakeholders involvement ▪ Education to Information Management ▪ Technical Education ▪ System selection process
Life Cycle Views	▪ Business Process Reengineering ▪ External stakeholders involvement ▪ Education to Information Management ▪ Technical Education ▪ System selection process
Roles or Disciplines	▪ Business Process Reengineering ▪ Technical Education
Change Management	▪ Business Process Reengineering ▪ Education to Information Management ▪ Technical Education
Business process	▪ Business Process Reengineering
Timeliness/Response	▪ Business Process Reengineering ▪ External stakeholders involvement ▪ Education to Information Management ▪ Technical Education
Delivery Method	▪ Education to Information Management

Table 4. Connections between CMM and CSFs (cont.)

CMM categories	Linked CSFs in the assistance model for BIM implementation
Graphical Information	▪ Technical Education ▪ System selection process
Spatial Capability	▪ System selection process
Information Accuracy	▪ Business Process Reengineering ▪ Standardization ▪ External stakeholders involvement ▪ Education to Information Management ▪ Technical Education ▪ System selection process
Interoperability/IFC Support	▪ Standardization ▪ System selection process

The second pairing is made between CSFs and actions: for every success factor, a set of actions is proposed. Correctly implementing those actions is bound to make the organization better with the corresponding factor. Justifications for the actions are found in the literature among the different case studies and proposals from experts. Fig. 1 summarizes the interrelations within the model.

The intended use for the model is plural. One hierarchical approach prescribes that an organization willing to implement BIM or to update the state of progress of a project that has already been started begins with the CMM evaluation. From there, this organization can identify its strengths and weaknesses and focus its work on the criteria where it performs poorly. This work can in turn be driven by different CSFs as defined in the model and linked to specific CMM categories. Actions are proposed and can be undertaken according to the recommended CSFs. The result of that approach is expected to be an enhancement of the situation in the targeted criteria. Also, only some parts of the model can be used. CSFs and actions are interesting on their own, on the one hand to know the issues involved in a BIM implementation and on the other hand, to know what to do. The entire process that is introduced with the model does not necessarily need to be followed.

3.5 Actions

Finally, there are the actions in the model. The purpose of these is to concretely assist BIM implementation projects. Case studies have been investigated in order to extract what did work for companies from different places in different environments, as well as recommendations made by expert authors on the subject.

As a result, a lot of information about things to do in certain contexts has been gathered and then rationalized through the connection to the CSFs from the list built earlier. Table 5 illustrates three possible actions for every proposed factor, which come from the previous literature study.

Table 5. Actions associated with CSFs

Business process reengineering	**Literature references**
Build models for "As Is" and "To Be" states, both for business processes and information flows.	[2]
Rationalize the production of data by assigning a unique role to get them, where it makes the most sense.	[2]
Track information by mapping out who the successive hosts are.	[2]
Standardization	**Literature references**
Introduce metadata to better manage the information.	[2],[20]
Organize information so that users' access can be controlled.	[20]
Define standards for the components and exclusions of building models.	[20]
External stakeholders involvement	**Literature references**
Adapt contracts to include BIM skills and expertise.	[1]
Adapt deliverables to include BIM documents and BIM analysis.	[1]
Communicate regularly with the partners on the organization's information needs and formats for these data.	[1]
Education to information management	**Literature references**
Increase awareness of the fact that information has to be synchronized with workflows.	[2]
Educate about information stewardship and responsibilities about information.	[2]
Force electronic transfers of information and prohibit paper-based models from communicating.	[2]
Technical education	**Literature references**
List every current and needed skill, who and how many people master each skill, and their average level.	[20]
List training needs for each skill, who and the length of the planned training.	[20]
Set up a training program for new members in the organization.	[10]
Selection	**Literature references**
List which functions are priorities and make sure to adapt software and tools.	[6],[20]
List which analysis the organization wants to be able to make and make sure to get adapted software and tools.	[6],[20]
Develop test cases to assess each potential BIM tool.	[6]

