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Building Information Modelling Implementation Models in Thailand: Drivers, Benefits, Barriers and Lessons Learned

*Francisco Sierra and Christayos Rodboonpha

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Abstract: This study provides an overview of the typical building information modelling (BIM) implementation models in Thailand and a BIM implementation guide for contractors to avoid repeating common mistakes. Generally, BIM is used to produce a three-dimensional (3D) model, update technical drawings, detect clashes, quantify take-offs and create 3D visualisations. The study revealed that the main driver for contractors to use BIM is the request by Thai private developers to use BIM in more than 60% of large projects. In addition, the present study discovered that the main barriers to the implementation of BIM are the productivity of the projects, high initial investment, lack of knowledge and information available about BIM, lack of leadership from the government to promote the change, resistance to change of practice and the long adoption period. As a result, most contractors use BIM below its potential and receive only limited benefits. This study also recommends suggestions to minimise identified barriers.

Keywords: BIM, Thai contractors, BIM drivers, Barriers to BIM, BIM in Thailand

INTRODUCTION

Large cities have a growing demand for increasingly complex projects. Likewise, there is a demand for such projects to be completed in increasingly shorter timeframes. This, coupled with the endemic inability of the construction industry to control costs and time, has put contractors under great pressure over the last decade. Hence, building information modelling (BIM) was developed to minimise these two endemic problems.

Thai experts recognise that the introduction of BIM will benefit the Thai economy by reducing construction time and cost as well as by eliminating the multiple duplications of an industry that works in isolated bubbles (Tangparitkul, 2015; Virulrak, 2016). Thus, the Thai Building Information Modeling Association (TBIM) estimates cost reductions of 10% to 25% are achievable in construction projects if BIM is used in Thailand (Pimanmas, 2019).

Many contractors in Thailand are aware of BIM, but there is still resistance to adopting it (Virulrak, 2016). This is because information on how to implement BIM in Thailand is limited and rarely considers the peculiarities of contractors. This research aims to identify the barriers that prevent Thai contractors from implementing BIM, collect lessons from contractors and consultants who worked with BIM to develop a guide for its successful implementation and establish BIM implementation models.

Faculty of Environment and Technology, University of the West of England, Bristol BS16 1QY, UNITED KINGDOM
*Corresponding author: fi.sierra@yahoo.co.uk

Additionally, this study aimed to identify the current drivers, uses and benefits experienced by Thai contractors using BIM. Therefore, this research is relevant, as it provides novel and crucial information for Thai contractors to plan strategies to implement BIM, avoid repeating common current mistakes and guide them to change their daily practice.

Although this research was based in Thailand, it could be applied to other countries at a similar stage of BIM pre-adoption, especially in South Asia, despite their local differences. The findings are also expected to benefit contractors, but because BIM is collaborative, it will also help other stakeholders, especially developers, consultants and policymakers.

LITERATURE REVIEW

This literature review identifies and extracts information from relevant research conducted on the adoption of BIM by contractors in Thailand found in the following databases, namely: Scopus, Google Scholar, Research Gate, Construction Information Service, Iconda, Emerald, DOAJ, Springer-Link and JSTOR from 2005 to 2022.

Theoretical Benefits of BIM for Contractors

BIM creates a "digital representation of the built asset" to share reliable information and facilitate decisions during the design, construction and operation processes of a project (ISO [International Organization for Standardization], 2018). BIM automates certain operations, reduces errors and reduces execution time. Therefore, in theory, BIM could improve the productivity of contractors who adopt it (Smart Market Report, 2009). However, the potential benefits that BIM can bring to contractors depend on the quality and quantity of information integrated into the BIM model.

Theoretical benefits and drivers for contractors in Thailand

Early studies by Sukkhi (2011) and Tangparitkul (2015) conclude that the main benefit of BIM for Thai contractors is the reduction in mistakes and conflicts between drawings and the subsequent re-drawing time. Second, BIM provides accurate and up-to-date information and quickly incorporates design changes (Sukkhi, 2011; Tangparitkul, 2015). Jongjit (2017) also states that BIM more efficiently manages "change orders", a significant benefit for contractors since these changes are inevitable in most Thai construction projects (Handayani, Likhitruangsilp and Yabuki, 2019).

In May 2013, two of the largest contractors in Thailand, Ritta Co Ltd. and Thai Obayashi announced the results of their BIM implementations to the public. This was when contractors in Thailand became aware of BIM (Virulrak, 2016) since the announcement showed the public how BIM could reduce the cost of their projects. However, few took the step. BIM is not yet common among Thai contractors (Sukkhi, 2011). The only driver is that some private developers have started to require BIM for complex projects. These Thai developers have seen BIM as a risk management method that is useful for accurately calculating construction costs, one of the biggest risks for their business (Virulrak, 2016).

