Building Information Modeling (BIM) Framework, Potential and Challenges

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***Abstract*— Building Information Modeling (BIM) is an emerging technology that is being increasingly used worldwide. However, according to recent studies, lack of awareness of both BIM tools, and their tangible benefits, especially in developing countries, remains one of the most impactful personal-related barriers toward its implementation. Therefore, this study was developed with the aim of stating the importance of these two challenges and proposing frameworks to overcoming them. Based on a literature review, a survey involving 370 Architecture, Engineering, and Construction (AEC) operators, and a focus group, this paper consists of developing a synthetic framework of the BIM concept summarizing all its related aspects (parameters, working flow, components, stockholders, tools, input, and output) that would help the users to have a clearer understanding of BIM. Moreover, it reveals the operational, economic, social, and ecologic potential of BIM with supporting evidences and metrics. On the other hand, this study highlights different categories of BIM barriers and emphasizes their weights and already-proved solutions.**

***Index Terms*— AEC industry, Construction, Added-value, BIM Framework, iBIM, Green BIM, BIM maturity, economic, social, operational, ecologic potential**

I. Introduction

BIM is a leading technology for AEC practices playing a vital role in facilitating projects delivery through 3D collaborative model [1]**,** allowing real-time track of the project modifications and progress in different stages of its lifecycle [2], planning erection and logistics [3], optimizing costs, time and efforts [4]–[6], and enhancing buildings' performances in terms of comfort, efficiency, and sustainability [7].

Considering BIM potential, an increasing number of countries are considering its implementation [8] as an innovative concept leading to cost-efficiency and ecological practices in the AEC industry. Indeed, several studies debating worldwide BIM review [9], [10] emphasized that BIM adoption has known a wide extend especially in Americas, Europe, Asia, and Oceania while Africa is still at the infant stage [11].

In the European Union, Charef et al. [10] confirmed that several initiatives toward BIM adoption have been undertaken starting by publishing, in early 2014, the European Union Public Procurement Directive (EUPPD) to urge EU member states to encourage, specify or mandate the use of BIM for publicly funded construction and building projects in the EU by 2016. After 2 years of work, the EU BIM Task Group delivered in 2017 a handbook explaining the common practices and principles to be adopted in the construction sector and unifying BIM policy across Europe. Since then, the EU countries are strengthening their BIM adoption policies through different measures namely mandatory BIM standards and guidelines [9]. However, they are progressing at a different pace, with on the top: UK, Sweden, Denmark, Finland, Estonia, and the Netherlands [10]. Likewise, in 2016, Bui et al. stated that the USA recorded more than 70% as rate of BIM adoption. However, as confirmed by the findings of the scientometric review of BIM in Africa undertaken by Saka and Chan [12], the first BIM release in Africa is dated back to 2010 in addition to insufficient involvement of African countries in BIM development. Hence, through a literature review of existing challenges in both Africa and other continents, this study aims at identifying, classifying and prioritizing barriers hindering BIM adoption and implementation in African countries.

On the other hand, Bui et al. [13] stated that developing countries' firms view BIM as a complex working tool and risky investment where its business value is unclear. In the same vein, Saka and Chan [12] confirmed that the first BIM release in Africa is dated back to 2010 and that African countries are barely involved in either researches and development (R&D) or implementation of building information modeling.

Literature review [14], [15] reveals many challenges hindering BIM adoption and implementation in both developed and developing countries especially those related to personal and process category including lack of BIM awareness and its benefits [14], [15].

In fact, it is known that having a good awareness and understanding of a concept and a clear idea about its tangible potential is the master key to improve its adoption and convince users to, firstly, adopt the concept and secondly overcome the other categories of challenges even economic ones. Therefore, this study aims mainly at, first, presenting a schematic framework of BIM concept that combines both technical and non-technical aspects of BIM and allows AEC operators, either beginners or experts, to have a clear understanding of BIM, second, bringing on the table the different added-value of BIM with supporting evidence and metrics.

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II. METHODOLOGY

This study aims at identifying ways to overcome the personal barriers to BIM implementation: lack of BIM awareness and lack of evaluation of BIM benefits value that would support solving many of other BIM challenges. For this purpose, the authors will list all detected BIM challenges in literature review. Then, through data collection, survey and experts' interview and workshop, the authors will built a synthetic and clear framework of BIM concept to enumerate operational, economic, social and ecologic potentials of BIM with relevant evidences and metrics.

A. *Literature review:*

In order to list the existing BIM definitions and challenges, and recognize the different added-values of BIM, a literature review has been conducted through a review of both scientific papers and technical documents available in the database of specialized operators. For the literature review, many databases have been used, namely Scopus, Google Scholar, ScienceDirect, and Web of Science (WoS).

B. *Survey:*

The survey served as a tool to assess the actual understanding of the BIM concept by the users. Therefore, a three-question questionnaire was sent to 370 operators in Moroccan Architecture, Engineering, and Construction (AEC) industry. 298 feedbacks have been collected which represents 81% of the selected sample. The feedbacks have been submitted to 5 experts for rating from 0 to 10 and ranking into 5 levels:

- Excellent definition: rated between 9-10
- Good definition: rated between 7-8
- Correct definition: rated between 5-6
- Confused definition: rated between 3-4
- Wrong definition: rated between 0-2

C. *Focus group*

Based on the findings of the conducted survey and collected data from the literature review, a focus group involving 5 AEC experts developed a synthesized and simplified framework of the BIM concept that would help the users to efficiently understand it. The framework had to combine all element related to the BIM concept, namely its parameters, tools, and flow.