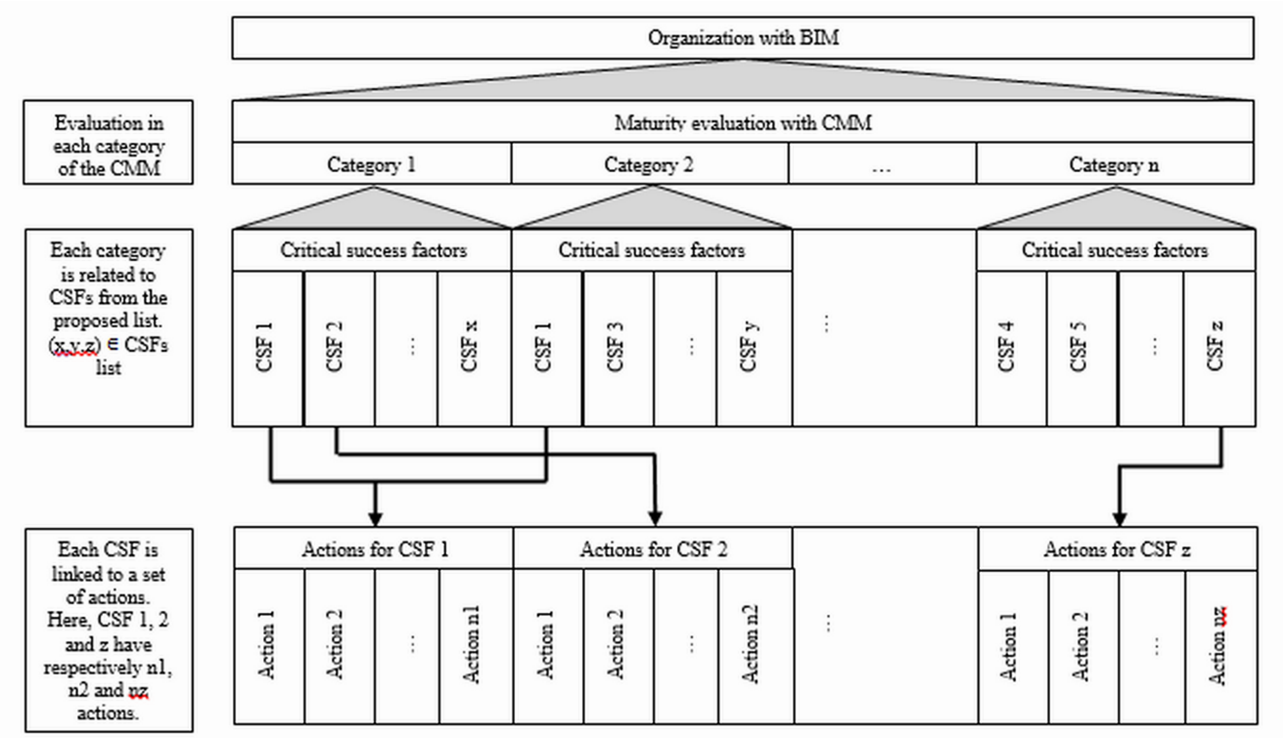

Fig. 2. Interaction model

3.6 Validation

To legitimize the model and the related work, interviews with BIM professionals were conducted with the collaboration of a Canadian engineering and construction firm. These interviews aimed to evaluate how relevant the proposed success factors and actions are and whether some crucial issues are missing. It was also possible to determine what should be excluded from the model as well as what should be added. Notably, it was expected that because of their focus on implementation, the experts would consider some other factors as important. Because of the practical experience of the responders, suggestions for future actions were also anticipated, as well as some suggestions for the adaptation of formulations, given that the clear understanding of each activity and its aftermath relies on few words.

In the validation process, a preliminary interview was conducted with a single expert in order to calibrate the proposed interview process and to obtain a first opinion on the model's consistency. Every factor and action has been reviewed with the underlying objectives of determining what should be added, modified or even suppressed.

As the links between CMM and CSFs and between CSFs and actions were quite obvious, these links were not discussed in the subsequent interviews. In fact, focusing on which stakes should be taken into consideration and what could be done to tackle them adequately seemed to be of more value than arguing the connections.

As a result, the whole model appeared truly coherent according to the experts, who expressed their interest in both lists of factors and actions, but also in the connections between CMM, CSFs and actions. As expected, this validation had some concrete impact on the model. No item was deleted, which provided an additional reason for the model to be legitimate. Some actions were introduced in the model, like the need to integrate quality standards within the metadata management, for the standardization factor. Above all, several adjustments were made to best reflect the realities of the AEC industry and its transition towards BIM. Since information is a preponderant and controversial issue, changes have been applied to some of the actions' formulations in order to be better understood. For instance, information flowing as a project resource has been highlighted instead of saying that information has no specific owner and that the original maker is not proprietary.

