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A Review of Building Information Modelling for Construction in Developing Countries

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Abstract

Building Information Modelling (BIM) is widely seen as a catalyst for innovation and productivity in the construction industry. BIM can assist a more sustainable construction that in turn may contribute to eradicating poverty in developing countries (United Nation Millennium Goals). While BIM is increasingly being adopted in developed countries, implementations in the developing country context are rare. Research has established how construction firms struggle from several limitations having to do with the socio-economic and the technological environment found in developing countries. Examples of issues preventing BIM adoption include a shortage of IT-literate personnel as well as an absence of national BIM implementation programs. Based on a review of recent research, this article addresses some of the hurdles and solutions for BIM implementations particular to low- and middle-income economies. Findings include that developing countries' construction firms rely on outsourcing of IT services or developing tweaks or workarounds, like using 'fake' IT licenses, for saving cost and enabling BIM. The article highlights shortcomings of existing research on BIM implementation in developing countries, and may serve as a starting point for researchers interested in how BIM technology can be adopted in a developing country context.

Keywords: barriers; Building Information Modeling; construction; developing countries; implementation strategy

1. Introduction

According to the World Bank [1, 2], there exist 135 middle- and low-income economies referred to as developing countries. These countries face large knowledge gaps and can be characterized by limited and occasional technological innovation [3]. In developing countries, construction is a labor-intensive industry. Wells [4] reported that the average construction output per person in low-income countries is just about one-ninth of that in high-income countries. Besides, construction is also considered as the most material intensive [5]. A variety of existing challenges lead to delays, poor site environments, poor working conditions, low quality, and accidents in developing country construction [6]. The low efficiency of construction in developing countries implies a promising area for development. Because construction could assist a more effective employment of human and material resources, the industry is often considered as a driver for growth and achieving development goals [7-9].

Like other industries, the construction companies benefit from a range of information and communication technology (ICT) solutions when delivering their projects. It has been suggested that construction projects will be more effective and productive with ICT applications [6]. One of these ICT applications is Building Information Modelling (BIM), which could have many benefits in supporting construction. In terms of more effectiveness and productivity, BIM yields advantages for scheduling, design, implementation, and facility management. From a stakeholder perspective, BIM helps owners, designers, contractors, and management teams to collaborate, visualize and manage construction work better [10]. Consequently, BIM technology receives significant attention from practitioners. In the light of improvement, increasing the use of ICT could help to address some of the currently experienced challenges. The implementation of construction ICT in general and of BIM in particular should be considered in the developing country context. Based on a review of recent research, this article thus focuses the following research questions: What is the current state of BIM implementation in developing countries, and what further research is required for advancing this? Addressing these questions is worthwhile for researchers and practitioners focusing on firms operating in developing countries, seeking to reap BIM's benefits.

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1.1. *ICT implementation in developing countries*

Information and Communication Technology for Development (ICT4D) is a research area in the information systems (IS) literature. Examples of this research include the study of healthcare systems, the internet, and e-procurement systems in developing economies. What unites this research is the focus on overcoming the recurring limitations and barriers for ICT adoption in developing countries. Some of the frequently mentioned ICT implementation challenges typical for developing countries are management related. Such issues include: qualified personnel, financial support, strategic perceptions, market support, social cultural environment, and security concerns. In addition, there are technical challenges such as: lack of framework, policies and procedures for adoption. Lack of research and development also hinders ICT implementation [11-14].

While many of the managerial and technical barriers would seem familiar from the study of ICT implementations in developed countries, some appear unique for developing countries. Security concerns are likely to be the most noticeable case, since software piracy is widespread in developing countries. Aleasa et al. [15] reported that the 25 countries with highest piracy rates are exclusively developing countries. Using cracked software, organizations may unintentionally be exposed to viruses and hacker attacks that could lead to unexpected disruptions and unmanageable damages. This article explores the implications of the aforementioned challenges for organizations operating in the architecture, engineering and construction (AEC) industry in their BIM implementations.

1.2. *BIM implementation framework*

The framework chosen for structuring the literature review was suggested by Jung and Joo [16], and developed from an application of IS planning methodology in construction. In the attempt to assess the effectiveness of IS in construction, the authors stressed managerial and technical issues, aiming to address all relevant BIM issues. The framework can be summarized as follows:

Table 1: The framework categories (adapted from Jung and Joo [16])

Technical (T)	**Perspective (P)**	**Construction Business Function (C)**		
1. Data Property 2. Relation 3. Standards 4. Utilization	1. Industry 2. Organization 3. Project	1. R&D. 2. General Admin. 3. Finance 4. HR. mgt. 5. Safety mgt.	6. Quality mgt. 7. Cost control 8. Contracting 9. Materials mgt. 10. Scheduling	11. Estimating 12. Design 13. Sales 14. Planning