D. *Schematization of the methodology:*

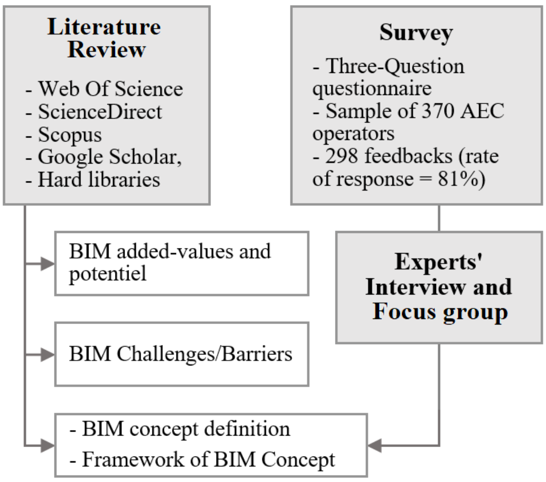


Fig. 1: Schematization of the methodology

III. BIM CONCEPT:

A. *Findings of the survey:*

The sample of 370-targeted respondents has been selected randomly from many countries combining operators in different sectors of the AEC industry: Architects, Engineers, Consultants, Developers, Technicians, and Topographers. In fact, among the 298 collected feedbacks 22.5%, 20.8%, and 19.5% were mainly issued respectively by architects, topographers, and civil engineers. The respondents have different level of experience with a predominance of those having between 11 and 15 year-experience (43%) followed by those between 6 and 10 year-experience (31%).

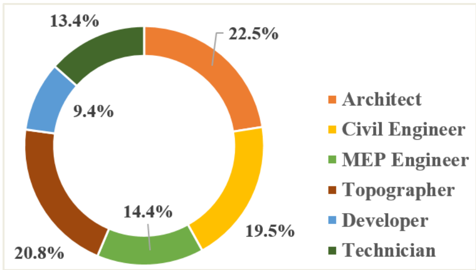


Fig. 2: Respondents' background

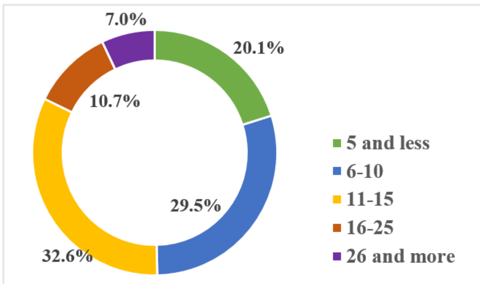


Fig. 3: Respondents' experience

The analysis of the respondents' feedbacks reveals that the majority of BIM users are still limiting the BIM concept to a 3D model and omitting the collaborative aspect needed for a model to be considered as a BIM model. Besides, many given definitions show that some AEC operators confuse BIM concept with software that allow creating 3D models of buildings. Actually, among the respondents, only 14% have a good to excellent understanding of BIM concept while 48% are barely aware of the concept as shown in figure 4.

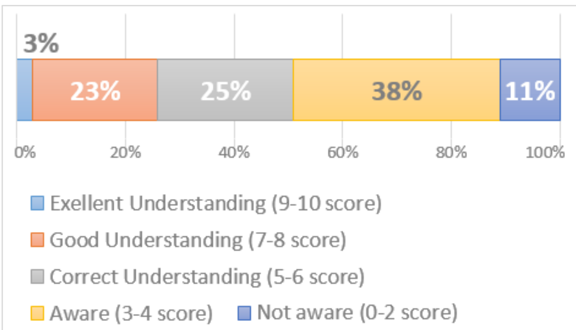


Fig. 4: Awareness and Understanding level of BIM concept

B. *BIM notion:*

BIM aims mainly to digitalize the AEC disciplines by setting collaborative digital model [16] via computing tools. Through this concept, all the stakeholders of an AEC project can simultaneously work on the same computer model [17] to finally make it a model that centralizes all schematic, qualitative or quantitative information related to architecture, engineering, materials' features, budget and delay [18]. It is taking more and more expansion, especially after the integration of the Industry Foundation Classes (IFC) [19], [20] which are governed by ISO16739, allowing, thus, a smooth compatibility between BIM tools (either software, collaborative platforms or hardware) as well as fluid communication between the stakeholders [21], [22]**.**

Considering the worldwide emergence of innovation and the importance granted to Research and Development (R&D), Information and Communication Technologies (ICT) were integrated into the AEC field with on the top BIM technology. Indeed, BIM is defined by Autodesk [23] as "*an intelligent 3D model-based process that gives Architecture, Engineering, and Construction (AEC) professionals the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure*". Meanwhile, US-National BIM Standards (NBIMS-US) [24] defines it as "*a digital representation of physical and functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility forming a reliable basis for decision making during its life-cycle from inception onward*".

In fact, BIM does not include [25]**:**

- Models containing only 3D volumes without attributes; generally intended for viewing purposes, it is not suitable for simulation;
- Models containing non-parametric objects unable to adjust their proportion or positioning because devoid of any intelligence, which makes changes extremely laborious;
- Models composed of 2D files or entities;
- Models allowing modifications in one view, which are not automatically reflected in the other views.

Based on the literature review, the collected definitions scored between 7 and 10, and the experts' interview, the BIM concept could be defined as "*a collaborative method that involves all stakeholders in the act of building via suitable software, hardware and collaborative platforms. It consists on creating and using a 3D digital model to allow design, visualization, quantization, budgeting and anticipation before the realization of the project on site as well as cross-checking of all data in real time. Besides, the BIM models can relate to the whole life cycle of a project from the design to demolition, passing through realization and exploitation*".