An overall evaluation has therefore been possible. It provided confidence in the model's potential, accuracy and relevance. A more robust version has been elaborated upon after that preliminary assessment.

4. Conclusion

This paper summarized the existing literature on this subject, which demonstrated a lack of guidance for BIM implementation projects. In response to the difficulties encountered in adopting and efficiently using BIM in industry, this paper proposed a model that brings together BIM maturity, which plays a preponderant role in approaching implementation, critical success factors and practical actions, as depicted by Françoise et al. [28]. Although the proposed model is not yet an exhaustive implementation model, it addresses the major issues of BIM adoption and brings some concrete responses to the main hurdles that they entail.

However, several improvements could be imagined and applied to this work. As said above, exhaustivity is a first limitation. In fact, as mentioned earlier, the emphasis is on issues that have a strong impact on both implementation and utilization. This choice was made because of the link between CSFs and CMM, which leaves out many implementation questions and assesses maturity and the current use of BIM. To stress critical success factors, it would be a great leap forward to determine and validate a list that entirely takes into account every issue implied in an adoption. This task has begun in the work presented in this paper, but is not the principal objective and no validation or any examination by experts was performed. Once again, taking a close look at the literature dedicated to ERP and PLM would be one approach of interest, as much of the research deals with the subject and has proven to be realistic and complete.

Moreover, the model does not aim to provide a full methodology for adoption through its actions. The model has been designed to have activities that allow for improvement in the CSF concerned, but do not guide an organization through the whole process of implementation. This limitation is explained by the different situations that organizations can be in when evaluating their maturity and the complexity involved in answering each one of these states with a structured plan. Therefore, it would be an improvement to define precise things to do and to prioritize actions according to the CMM results. A complete roadmap for adoption with precise activities, roles and deliverables would be a final objective that would suit the industry's need of guidance.

CMM is also a matter of concern for keeping an accurate and up-to-date model. Indeed, NBIMS regularly adjusts this tool in the AEC industry. The latest version describes the I-CMM, or Interactive Capability Maturity Model, based on the initial CMM, but involves users differently [31]. An alignment between the model and CMM seems to be necessary to keep pace with the trends in the industry.

Several other additions could be of interest. For instance, adding a level of difficulty for the actions would indicate where to begin or the amount of effort that should be invested by the firms using the model.

Finally, validation stays in the remaining part of the research and is necessary to truly justify the content of the model. Further work will surely fill this gap. Expert panels will have to play a crucial role in this process. Above all, the amount of experts and their backgrounds will be critical elements in the validation process.

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Biographical notes

Romain Morlhon
Romain Morlhon completed his first degree at the *Ecole des Mines de Saint Etienne*, a French school delivering a highly recognized engineering degree. Interested in industrial engineering issues during his studies, he later joined *Ecole Polytechnique de Montréal*, Canada, to obtain a Master of Science (M.Sc.) diploma in Industrial Engineering. He has worked on Information Systems and specifically on Building Information Modeling.

www.shortbio.net/rmorlhon@gmail.com

Robert Pellerin
Robert Pellerin is Full Professor in the Department of Mathematics and Industrial Engineering at École Polytechnique de Montreal. He holds degrees in engineering management (B.Eng.) and industrial engineering (Ph.D.). He is also a certified professional in Operations Management (CPIM) and Project Management (PMP). He has practiced for more than 12 years as project director and program manager. His current research interests include project planning, manufacturing execution, and enterprise system implementation and integration. He is a member of the CIRRELT research group and he is the Chairman of the Jarislowsky/SNC-Lavalin Research Chair in the management of international projects.

www.shortbio.net/robert.pellerin@polymtl.ca

Mario Bourgault
Mario Bourgault is a full professor at Polytechnique Montreal, Canada. He has conducted over a decade of research in the field of innovation and project management. Dr. Bourgault has held the Canada Research Chair in Technology Project Management since 2004. He is also head of Polytechnique Montreal's graduate program in project management. His work has been published in a number of journals, including *Project Management Journal*, *International Journal of Project Management*, *R&D Management*, and *International Journal of Managing Projects in Business*. In addition to his academic credentials, he spent several years in the field working as a professional engineer, and he maintains close ties with the industry by participating in various research projects and acting as an expert consultant. He also holds Project Management Professional (PMP®) certification.

www.shortbio.net/mario.bourgault@polymtl.ca