Barriers to BIM Implementation

Jongjit (2017) revealed three main barriers for Thai contractors: the high economic investment, unclear leadership and the lack of qualified personnel to work in a BIM environment. In their subsequent study, Jongjit and Prasitsom (2018) reordered and expanded the list, starting with the lack of knowledge, difficulties in breaking traditional organisational practices, the high investment needed and the attitude of the staff against change. Finally, Pimanmas (2019) includes the costly annual fees for using BIM software as the greatest obstacle for small- and medium-sized (SM) contractors, followed by the shortage of qualified BIM labour and a building control system based on conventional 2D drawings.

Initial high cost of adopting BIM

The literature reveals that adopting BIM requires a large investment in hardware and software licenses, training the existing workforce and hiring specialists. Amongst all, software prices are a real problem for SM contractors (Pimanmas, 2019) because, in Thailand, a REVIT license costs roughly the annual salary of a junior engineer (Virulrak, 2016). Although this is a high initial investment in time and money, it would save time and money a few years later (Kiviniemi, 2010). However, with minimal budgets, SM contractors prefer investing money only in quick-return investments (Hamada et al., 2016). Therefore, they prefer to continue using traditional systems instead of BIM because BIM requires high investment (Hamada et al., 2016; Bataw, Kirkham and Lou, 2016; Criminale and Langar, 2017; NIBT, 2018).

Lack of understanding of BIM in the Thai construction industry

Countries in the early stages of BIM implementation generally lack knowledge regarding the steps necessary for the full implementation of BIM in the daily practice of an organisation. Being "BIM-ready" is not about buying a simple piece of software, training your staff and then flipping the switch (McPartland, 2016) but is more than just a switch from 2D to 3D and clash detection. This lack of understanding of BIM and the steps to unleash its full potential lead to sub-optimisation, limited implementation and use of BIM and frustration at not receiving the promised benefits (Kiviniemi, 2010; Hamada et al., 2016; Bataw, Kirkham and Lou, 2016). CICRG (Computer Integrated Construction Research Group) (2011) provides examples where, due to poor planning and unfamiliarity with BIM, the implementation adds little or no value to the project and increases the cost of paying for external modelling services. Only if BIM is used correctly will it provide the expected benefits for the project and company. As Kirkham (2015) said, "In essence, it is only as good as the people using it".

A similar situation has been observed in Thailand. Early studies by Sukkhi (2011) and Panuwatwanich and Peansupap (2013) conclude that the Thai construction industry has many misconceptions regarding BIM and its real benefits. Most Thai organisations send their staff to learn REVIT and upon their return, corporations believe they have entered the BIM era (Virulrak, 2016). In addition, contractors always have limited time to finish projects and receive penalties if there is a delay. The implementation of BIM requires time, owing to the learning curve. This additional time affects the timeline of the project. Therefore, after a few months,

some contractors return to the traditional 2-D methods to comply with the project deadlines (Ruthankoon, 2015). Finally, two key areas are part of this barrier that is barely covered in Thai literature. These key areas are discovered through the literature of countries in a similar situation.

First, the lack of extensive implementation means that different stakeholders of the same project tend to have different experience levels in BIM, or some do not use BIM at all (Sahil, 2016; Criminale and Langar, 2017). Subcontractors and suppliers tend not to use BIM because they have no incentive to adopt it (Chan, 2014). Contractors need subcontractors and manufacturers to be "BIM literate" to fully benefit from BIM (Eadie et al., 2014). If stakeholders are reluctant to implement BIM, the concept of collaboration and the fluid exchange of information disappears.

Second, each activity in a construction project owns a computer application. A common misconception is that BIM can fluidly import and export data to and from all applications. Most current software packages are developed to function as standalone applications and are not ready to interact with other applications. Bataw, Kirkham and Lou (2016) identify the lack of interoperability between different pieces of software as a major problem in the efficient exchange of information during design and construction. Therefore, it is essential to establish a standard information exchange format for all partners and activities at the beginning of the project to avoid task duplication (Bataw, Kirkham and Lou, 2016; Criminale and Langar, 2017; NIBT, 2018).

Lack of qualified professionals to work in a BIM environment

This problem affects all levels of an organisation. Tangparitkul (2015) reveals that many professionals, especially engineers, have never used BIM and have minimal understanding of it. This is worrying for a country such as Thailand, where most contractors are civil engineers (Virulrak, 2016).