IV. BIM BARRIERS

1) Global BIM barriers:

Despite the significant efforts provided for BIM implementation, BIM use is still largely limited in five continents because of several challenges, with Africa on the last place. Indeed, a recent systematic review **[15]** related to the worldwide barriers hindering BIM implementation, 34 BIM barriers has been listed and divided into five categories:

- Personal/Process-related barriers (PP),
- Government-related barriers (G),
- Cost-related barriers (C),
- Technical barriers (T),
- Legal barriers (L).

As indicated in Table 1 and Fig. 5, comparing to other continents, Africa is still struggling with primitive barriers related to lack of adequate Infrastructure (BRa1), lack of steady power supply (BRa2) and Lack of Internet access or connectivity (BRa3). Meantime, Africa does not experience the barriers related to advanced stages of BIM implementation such as Reluctance of sharing (BR8), Risks related to Data Management (loss, Misuse...) (BR24) and Lack of collaboration Management tools (BR25). Which confirms the findings of several researches [12] emphasizing the infant stage of BIM implementation in Africa.

TABLE 1 : global BIM Barriers / Challenges **[15]**

Code	Barrier	Categories					weight	
		PP	G	C	T	L	African continent	Other continents
BR1	Lack of academic BIM education and staff	✓	✓				0.6250	0.2500
BR2	Disturbance of the Workflow	✓					0.2500	0.2941
BR3	Resistance to change	✓					0.8750	0.3824
BR4	Poor collaboration among stakeholders /teams	✓					0.1250	0.1765
BR5	Lack of BIM expertise	✓					0.6250	0.2206
BR6	Lack of clients' demand	✓					0.6250	0.2794
BR7	Fragmentation & Business Culture	✓					0.2500	0.1618
BR8	Reluctance of sharing	✓					--	0.1176
BR9	Lack of executive Buy-in	✓					0.7500	0.2353
BR10	Cultural Resistance	✓					--	0.1176
BR11	Incapacity to ensure the same level of BIM adoption in all operators of the chain value	✓					--	0.0882
BR12	Needed time for BIM implementation (learning curve, accuracy…)	✓					0.1250	0.1176
BR13	Lack of BIM Awareness	✓					0.7500	0.1765
BR14	Lack of qualified workforce	✓					0.6250	0.1618
BR15	Lack of adequate training	✓					--	0.1324
BR16	Lack of common Standards & Guidelines		✓		✓		0.8750	0.4559
BR17	Unclear or Absence of strategies and policies toward BIM adoption		✓				0.3750	0.2647
BR18	Lack of incentives		✓				0.3750	0.0735
BR19	High initial cost for implementation			✓			0.7500	0.4706
BR20	Lack of evaluation of BIM benefits value			✓			0.6250	0.1912
BR21	Lack of interoperability				✓		0.6250	0.3382
BR22	Immaturity and limitation of BIM applications				✓		--	0.1618

BR23	Risks related to data Security & Reliability				✓		0.3750	0.2500
BR24	Risks related to Data Management (loss, Misuse...)				✓		--	0.1618
BR25	Lack of collaboration Management tools				✓		--	0.0294
BR26	Lack of Compatibility with existing tools				✓		0.6250	0.1029
BR27	BIM tools complexity (Software)				✓		0.1250	0.1029
BR28	Lack or absence of clear contractual terms adapted to BIM utilization					✓	0.7500	0.2059
BR29	Confusion of ownership and copyrights					✓	0.3750	0.2353
BR30	Lack of insurance					✓	--	0.1029
BR31	Confusion in responsibility distribution					✓	0.3750	0.1765
BRa1	Inadequate Infrastructure		✓				0.1250	--
BRa2	the lack of steady power supply		✓				0.5000	--
BRa3	Lack of Internet access or connectivity		✓				0.5000	--