- [T1] Data Property covers the technical aspects of geometric and non-geometric BIM data, their arrangement in databases, and their metadata with construction material objects being classified.
- [T2] Relation deals with the technical interdependency of data properties in parametric BIM objects. Moreover this category deals with technical aspects of file exchange (i.e. industry foundation class file exchange format)
- [T3] Standards include BIM studies exploring technological aspects of file exchange and related standards such as ISO, Uniclass, and MasterFormat.
- [T4] Utilization entails studies seeking to develop the technological aspects of BIM to better support practical project level use of BIM. Here the different construction disciplines contribute studies on how to make BIM a technologically better system for its respective purpose.
- [P 1, 2, 3] Perspective covers overview studies focusing the industry, organizational and project wide diffusion of BIM.
- [C 1-14] Construction Business Function covers studies focusing on BIM's effect on organizational performance and work in different aspects of the construction supply chain. This stream of research takes into account how BIM and IS influence the day-to-day operations in the construction industry and projects.

2. Methodology

A literature review is an extensive reference providing background and justification to the conducted scholarly works in a specific research field [17]. This paper contributes an update of BIM implementation in developing countries. To collect relevant literature, a 6-step literature search process was adopted [18]. (1) The search focused on peer-review outlets. Moreover, as conference papers usually are of lower quality and less mature than journal articles, only journal articles were considered [19]. No restriction to specific journals was made, to provide an overall view of scholarly work in the area. (2) The search was conducted in the Elsevier Scopus database, the largest database for peer-reviewed abstracts containing over 57 million records. (3) The topic keywords informing the search were "Building information modelling" and "Building information modeling". Geographical keywords were "developing countries" and the specific names of 135 developing nations. Topic keywords were connected to each other by using the Boolean operator "OR". Likewise, we linked the geographical keywords by "OR". Only English language articles were considered in our study leaving aside potentially relevant work published in other languages. (4) A limitation of this work is that we did not consider the impact and influence of articles in terms of citations. (5) The initial return of the search were 39 articles. However, through initial screening for topical relevance we excluded articles not having to do with BIM in construction (i.e. biomedical engineering etc.), leaving a total sample of 27 articles (6) This was followed by a full text evaluation to categorize the collected articles according to the BIM implementation framework presented in table 1. After step (6), two more articles were excluded. One article was about a hospital BIM design case study in the Middle East, but the task was outsourced to a design team in the US [20]. The other excluded article [21] was an on-going study by Enegbuma et. al. because their latest work was included in the sample. Thus, a total of 25 articles were classified. For articles covering several topics, only the main focus was used for classification. The main focus was identified by reading what specific purpose was stated in the article. Table 2 summarizes the search conducted.

Table 2: Scopus search summary

Keywords	[1] ((Building information modelling) OR (Building information modeling)) AND ((developing countries) OR (developing country)) [2] ((Building information modelling) OR (Building information modeling)) AND ((countries*))		
Database and date assessed	[1] Elsevier SciVerse Scopus assessed 15.12.15 [2] Elsevier SciVerse Scopus assessed 15.12.15	Return	2 37
Scopus search strings	[1] (TITLE-ABS-KEY({Building information modelling} OR {Building information modeling}) AND TITLE-ABS-KEY({developing countries} OR {developing country})) AND DOCTYPE(ar) AND (LIMIT-TO(LANGUAGE,"English")) [2] (TITLE-ABS-KEY({Building information modelling} OR {Building information modeling}) AND DOCTYPE(ar) AND (TITLE-ABS-KEY(countries*)) AND (LIMIT-TO(LANGUAGE,"English"))		
Number of relevant articles: 27			
* names of 135 developing countries as defined by the World Bank.			

3. Findings

Sixty-four percent (16/25) of the articles were published in the last two years. This can be viewed as an increasing interest on BIM implementation in developing countries. Among the 135 developing countries, BIM implementation studies were only reported in China (13), Malaysia (9), and India (3), indicating a research gap regarding the other 132 countries. Figure 1 shows the distribution of articles by country over time. An overview of the classification results based on the framework by Jung and Joo [16] can be found in table 3. Table 4 presents frequently mentioned keywords classified by article topic area. In what follows the results of our review are presented by topic area.