Resistance to change of practices at different levels

At the industry level, it is difficult to change traditional practices (Jongjit and Prasitsom, 2018). However, the Thai construction industry is reluctant to collaborate. It follows a fragmented practice in which the duplication of tasks is constant. There is a lack of trust between designers and contractors as they work in isolation and aim towards different goals due to the Thai design-bid-build practice. Traditionally, in Thailand, when a contractor wins a bid, they would redo all drawings and documentation due to a lack of trust in the designers (Virulrak, 2016), insufficient consideration during the design stage of constructability and the specific conditions of the site (Son, Lee and Kim, 2015). Sukkhi (2011) asserts that in Thailand, the design drawings that contractors receive are difficult to build and rarely match the as-built drawings. As a result, contractors are forced to constantly review, redesign and rework these documents (Sukjaroen, 2016).

Traditional practice is time-consuming in terms of illustrating alteration, generating inaccuracies and finding differences in drawings and documentation. The same happens when contractors calculate the impact of changes on the cost and schedule (Handayani, Likhitruangsilp and Yabuki, 2019). This leads to misunderstandings between parties, eventually leading to construction errors. Construction managers and fieldworkers in Thailand spend a significant amount of

time on non-value-adding activities, such as duplicating drawings and transcribing records, as well as in value-adding yet time-consuming activities, such as gathering project data, communicating with project participants and tracking project quality. These duplications and the lack of accurate information lead to errors and exponentially increase construction time and cost. BIM can be a solution to these problems. However, instead of changing practices, Thai contractors assume these problems will occur and thus accept the cost of adding additional labour to detect clashes and manually re-draw details (Sukjaroen, 2016; Handayani, Likhitruangsilp and Yabuki, 2019).

At the project level, the Thai industry follows a 2D compliance system (Pimanmas, 2019). Documents submitted to receive building permission are still based on conventional 2D drawings (Hamada et al., 2016). Therefore, contractors feel they can continue to work traditionally (Hatmoko et al., 2019). In short, employees resist change (Jongjit and Prasitsom, 2018). Learning new technology and becoming comfortable takes time and always involves resistance from those who have to change their habits. Therefore, a lack of enthusiasm is common in adopting new methods.

Insufficient CEO leadership and BIM integration at the organisational level

Implementing BIM is a business decision that should be led by the head of the organisation using a well-documented strategy. However, it is rare to find contractors in Thailand implementing BIM at the corporate level. Also, most organisations see BIM as an external activity for an external BIM modeller (Virulrak, 2016).

Insufficient government leadership and lack of national standard

In Thailand, the government is yet to implement BIM policies, standards or incentives. This is similar to India, in which the government is yet to mandate its use for public projects, which is one of the critical reasons for the low level of adoption of BIM in the country (Sawhney, 2014). On the other hand, some countries have proven that in countries where BIM is mandatory for public projects, its adoption has accelerated (Smith, 2014; Zhou, Yang and Yang, 2019). For example, the Hong Kong government has established these incentives, and accordingly, BIM implementation has flourished in the country (Chan, 2014). Nevertheless, the lack of local standards in Hong Kong to guide the implementation of BIM still causes a delay in the adoption of the new technology.

In countries where the government does not set standards, clients tend to set their own standards. In some cases, they may not set it on time or fail to set it. This bad practice creates constant misunderstandings and problems during the construction stage (Zejnilović 2017; NIBT, 2018). Over the last three years, there have been several initiatives to address this issue. In 2019, the Engineering Institute of Thailand (EIT) founded the BIM Institute of Thailand to promote the implementation of BIM in Thailand. They have been publishing highly valuable documents to increase Thai standards, such as the *Building Information Modeling Guide* (EIT, 2019a), *BIM Adoption Guide* (EIT, 2019b) or *the BIM Standard* (EIT, 2020). Then recently, in 2021, TBIM published the *Thailand BIM Object Standard Guideline* (TBIM, 2021).

METHODOLOGY

The literature review reveals that further research is needed to clarify the current drivers, use, benefits and implementation methods that Thai contractors followed and the barriers that prevented them from implementing BIM. It also reveals the general need for information about BIM in Thailand (Udomdech, Papadonikolaki and Davies, 2021) and the steps to follow for smooth and fruitful BIM implementation among contractors in Thailand in particular. To this end, a qualitative study was conducted in two stages. Qualitative research is valuable for this study, as it provides detailed descriptions of complex phenomena and lessons learned from experts in the implementation of BIM in Thailand, which allows insights into the current knowledge in the literature to develop a BIM implementation guide for Thai contractors.