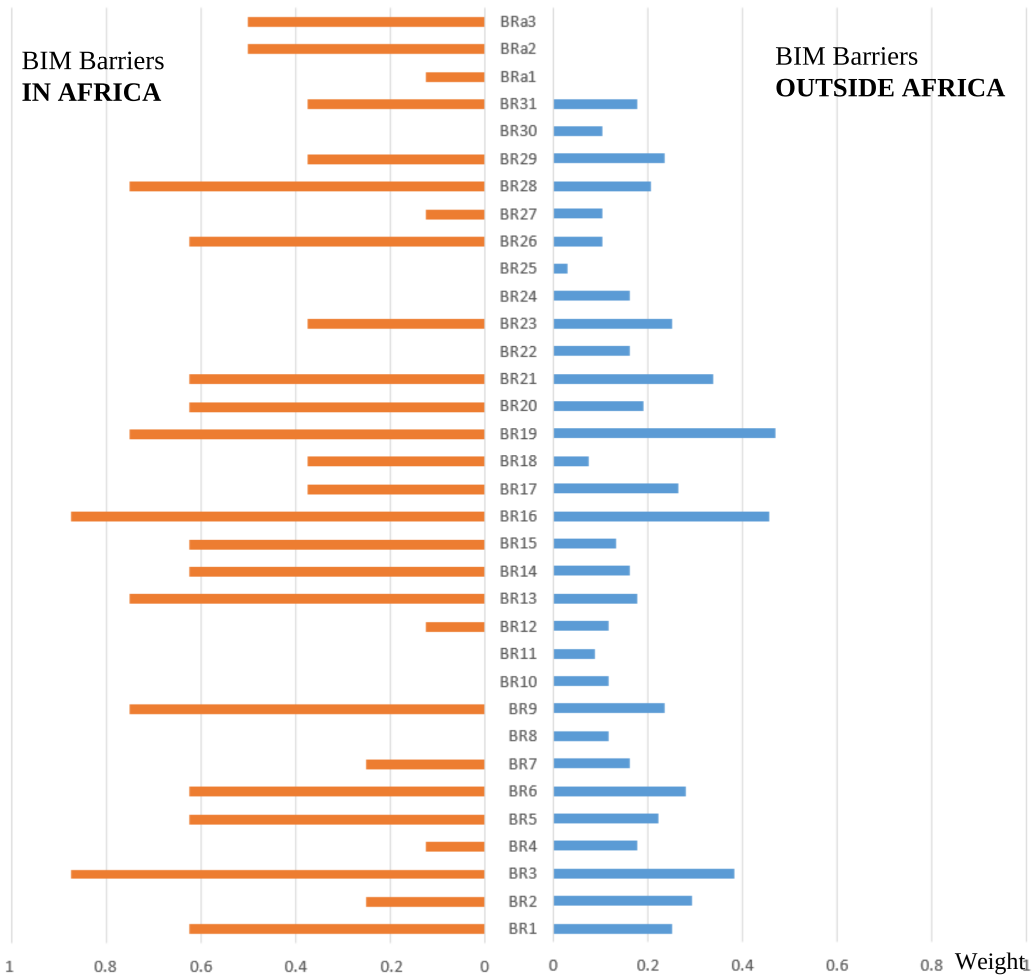


Fig. 5: Comparison of BIM barriers in and outside Africa *[15]*

The Personal/Process-related barriers are much more numerous than all other categories where Resistance to change (BR3) is the most percussive challenge followed by Lack of BIM expertise (BR9) and Lack of clients' demand (BR6). However, Cost-related barriers are the most impactful barriers on BIM implementation in the world (Fig. 6) with the high cost of the initial investment needed for both trainings and purchase of BIM tools (BR19) on the top (Table1).

Meantime, other than the category of cost-related barriers, the order and the weight of four other categories of BIM barriers for African continent are noticeably different from those of the other continents. In fact, in the African continent, the four other BIM barriers' categories have almost the same impact with an average weight of 50.5% (Fig. 6). While, for other continents, the governmental-related barriers are headed by Unclear or Absence of strategies and policies toward BIM adoption (BR17) and Lack of academic BIM education and staff (BR1). Hence, despite the engaged efforts by governments in this context [9], [10], the literature review reveals that those efforts are either still intangible or should be reinforced.

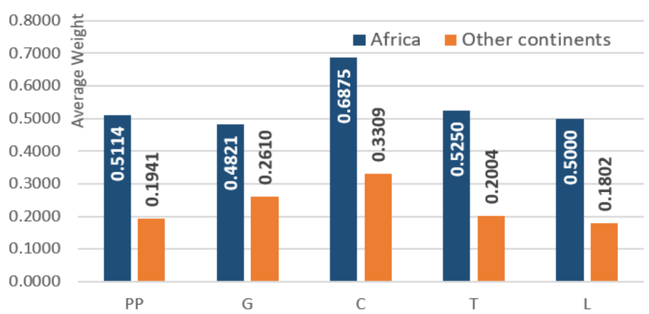


Fig. 6: Average weight per BIM barriers' category

2) Approaches to remedy BIM barriers:

Several studies discussed solutions helping on overcoming BIM challenges. For government-related barriers, Cheng and Lu [9] trace the important role played by the public sector in USA, Europe, Asia and Australia where several countries adopt progressive strategies and financial incentives leading, then, to a noticeable emergence of BIM adoption as well as a significant decrease of legal-related and cost-related barriers. Actually, the countries pioneer in BIM implementation set signification incentives, guidelines and common standards allowing, then, to fasten the spread of BIM adoption [9] and reach, in 2015, a rate of 60% in Middle East, 23.7% in Oceania and 51.7% in the north Americas [26] with 70% in the USA in 2016 [13].

Meanwhile, technical barriers are mainly related to the advanced stage of BIM implementation. Many studies proposed innovative approaches, algorithms, or frameworks to resolve several technical barriers. Belsky [27] pointed out that the IFC provides a large flexible standardized data model and presented a framework for a new approach improving the overall semantic interoperability. Arif and Khan [28] associated BIM with videography through a low-cost Internet protocol (IP) camera and Matrix Laboratory (MATLAB) to develop a new framework that provides a smart tool for construction progress monitoring and helps to optimize both time and cost of a building project. Figl et al. [29] created a smart protocol to allow an integrated flow for BIM-based sustainability assessment through direct communication between BIM design software and stored databases related to Building's Life Cycle Carbon Emissions (BLCCE).

Moreover, for personal/process-related barriers, resistance to change and business culture are rated as blocking challenges in both developed [10], [14] and developing [11], [14] countries where many researchers tackled these issues to propose solutions [30], [31]. MacLoughlin [30] presented a five-step process of management change plan (see figure 13) adapted to BIM implementation and taken into account the different actions to be undertaken in each step to overcome the impacts of these challenges.

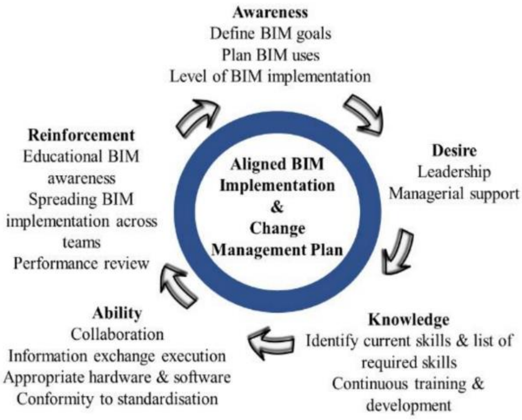


Figure 1: Management change plan to overcome Ch8 [30]

However, whereas, barriers related to unawareness of the BIM concept and its tangible added-value are one of the most impactful personal/process related barriers, especially in Africa (Table 1), the studies discussing them and providing clear and simplified elements defining both the BIM concept and its related-benefits remains limited in the literature. Which emphasis the importance of this study.