Figure 1: BIM studies in developing countries

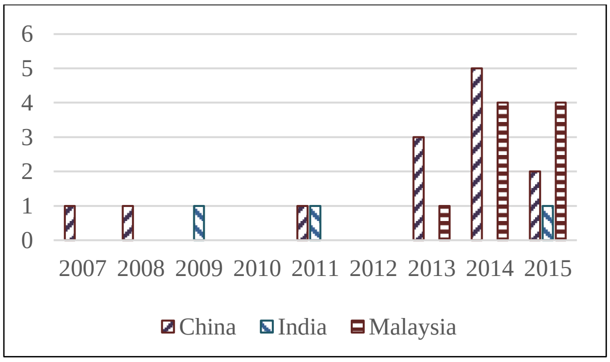

Table 3: Classification of articles

Dimension	**Articles**	**Percentage**
Technology	12	48 %
T1-Data property	1	4 %
T2-Relation	0	0 %
T3-Standards	4	16 %
T4-Utilization	7	28 %
Perspective	7	28 %
Construction Business Function	6	24 %
Total	**25**	**100 %**

Table 4: Mentioned terms

T1-Data property	As-built, cloud computing, construction management, data management, facility management
T3-Standards	Cost estimation, engineering contract, Industrial foundation classes
T4-Utilization	As-built, carbon footprint, construction management, construction safety, facility management, geographic information system (GIS), terrestrial laser scanner (TLS)
Perspective	Construction management, industrialized building system, information technology strategy, participant involvement, Structural equation modeling, sustainable construction
Construction Business Function	Innovation adoption, innovation diffusion theory (DOI), Institutional theory, integrated project delivery (IPD), lean construction, parametric modeling technology (PMT), technology acceptance model (TAM)

3.1. *Technical*

Viewing all technically focused articles together (T1-T4), we find a relatively strong focus on technology in developing countries (48% of all articles). Maybe not surprising, there are several studies focusing on the alignment of technological standards, taking into account national, regional and local regulations and legislation. Moreover, making BIM a technically better tool to support its utility for developing country construction firms receives much research attention. From the classification of the articles it appears that technological relation (T2) topics receive no research attention in developing countries.

T1 – Data property: Claiming that data management in construction and facilities management is challenging, Jiao et. al. [22] suggest a "cloud application model", namely LubanWay, enabling data sharing and gathering. This cloud computing model was applied and developed for facilities management in the Shanghai Tower. LubanWay can be used to combine engineering and management data, collect data, and proves "particularly effective in cost control"[22].

T3 – Standards: The identified studies focused on transferring BIM standards to the developing country context. This includes studies on how international BIM standards (e.g. AEC/UK or openBIM), can be adapted to the Chinese national context. There are presently no legal barriers for utilizing such standards in China as long as these are specified as contract addendum to the tender document [23]. Scholars have studied how industry foundation class file exchange (IFC) following the openBIM method can be employed in developing country civil engineering projects [24, 25]. This would allow for tighter integration across several different engineering systems [25], as well as aligning different estimation methods [24]. The findings are promising as they show that BIM has the potential to "significantly reduce" workloads and errors in civil engineering projects in developing countries [26].

T4 – Utilization: When implemented in projects, BIM provided design support resulting in overall reduction of design time [27, 28] and clashes [27]. However, it was evident how issues of low data quality and poor coordination hinder effective BIM utilization [29]. How Terrestrial Laser Scanning and Geographic Information Systems data could be merged with BIM for creating 3D as-built visualizations receives attention from developing country researchers [28]. Other areas focused in this category include: BIM's utility for increasing construction safety [30], how to drive construction efficiency by deploying BIM [30], and how to overcome hurdles for BIM-based collaboration across companies [28]. Finally, sustainable or green construction is another area of BIM research and "energy saving and carbon reduction" [31] as well as "energy conservation" in the early construction design stages are studied in the developing country context [32].

3.2. *Perspective*

BIM implementation surveys in developing countries can be found at industry, organizational, and individual levels. A survey of the Chinese industry surfaced that BIM was primarily viewed as useful for promoting contractor competitiveness [33]. Organizational BIM adoption levels in Malaysia and China remain low, with less than 20% of the surveyed construction organizations applying BIM in practice [34-36]. Moreover, even when BIM has been implemented in individual construction companies, its usage is limited and still in its "infancy" with many barriers to be tackled [35]. Taking a technical view, practitioners would need to improve "the compatibility and integration" between BIM and current construction software [35, 37]. Moreover, BIM use would need to be in alignment with daily construction activities [35]. Presently, BIM is viewed to be fairly complex and difficult to use [38]. In addition, developing country firms view BIM as a 'risky' investment since its business value remains unclear [33]. While practitioners appear interested in BIM adoption they appear unwilling to change the status quo in their firms [38]. Drivers such as "economic benefits" and "effectiveness and efficiency" could motivate these practitioners [37]. BIM needs to be supported from clients, contractors and government before it will become used in developing countries [33, 38]. Moreover, technical training is viewed as important to drive BIM implementation [37].