In the first stage, a literature review critically analysed the selection of published secondary sources between 2010 and 2022 in Thai or English. This review produced a preliminary identification of the benefits and barriers that prevent the implementation of BIM.

In the second stage, structured interviews were conducted to refine and expand the theoretical background of the literature review. This method provides not only answers but also the reasons for the answers, opinions, beliefs, examples and lessons learned. The questions were derived from the literature review and aimed to establish a deep understanding of four main themes: (1) current drivers and benefits, (2) barriers (internal and external), (3) implementation models and (4) good practice and lessons learned to minimise these barriers.

The author conducted nine face-to-face interviews between June 2019 and January 2020. In July 2022, nine respondents were contacted again to provide an update on their response to add any significant changes that occurred in the last three years. Another Thai contractor was then added to the sample. Updates were included in the analysis and conclusions. The researcher recorded all interviews using digital audio before transcribing them verbatim and anonymised.

Potential participants were selected using a purposive sampling method to generate a robust set of expert opinions from which good practices could be established. The participants were selected based on their experience in the BIM implementation process in Thailand and their ability to generate rich, reliable and generalisable information. The participants had more than five years of experience with the subject and covered three slightly different points of view on the same problem. The sample included executive directors of four Thai contractor companies, referenced as Respondents 1, 2, 3 and 10. Respondents 1, 2 and 10 were large contractors, and Respondent 3 managed a medium-sized contractor firm. All these companies practised BIM daily. Respondents 4, 5 and 6 were professors and associate professors with a record of BIM publications in Thailand. Finally, Respondents 7, 8 and 9 were BIM consultants who provided BIM services to contractors. Even though the number of samples was small, considering the limited number of experts in Thailand with the required extensive practical knowledge of BIM implementation by contractors, the sample size of the current study was proven appropriate because the saturation of themes was achieved.

Thematic analysis was then used to organise and analyse the data collected from the interviews in detail. The results of the interviews were analysed by comparing

experiences and establishing and explaining the patterns and associations found. The results were also subjected to a validation/comparison process based on findings in the literature.

RESULTS AND DISCUSSIONS

This chapter identifies the current drivers, uses, benefits and barriers in actual practice and, more importantly, establishes, for the first time, the implementation models and the lessons learned for BIM implementation that did not appear in the limited Thai literature.

Implementation Rates and Drivers

While the literature shows a low BIM implementation rate, the interviews revealed a recent increase in this rate. In 2019, large contractors who worked daily on large private projects declared that they used BIM in 30% of these projects (Respondents 1 and 2). Academics (Respondents 7, 8 and 9) supported this percentage, and the three BIM consultants (Respondents 4, 5 and 6) reported that the percentages were approximately 50%. However, they worked on BIM projects because their business was BIM consultancy. Accordingly, their data could probably be considered optimistic. Finally, mid-sized contractors used BIM in less than 20% of projects (Respondent 3). In 2022, it was found that the process of adopting BIM in Thailand by contractors accelerated over the previous two years. Today, the Thai market is familiar with BIM (Respondents 1 and 2) with 80% of large contractors can use BIM, despite that sometimes with limited understanding (Respondent 10). The three large contractors (Respondents 1, 2 and 10) agreed that about 60% of large private projects in Thailand used BIM. Finally, medium-sized contractors still used BIM in less than 30% of the projects but were very interested in improving the incorporation of BIM into their daily routine to keep updated with the trend (Respondent 3).

Private developers were responsible for Thai contractors starting to use BIM in projects (Respondents 1, 3, 4, 5, 6, 7, 8, 9 and 10) as they required BIM to bid on large projects. Respondent 7 stated that "Contractors increasingly need to be able to work in a BIM environment to win bids for the construction of high-rise buildings. Contractors who build these kinds of projects must start training now, or they soon will not have any projects in Thailand". In principle, it could be that the benefits provided by BIM become the driver for its implementation. However, the results show that Thai contractors implement BIM only because they need to do so to remain in the market. Only one contractor (Respondent 2) claimed that BIM was implemented to improve the "efficiency" of its organisation.