V. Framework of BIM Concept:

A. BIM parameters:

Technically, for any AEC project, a BIM model involves three parameters [32]: dimension, level of development and level of collaboration commonly named level:

1) Dimension (D):

This parameter reflects the different elements that could be included into a project model [33], where:

- **2D** means that the model is designed only in surface which is not considered as a BIM model,
- **3D** model is designed in volume, which is the first criteria of a BIM model but it is still not enough to consider a model as a BIM one,
- **4D** models (3D+Time) where all elements are time-related which helps the users to have the schedules of construction and/or maintenance of either the whole building or each specific element in the model [34],
- **5D** models include cost information of all components in different stages of building. Hence, through a 5D BIM model, users can have either the total or detailed budget (purchasing, erection, installing, maintenance and so on) [35],
- **6D** BIM models take into account the sustainability aspects in construction project namely energy performance [36], recycling and environmental aspects. Starting from this dimension the models are upgraded to integrated BIM (iBIM),
- **7D** BIM models support facilities management and operation aspects where facilities managers have a clear idea about what, where and when components should be maintained and how much they will cost [37],
- **8D** BIM model: this dimension could be associated to two different aspects, 1st one is related to demolition phase [38], [39] and 2nd one is related to models' safety. However, considering the revolution of Blockchain technology, 8D BIM models are commonly attributed to the models' safety aspect [40] related to security, IP, trust and transparency of BIM models [41],
- **nD**: is related to any other aspect that a designer or a user would add to a BIM model,

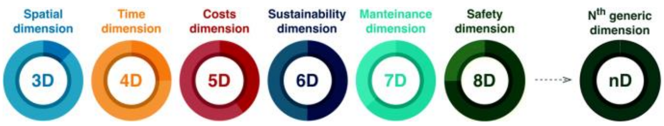


Fig. 7: Dimensions of BIM models *[42]*

2) Level Of Development (LOD):

LOD refers to how far the components of a BIM model has been detailed in the model [43]. There are 5 levels defined by American Institute of Architects (AIA) in 2008 [44] LOD100 to LOD500 another level has been added lately LOD350 [45]:

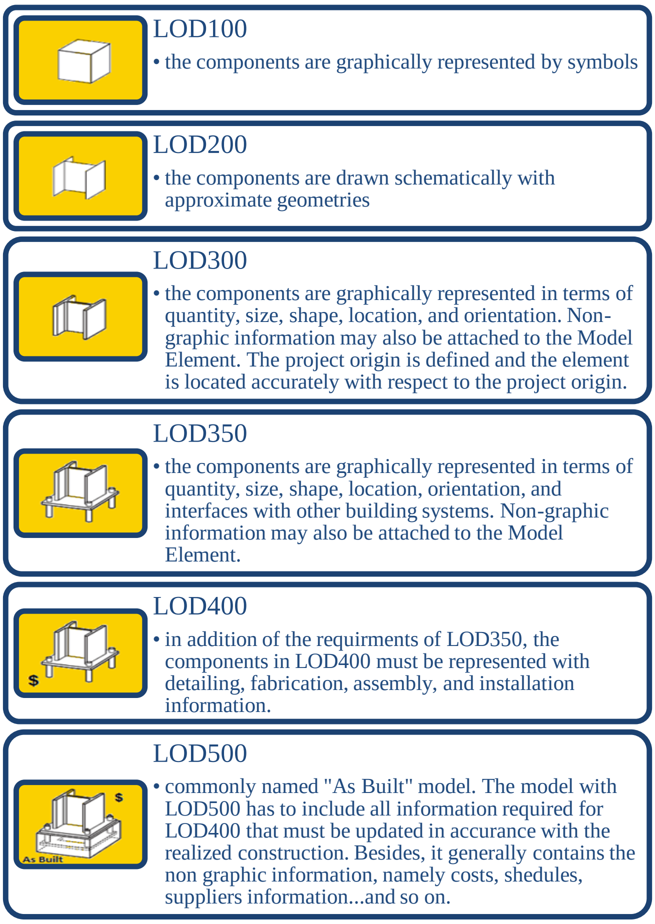


Fig. 8: Dimensions of BIM models

3) *Level of Collaboration, commonly named Level (L):*

The Level parameter is closely associated with BIM models' maturity. In fact, it defines whether the stockholders collaborate on the same digital model leading, then, to full integration (Level 3) or are completely independent (Level 0) with Level 1 and Level 2 to relate the intermediate levels of digital collaboration.

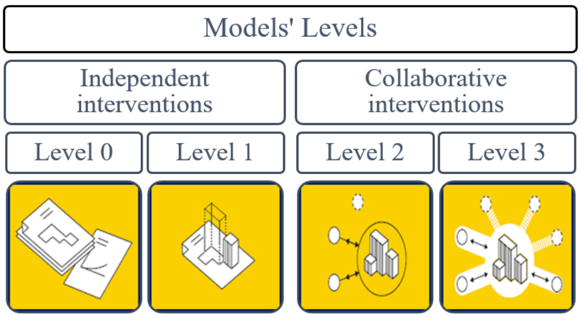


Fig. 9: Level of model

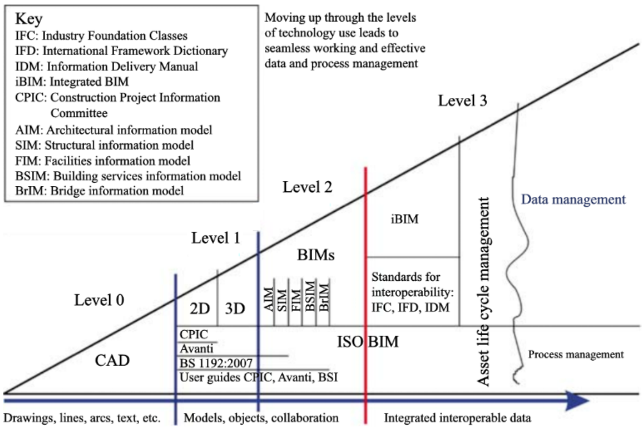
In 2008, Bew and Richards [46] have developed a scheme representing the specifications defining the limits of each level (figure 10) and was simplified by Porwal and Hewage [37] (figure 11). In fact, according to Eadie et al. [38]:

− **Level 0**: Unmanaged CAD probably in 2D paper or electronic format as the most likely exchange mechanism. This is related to traditional practices but not to BIM.