3.3. *Construction business function*

Theories frequently applied in IS research such as Institutional theory, TAM and DOI are also used to investigate how to implement BIM in practice. A survey of 92 construction projects in China revealed that coercive or "authoritative pressures" have a great impact on the attitudes of clients/owners towards BIM adoption, while architects and contractors were mostly motivated by mimetic pressures seeking to imitate "successful conduct" of others [39]. Furthermore, practitioners' BIM adoption intentions were influenced by their "willingness and interest" [40]. Entrepreneurs viewed IPD based on PMT as promising avenues for improving their ways of doing business. IPD was considered a good approach for achieving tighter integration in developing country construction projects [41]. PMT was viewed as essential basis for a better alignment of design technologies [42]. Utilizing relational database systems allows graphical and non-graphical data to be managed in one system. Such information infrastructure will support to manage, capture, and represent project data in a dynamic way [42]. Moreover, BIM systems still allow users to continue generating traditional two-dimensional paper drawing sets [42]. However, BIM adoption continues to be low in developing countries [35]. Some barriers typical for developing countries are limited financial resources for IT investments, lack of national BIM standards, and inexperienced modelers [40]. Moreover, developing country firms are so far not convinced as to whether BIM usage will provide acceptable returns. An attempt to develop a model for evaluating construction IT application in general, and BIM implementation in particular, has been presented in the literature [43].

4. Discussion

Most of the articles included in the review have been published in the last two years, showing how researchers in developing countries have just begun to explore BIM topics. When comparing the extent of this work to the BIM research efforts undertaken in developed countries over the past two decades, it is reasonable to claim that this work is still in its infancy. Moreover, research interest so far appears to be limited to China, India, and Malaysia. Thus, the findings presented in this article need to be viewed against the background that there exists little BIM related research from other developing countries.

Technology - The articles have their main focus on transferring available BIM technology to the developing country context. Researchers focus their inquiries mainly on 'vanilla' implementations of commercially available BIM software packages made by software vendors located elsewhere. A notable exception from this trend is the LubanWay [22] software developed by a local Chinese software developer. Evidence from developed countries indicates that off-the-shelf BIM solutions will need some degree of customization and/or 'add-ons' to best fit the realities of local legislations and building traditions. Taking Norway as an example, there exists a range of commercially available BIM add-on software packages providing Norwegian construction companies with digital object libraries featuring construction materials typically used in Norway. Moreover, software packages for energy or costing solutions are developed to fit the realities of the national Norwegian context. Judging from the articles reviewed, there appears a need for researching and creating local BIM software adaptations customized for the various developing countries. This constitutes an important area for further research.

Perspective - There are relatively few instances of practical BIM use reported in the developing country context. However, in China, India, and Malaysia, there are cases of BIM use similar to what is done in advanced projects elsewhere (e.g. the Shanghai Tower). However, in terms of industry wide BIM diffusion, China has fewer than 20% percent of its AEC firms reporting BIM use, whereas the US has BIM adoption rates of above 70% [44]. In absence of data on BIM diffusion in other developing countries, we also draw upon the insight from the first author, after working several years for a Vietnamese metro administration. According to his experience, in Vietnam there are very few cases of BIM use, and if ever used then it is by Japanese and Korean consultants working in the projects. This indicates a need for further research mapping BIM uptake in other developing countries. This could be done based on existing BIM capability and maturity indicators.

Construction business function - The research classified under this sub-topic studies what can be gained by BIM implementation in different parts of the building construction supply chain in developing countries. Like their peers in developed countries, scholars from developing countries have argued for how sustainability, construction management and logistics could all benefit from increased BIM use. While conceptual studies from India and Malaysia debate BIM, GIS, and TLS integration [28, 30], studies exploring BIM use in transportation (roads, bridges, metro, etc.) and facilities (water pipes, sewers, etc.) projects are absent. Considering the importance of transportation and facilities projects for development, researchers should consider conducting further work in this area. Moreover, it is somewhat surprising that there are few studies seeking to address the major barriers for BIM implementation in developing countries, similar to what is done in ICT4D research. This can be viewed as a limitation of the present work that would need to be addressed before BIM can be implemented successfully.

5. Conclusion

From the systematic review in this article, an overview of BIM research in developing countries has been provided. Almost no research on BIM in developing countries exists prior to 2013, and the focus of the present work is limited to the three countries of China, India, and Malaysia. Further, the scope of the work appears to be limited to technology transfer research topics seeking to import technology, standards, and collaboration approaches to the context of developing countries. Limited attention is given to BIM implementations in infrastructure and facilities projects in developing countries. This leads us to conclude that more work is needed to develop new BIM solutions that address the context of the local construction industries in developing countries better.

In general, more studies are required to cover the gaps identified in this paper. Technological and managerial aspects to enhance BIM implementation are also promising for further work. We propose to conduct research in developing countries and the framework dimensions (T1 and T2) that are under-represented. From the technical view, approaches or requirements for collaboration such as openBIM will be essential to focus in further studies. From the managerial view, an effective strategy for BIM implementation in developing countries should gain more attention. In this vein, a comparison between developed and developing contexts is applicable.

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