Benefits

The experts agreed with the literature and acknowledged that Thai contractors primarily used BIM to improve the redevelopment and update of technical drawings. Thai contractors had to rework all the construction details they received from designers because of buildability issues (Respondents 7 and 10). Therefore, BIM helped automate the updating of technical drawings and facilitated access for the rest of the team to be more precise (Respondent 6), updated (Respondent

9) and to avoid errors (Respondent 3). Respondents 3 and 5 also perceived the increase in the accuracy of shop drawings for better/faster fabrication and installation of components since they started to use BIM. The second most common use was 3D visualisation (Respondents 1, 2, 3, 4, 6, 7 and 9). BIM was used for faster and more accurate early detection of clashes between different elements and trades before construction, which reduced field errors and costs (Respondents 1, 2, 3, 4, 7, 8, 9 and 10). In 2022, it was found that most large contractors used BIM during tender processes (Respondents 1, 2, 4, 7 and 10) because it improved the accuracy of quantity take-offs. Subsequently, the budget was also more accurate. In this way, "We can know if a project/budget is feasible or not and this makes us more competitive in the market" (Respondent 10). In addition, Thai contractors with a better understanding of BIM used it to improve the efficiency of a greater number of processes, such as structural analysis (Respondents 5 and 8), on-site construction progress monitoring (Respondents 1 and 6) and site analysis (Respondent 2).

The contractor and other parties in a project should integrate 4D (time) and 5D (cost) data into the 3D geometric model and collaborate with BIM to deliver the full benefits promised in the literature. However, only contractors who integrated BIM into the core of the organisation (Respondents 1, 2 and 10) reported increased collaboration levels. A good example was the contractor (Respondent 2), who developed a holistic plan and created a BIM society to promote collaboration within the organisation, with debates and exchanges of ideas on BIM between departments. This contractor received the most benefits from the investment. Unfortunately, most Thai contractors preferred to externalise BIM.

Based on the findings, two clear strategies were discovered. First, BIM was used to create a 3D model to meet customer requirements and helped improve three processes: the development of technical drawings, 3D visualisation and clash detection. However, these led to the use of BIM below its potential, generating minimal benefits and dissatisfaction. Second, BIM was implemented to improve the efficiency of processes, integrate cost and time information into the geometric model and strive for collaboration. This strategy was a good practice and provided the expected benefits. Unfortunately, it "occurs less than expected in Thailand" (Respondent 6).

Barriers

The literature review produced a preliminary identification of the barriers that prevented the implementation of BIM. In the second phase, experts were interviewed to validate, refine, enrich and rank barriers identified in the literature. Each contractor faced these barriers to a greater or lesser extent, depending on their size and budget, implementation model and level of knowledge of BIM. The barriers were arranged in descending order of importance. At the end of the list, a different theme was added due to the sum of all other themes. This extra barrier was not included in the literature but was of great relevance to Thai contractors.

Barrier 1: Large and constant investment in time, money, resources and training are required

In Thailand, hardware and software licenses and training entail large initial investments (Respondents 1, 3, 4, 8 and 9). Therefore, organisations had to understand that the implementation of BIM is a non-finite process because BIM

is a very dynamic environment that requires constant updates and training (Respondent 7). This barrier was not accentuated by large contractors who could purchase servers in the cloud and internal servers for storage and quick access to information (Respondents 1 and 2). In contrast, SM contractors had difficulties meeting these expenses (Respondent 8). For example, most had sufficient budgets to back up information on hard drives (Respondent 3).

Barrier 2: Limited knowledge of BIM at every level

Many contractors did not understand BIM (Respondents 4 and 7) or had a minimal understanding of how to implement BIM to receive its full benefits (Respondents 5 and 6). This led to constant misunderstandings about the steps needed during the implementation process, which resulted in great losses of time and money as well as benefits (Respondents 1, 3 and 6). For this reason, many early adopters worked in parallel in 2D-CAD (computer aided design) to finish projects on time. Four sub-barriers, which were barely covered in the literature, were identified in this study.

First, reviews revealed that in Thailand, there is minimal information available about the implementation of BIM for contractors, and most are in English, including online tutorials and forums (Respondent 1). Udomdech, Papadonikolaki and Davies (2021) note a "lack of English proficiency" as the first barrier to BIM adoption by Thai designers. Since 2019, the Thailand BIM Institute by EIT, TBIM, and a few universities have been publishing documents in Thai and holding workshops and seminars to disseminate valuable knowledge about BIM in Thai. This has accelerated BIM adoption by contractors in Thailand. However, contractors in Thailand still claimed they lacked "examples of successful implementations to learn from" (Respondent 7).

Second, only a few Thai professionals had working experience in BIM environments (Respondents 8 and 9). Even though information about BIM is becoming more available, experience matters (Respondent 10). It was difficult for contractors to find "BIM-ready" workers with experience, even at a basic level, such as BIM modellers (Respondents 5 and 9). But more worrying was the low level of knowledge at the decision-making level of companies (Respondents 7 and 9).