− **Level 1**: Managed CAD in 2D or 3D format with a collaboration tool providing a common data environment, possibly some standard data structures and formats. Commercial data are managed by standalone finance and cost management packages with no integration.

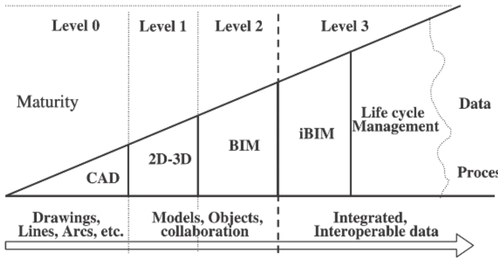
− **Level 2**: Managed 3D environment held in separate discipline "BIM" tools with attached data. Commercial data could be managed by an Enterprise Resource Planning (ERP) application. Integration on the basis of proprietary interfaces or bespoke middleware could be regarded as "pBIM" (proprietary) [47]. The approach may utilize 4D program data and 5D cost elements as well as feed operational systems.

− **Level 3**: Fully open process and data integration enabled by web services compliant with emerging Industry Foundation Classes (IFC) and International Framework for Dictionaries (IFD) standards, managed by a collaborative model server. Level 3 could be regarded as "iBIM" or integrated BIM potentially employing concurrent engineering processes [48].



Source: Bew and Richards (2008)

Fig. 10: BIM level, Bew & Richards model for BIM maturity *[46]*



Source: Porwal and Hewage (2013)

Fig. 11: BIM level, Porwal & Hewarge model for BIM maturity *[49]*

B. *BIM tools:*

As revealed by the survey (§ III.A), many AEC operators limit BIM concept to software tools. However, BIM involves three different tools: software, hardware and collaboration platforms.

− **Software**: Tivendale and Liu [50] reported that BIM concept was initiated for the simple computing applications in the 1960s and improved for solid modeling programs in the 1970s but the development of the ArchiCAD software was the real beginning of BIM. Actually, since 2004 when BIM was firstly mentioned in the literature review [51], many suppliers have been either upgrading construction software or developing new ones to take into account BIM parameters and include the common extension of BIM files named IFC [22]. The most known BIM software suppliers are: Autodesk the developer of Revit which is considered the most known BIM software, Trimble (editor of Tekla), Graphisoft (editor of Archicad) and Nemeschek (editor of AllPlan).

− **Hardware**: in addition to IT hardware (computers for instance), the most known BIM hardware are laser scanners and 3D printers. Actually, the laser scanner helped the HBIM (historic BIM) [52] to thrive where many countries have launched the scan and numerically store both historical monuments and existing facilities in order to facilitate their exploitation and maintenance. On the other hand, by using the developed BIM models, the 3D printing technology is experiencing an increasing trend [53] mainly in terms of precasting and construction of some specific buildings.

− **Collaboration platforms**: they are web platforms that offer to the building professional the necessary working tools in order to operate correctly with the BIM methodology on the cloud. The main features of collaboration platforms [54] are:

- Support architecture, engineering and more generally, the building industry professional to create and manage BIM models in a correct manner and under every specialized aspect all within a single data sharing environment (CDE – Common Data Environment),
- Allow exchange of knowledge and accurate real-time update of available information,
- Reduce errors and Improve overall process,
- Warrant storage and confidentiality of the data,
- Manage, store and track information,
- Manage the role accessibilities.

C. Synthetic Framework of BIM Concept:

For a building or infrastructure project, BIM enables the stakeholders (architects, investors/owners, engineers, economists, contactors, coordinators, concessionaires, suppliers, topographers and users) to collaborate through, eventually, the same digital model to design, develop, assess and control simultaneously the different aspects of the project (architectural, structural, mechanical, electrical, plumbing, interior design…) under the control of the BIM manager. Moreover, the equation (1) synthesizes the all BIM parameters:

$$BIM\ Models = Models\left(xD,\ yLOD, zL\right) \quad (1)$$

$$\text{with} \begin{cases} \text{D=Dimension}, & x \in \{3, 4, 5, 6, 7, 8, X\} \\ \text{LOD=Level Of Development}, & y \in \{100, 200, 300, 350, 400, 500\} \\ \text{L=Level (of collaboration)}, & z \in \{1, 2, 3\} \end{cases}$$

In order to simplify the comprehension of BIM concept, the framework bellow (Figure 12) was developed to summarize and visualize all BIM notions in one illustrative schema.

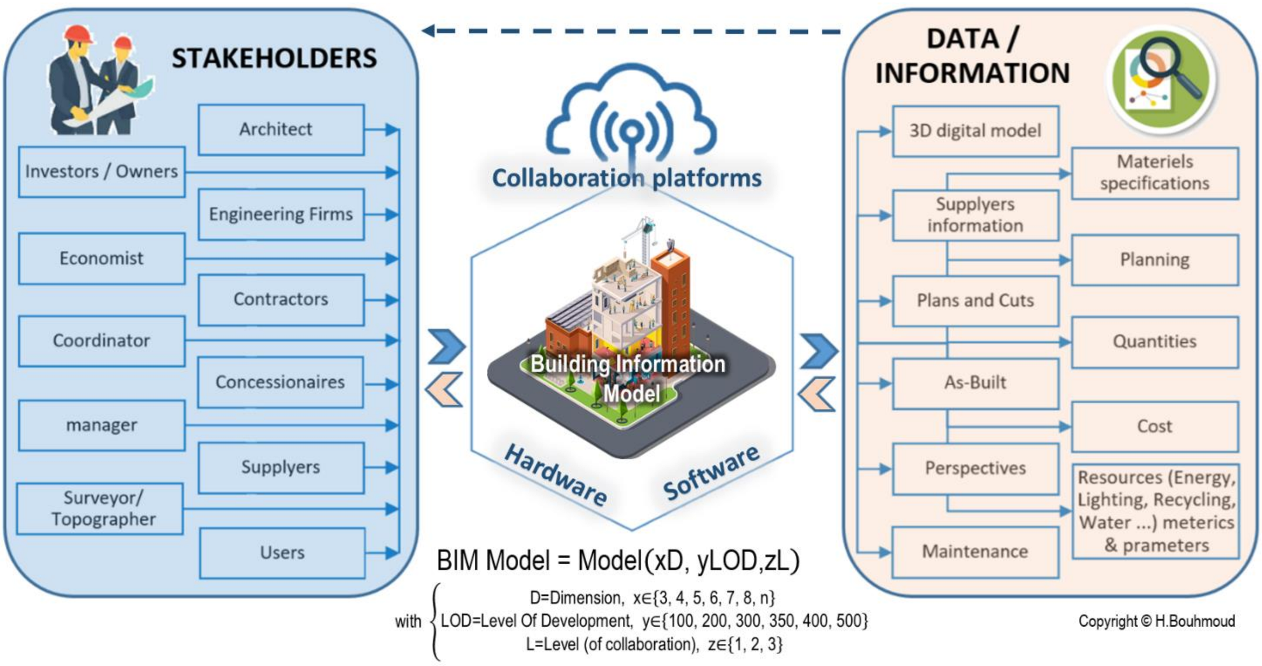


Fig. 12: Synthetic framework of Building Information Modeling concept

VI. BIM Potential

A. BIM operational potential: BIM and iBIM

Using Building Information Modeling (BIM) allows the stakeholders of the AEC projects to significantly optimize the workflow, the efforts and the time spent on the project comparing to traditional practices [55]. In fact, collaborative BIM tools allow to enhance design accuracy, erection quality, coordination and communication amongst parties [56] and to improve lifecycle data management [12], claims management [57] and site management [3].

BIM helps to visualize the projected buildings before going to erection [25] which permits anticipating all kind of risks, saving cost, and raising collaboration [58]–[60]. In fact, according to Le Moniteur [25], BuildingSMART confirms that BIM helped, in one hand, to improve the understanding of design intentions, the overall quality of the project and the cost control in Europe by respectively 69%, 62% and 43% and in North America by respectively 65%, 54% and 37%. On the other hand, BIM reduces the conflicts between project stakeholders, the modifications during construction and the clarification requests by respectively 59%, 56% and 43% in Europe and 68%, 54% and 47% in North America.

Furthermore, BIM allows the designers (architects and engineers) to create 3D model including all needed details (iBIM) to accurately precast all building's elements namely the floors including ceiling and the appropriate mechanical, electrical and plumbing (MEP) networks. Which helped many large scale projects to be built in record time such as the 3.4Ha-hospital built in Wuhan, China within 10 days to face the Covid19 pandemic [61].

B. BIM economic potential:

BIM allows a considerable saving costs especially during the erection and exploitation phases of the AEC project lifecycle [62]. In fact, BIM consists on building a 3D collaborative model during the feasibility and study phases, taking into account all operational aspects to be considered during erection and exploitation phases, namely, erection planning, erection logistics and needed material for both erection and exploitation. Elghaish and Abrishami [63] show that 4D BIM allows an automated multi-objective to optimize and leads to cost-saving of 22.86%.

In fact, the operational potential of BIM allows cutting costs due to modifications during the erection, inaccurate estimate of material quantities and design faults. Besides, many studies substantiated its efficiency in improving productivity [25], [64]–[66]. Indeed, according to World Economic Forum Report about construction future [67], 1% rise in productivity worldwide worth $100 billion saving per year.

In the same vein, Abdelbary et al. [68] prove that Client-Related Rework (CRR) provoke an average project cost increase of 22% and an average delay of 23%. However, using BIM allows a reduction of CRR cost and schedule by 49% and 57% respectively.

Based on experimentation, McGraw Hill SmartMarket report [69] confirmed that, despite the prior investment needed for BIM tools they are still profitable and considerable cost saving. For instance, through BIM tools, a project field could be scanned in 30minutes and its collected point cloud could be post-processed in other 30minutes, leading, then, to a cost cut of US$30,000 per use. Besides, they could be used to enhance the building's exploitation expanses such as electricity and maintenance.

C. BIM social potential:

The AEC industry is generally defined as men-field industry. In fact, according to Construction Skills Queensland (CSQ) report [55], women, in Australia, represent only 3% of workforce in AEC field against 51% in other non-construction field. However, the automated aspect of BIM facilitates the access of women to construction fields, which would be a potential solution for women empowerment.

Meantime, BIM model simplify the construction processes. Indeed, with only a 3D printer and BIM model, fast-tack projects could be built in tight time and with optimized costs [70], [71]. Therefore, this technology could be used to build large neighborhoods for either destitute people in poor countries or refugees coming from countries in war and, thereby, help to solve a critical social problem.