The third was the knowledge gap and disagreements between parties. If part of the organisation or some stakeholders in a project lacked the necessary competence to work in BIM, it would be complicated to change (Respondents 5 and 6). This occurred widely in Thailand, where some stakeholders, especially subcontractors and the supply chain, did not use BIM at all (Respondent 6). Others did not fully understand this. For instance, Thai developers may ask for a 3D model to visualise the development of a project (Respondents 7, 8 and 10). However, some developers specified employee information requirements (EIR) of maximums. This led to disagreements regarding, for example, the level of development specified by the developer. Respondent 10 also stated that "There is no value in detailing pipes up to level 500 for clash detection, but it does take additional work for the contractor". On other occasions, some responsibilities were not entirely clear. Once clashes were detected, deciding who was responsible for the additional work became a conflict as no one wanted to spend more time or money on the project (Respondents 1, 2, 3 and 10). It was scarce to find projects with no EIR (Respondents 1, 2 and 10). In these cases, problems appeared when the contractor started building with no clear BIM plan. The contractor was forced to complete the project

in the traditional way using CAD, owing to the high cost of construction delays (Respondents 1, 2, 3 and 8).

Lastly, the interoperability issues. BIM is used to exchange information efficiently. Therefore, it is essential to understand and agree on common information exchange formats or the use of industry foundation classes to facilitate collaboration between parties. Otherwise, key information will be lost when trying to combine models and the information will have to be re-added manually (Respondents 1, 2 and 6). Limited knowledge led some Thai contractors to start implementing Archicad. However, soon after, they were forced to switch to Revit at an additional cost when they encountered interoperability issues when trying to exchange information since most of the construction industry in Thailand worked in an Autodesk environment (Respondents 1, 9 and 10).

Barrier 3: Insufficient government leadership

A limited number of national policies or Thai standards create a clear and unique path for BIM implementation (Respondents 6, 7 and 9). This creates a regulatory gap because each organisation follows different standards, such as from Singapore, the US, the UK and Japan, or creates custom standards. Therefore, contractors often found each project requiring different action protocols, which was a source of misunderstanding, confusion and delays, even for well-trained contractors in BIM (Respondents 1 and 2). Moreover, Thailand does not require BIM in public projects. Thai contractors knew they could access these projects without implementing BIM (Respondents 4 and 7).

Barrier 4: Resistance to practising changes

Some contractors, especially SMEs, saw traditional methods as "more efficient and less expensive" methods to work with that perfectly comply with building regulations (Respondent 3).

There had been resistance to change from working in isolated bubbles (Respondents 1, 2, 5, 6 and 9) to collaboration. Stakeholders were reluctant to share information because they had different objectives and goals (Respondents 3, 7 and 8). Contractors who outsourced BIM or added minimal information to the BIM model did not create the right environment to receive the benefits that emerged from information-sharing and collaboration.

There was also resistance to changes in practices at the employee level. The workforces of the three contractors (Respondents 1, 2 and 3) were reluctant to attend BIM training because they preferred to continue using CAD (Respondents 4 and 6). The executive team of each company were forced to make training mandatory. After the training completion, the staff of Respondents 1 and 2 (contractors) began to agree to work in the new BIM environment. In contrast, in the case of Respondent 3, a limited number of staff received the training and reluctance towards BIM persisted. The lesson learned is that all employees should receive BIM training.

Barrier 5: Lack of leadership in some companies

The chief executive officers (CEOs) of contractor companies in Thailand were not fully involved in the change in practice (Respondents 3, 4 and 5). The experts agreed that, in these cases, the opposition of their employees to the change was greater (Respondent 3) and the benefits were minimal (Respondents 7, 8 and 9). Most of these managers had limited knowledge about BIM and often outsourced it rather than integrating it into the organisation (Respondents 3, 4 and 9). Some senior management had a generational problem of low capacity or will to adopt new technologies. Others were used to look for short-term financial gains and did not see that BIM is a core skill for businesses to continue operating in the long term (Respondent 10). However, when leaders had a clear vision and led the change, they motivated the staff to accelerate the change (Respondents 1 and 2). There are excellent examples in Thailand of innovative CEO/senior management teams implementing BIM, such as Ritta Co Ltd. and the Thai Obayashi Corporation. Therefore, the key factor for the success of BIM implementation is that the head of the organisation understands, leads and supports the change.