In the same context, BIM technology allows to precast almost all components of any building project and anticipate planning logistics. In fact, those aspects have been used during the Covid19 emergency by a Chinese company that was able to build a 1000-room hospital in only 10 days [61] and respond, then, to the imminent need to save people affected by the pandemic.

D. BIM ecologic potential: Green BIM

The construction industry and related activities consume 50% of natural resources [72] and 40% of global energy [73] and they are responsible for production of 75% of global waste [74] and 40% of global carbon dioxide emission [75]. On the other hand, the natural resources are experiencing a considerable drop and the global warming is significantly rising [76].

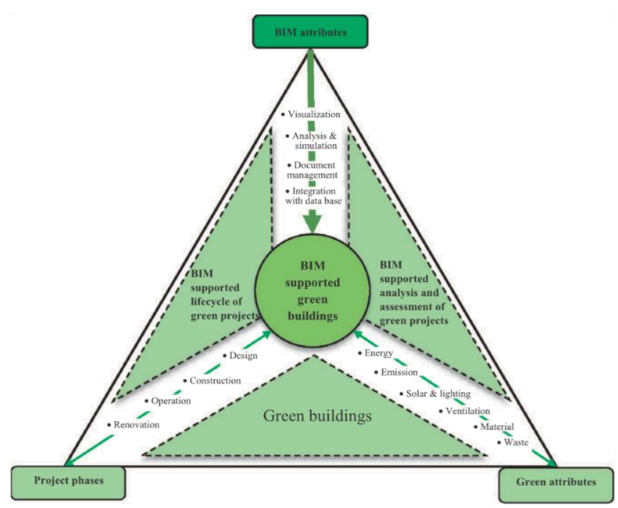


Fig. 13: Green BIM: Aspects of BIM to reduce construction impacts on environment [7]

Yet, BIM allows multi-disciplinary information to be combined into one model, and thus incorporates, simulates and analyzes the sustainability measures during the design process [77] to find the most optimized eco-friendly scenario [73]. Indeed, several BIM applications are designed for simulations and analyses of building performance, namely energy performance analysis [78], [79], CO_2 emission analysis [80] lighting simulations [81] and waste optimization [82].

According to many researches [7], [83], [84], BIM has a great potential to reduce construction impacts on environment in the different phases of a building lifecycle. In fact, Jiao et al. [85] reported that Shanghai Center, the tallest building in China, adopted a BIM-based approach of lifecycle data management that has helped to achieve a material waste rate of 4%, compared with the average level of 10% in China. Likewise, Jen and Vernatha [86] studied a conceptual framework for a BIM-based Energy Management Support System to perform a real-time energy simulation by adoption of sensors and smart meters. The output can be visualized using the geometric data available in the BIM model, which allows the user to monitor real-time energy performance of different zones in a building and optimize the energy consumption [87].

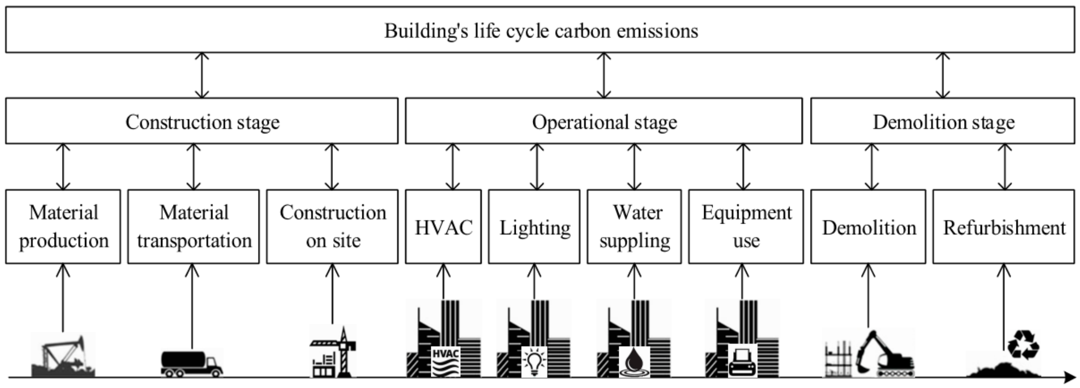


Fig. 14: Composition of a building's life cycle carbon emissions (BLCCE) [88]

Meanwhile, the calculation of building's life cycle carbon emissions (BLCCE) requires high costs and significant time investment [89], [90]. However, BIM provides the opportunity to considerably reduce time and effort required to manage building information and life cycle assessment (LCA) data and remarkably accelerates the establishment of the LCA model [91]–[93]. This helps to optimize each parameter of the BLCCE (figure 14) and, thereby, considerably reduce the carbon emissions in all buildings' stages [88].

VII. Conclusion

Considering BIM potential, several countries have already engaged their efforts to develop and implement the needed standards and strategies for BIM adoption [9]. However, despite the overall provided efforts, BIM is still facing several limitations [14]. According to literature review [15], personal-related barriers are the most influential challenges on BIM implementation in both developed and developing countries. Among the most cited personal-related barriers are Resistance to change, Lack of BIM awareness and Lack of awareness of BIM tangible added-values. In fact, many AEC operators are still either confusing BIM to software creating 3D building's models or omitting the mandatory collaboration aspect of BIM.

Therefore, to earn the AEC operators buy-in, it is necessary to overcome those challenges. This study handles mainly two impactful challenges: Lack of BIM awareness and Lack of awareness of its tangible added-values, and thereby helps the private and governmental decision makers to have a clear idea of all aspects of BIM and have the main materiel to prepare BIM adoption strategies.

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