Barrier 6: Reduction in productivity

Respondent 3 noted that "BIM delays all of our daily tasks". Little was said about this in the literature, but this problem affects all contractors in Thailand because it is particularly costly for SM contractors. To an extent, previous barriers lengthened the normal BIM learning curve (Respondent 2). The BIM implementation process slowed the construction of buildings and added new tasks related to the planning and generation of models. The process of learning BIM while simultaneously attending to the urgency of completing a project was challenging. Contractors who did not know how to use BIM at the beginning of the project had severe problems meeting deadlines (Respondent 8). Therefore, the main barrier Thai contractors encounter in the first projects using BIM is its negative effect on the schedule/productivity of those projects. A traditional schedule of a project does not consider the learning curve to deal with BIM processes, even when some people do not know how to use it, "when we all get used to this new method, it won't take that long, but right now BIM has a huge impact on the project schedule for a contractor" (Respondent 10).

During the early stages of the implementation process, in which contractors might hire an external BIM consultant to create a BIM model (Respondent 3), many contractors continued to work on CAD in parallel to speed up the resolution of technical problems. Once construction began, developers and contractors aimed to finish the construction, and the lack of experience in BIM made them develop the habit of working in parallel in the traditional way. This habit lengthened the implementation period (Respondents 3 and 8) and caused task duplications, further reducing productivity (Respondent 3). For these contractors, BIM reduces their productivity without receiving any benefit, but only complaints from staff and customers, which shown that "our company still does not see any of the benefits attributed to BIM" (Respondent 3).

BIM Implementation Models and Lessons Learned to Minimise the Barriers

The collected responses showed that Thai contractors tended to customise their implementation strategy to align it with the culture of the organisation as well as its needs and budget. In general, there are three models in Thailand. The first model integrates BIM into an organisation among large contractors (Respondents 1, 2 and 10). The second model requires contractors to hire an external BIM consultant to lead the implementation of BIM in the organisation (Respondent 4). Finally, due to their size, resources and budget, most SM organisations (Respondent 3) use the third model, which is to hire external consultants that produce BIM models to complete the tasks required by clients (Respondents 5 and 6). The 2022 update reveals that Thai contractors are developing more internal BIM teams. As a result, outsourcing BIM is no longer being used as much anymore (Respondents 1, 2, 3 and 10).

First model

In the first model, senior management creates a vision and leads the change from top to bottom (Respondents 1, 2 and 10) through an internal team that prepares, supports and supervises BIM implementation. This team is responsible for studying the available standards, guides and case studies to understand how to work in a BIM environment, then integrating it into the workflow of the organisation by identifying the specific uses of BIM that could benefit their organisations. They then plan implementation milestones, which require workforce resources and training (Respondents 1 and 2). Then, a trial-and-error strategy follows, where progress is monitored and success is measured until BIM progressively expands within the organisation (Respondents 1, 2 and 7).

The first model has variants. Respondent 1 studied BIM independently and established a central BIM implementation department that set global goals and managed integration across the organisation. Therefore, this contractor trained only a few drafters and engineers to achieve global goals. In contrast, Respondent 2 sought foreign mentors, contacting two similar companies with experience in BIM adaptation; one was in Japan, the other in Australia. Consequently, Respondent 2 learned from the lessons previously identified by their mentors. This is why they worked at the department level, with a BIM leader within each department responsible for determining the use of BIM in the department and inspiring their staff to learn BIM. Once the use of BIM for each department was identified, objectives and training were assigned to each department. They had all employees study the basics of BIM and then provided specific BIM training by department, such as site analysis, estimating and scheduling. Thanks to this, they were able to add more information to the 3D model, which generated more benefits with almost the same investment. In addition, they created a BIM society in which staff members could discuss and exchange ideas about BIM.

Consequently, Respondent 1 revealed in the interview that "the organisation still does not fully trust BIM, which translates into an increase in work, as it still does not reduce some duplications and adds the new tasks of generating models". In contrast, Respondent 2 felt very confident in the BIM environment as "collaboration between departments has increased and more information is being shared".

While it is reported that it is possible to learn to model in 3D quickly, it takes longer to build collaborative habits and use BIM to its full potential (Respondent 8). Each contractor can create a 3D model, but adding or reducing dimensions

of information requires strategies. Respondent 2 added that the increase in dimensions of information resulted in a richer 3D model, accelerating a greater number of tasks and favouring collaboration and information exchange between departments and stakeholders to make faster and better decisions. Contractors model (Respondents 1 and 2) who followed the first model managed to improve their productivity and reduced costs in both money and time in the long term. Therefore, the first model is a good practice and a worthwhile investment.

Second model

The second model hires an external BIM consultant (Respondent 4) as an expert to accelerate the implementation process. The consultant studies the company and establishes basic implementation goals by identifying the type of BIM used by the organisation. The consultant also provides training to a small, selected part of the organisation (primarily the drafters), creates BIM execution plans and assists the contractor with their expertise to build the BIM model. An intermediate implementation model allows the contractor to access projects where the developer requires BIM and to suffer fewer delays during the project, as an experienced external consultant supervises it. This model facilitates the reduction of errors during implementation and projects but does not favour a spirit of cultural change within the company since it is not led by executives. In addition, it is difficult to find external consultants in Thailand with solid experience in BIM (Respondent 8); hence, companies may hire the same external consultant, leading to the loss of a good team that understands a company's internal culture (Respondent 8). Finally, with less integration of BIM into the core of the organisation, the implementation process takes longer and contractors receive fewer benefits from using BIM than the first model. Therefore, model two is not the best possible practice.

Third model

In the third model, organisations fully externalise BIM (Respondent 3). They hire external consultants to produce the BIM model and any BIM tasks required by clients (Respondents 5, 6 and 7). This type of contractor does not implement BIM in the organisation, but they hire an outside party that provides basic REVIT training to a minimal number of senior engineers or draftsmen (Respondents 3 and 6) without following any long-term strategic plan. The external consultant performs most of the 3D modelling of the contractor, following the specific requirements of the client. They add hardly any information and do not exploit the benefits that this model could provide. Contractors following this strategy do not feel "safe in the BIM environment, at all" (Respondent 3). Consequently, they continue in parallel, "executing the construction process in the traditional way because it is more efficient and less expensive" (Respondent 3). This is a short-term solution for continuing in a market that does not integrate BIM into a company because the investment is not recovered, tasks are duplicated instead of reduced and no expected benefits of BIM are received. In short, this practice is not advisable.

Guide for BIM Implementation

This research found that in countries like Thailand, there is a lack of precedents in the literature to learn from, turning the implementation of BIM into a painful learning process based on trial and error. This section aims to provide recommendations for Thai contractors on implementing BIM. The following recommendations are based on the steps suggested by key authors on how to lead changes at the organisational level based on the contextualisation of successful actions carried out in other countries found in publications and the advice by the interviewed Thai experts:

1. BIM implementation should be a top-down process: Barriers 1, 4, 5 and 6

   Top management is responsible for the culture of an organisation and, therefore, must lead any change in practice because, without their leadership, success is likely to be elusive (McPartland, 2016; Pimanmas, 2019). The process should start with educating the senior management about BIM to establish the correct vision (Sahil, 2016) without wasting dedicated resources.

2. Each contractor should have a personalised plan based on needs and resources: Barriers 1, 5 and 6

   Each contractor is different in terms of size, structure and speciality. The implementation must be driven by a clear business plan that is specific to the needs of each organisation and department, outlining the affected processes, roles and responsibilities, necessary resources and training and a schedule with incremental milestones to reduce unnecessary costs (Eadie et al., 2014).

3. Plan to update hardware, software and staff training: Barriers 1, 2, 4, 5 and 6

   First, the required BIM tools and data storage to support the BIM practices of a company are decided (Sahil, 2016). Then, the potential BIM tools business partners use to facilitate interoperability and information exchange are investigated. Next, motivated champions should be selected for training and testing (McPartland, 2016). It is also crucial to understand that BIM implementation is a never-ending process and that BIM is constantly growing and evolving. Therefore, engaging with BIM networks and attending conventions and seminars are necessary to stay on track.

4. Implement an integral cultural change in the company: Barriers 2, 4, 5 and 6

   All employees should receive BIM training to perform tasks in a collaborative BIM environment. Contractors should follow the first implementation model, which is integrating BIM into every department and not outsourcing it.

   Implementing BIM is not simply a change from 2D to 3D. A BIM model generates benefits when information dimensions are added, namely 3D, 4D, 5D, 6D and 7D. The more information included, the more capable

BIM is to automate and improve the processes carried out by contractors, especially in controlling time, costs and errors.

In addition, leaders must inculcate the value of collaboration as a transformative resource in their team because collaboration facilitates access to accurate information, making better decisions and reducing duplications.

5. BIM is tested in a small pilot project and then expanded to its full potential: Barriers 1 and 6

   Regular performance reviews should be established to monitor proper adaptations of traditional processes to BIM methodology (Kotter, 1996). These reviews also help determine what is working and what is not, refine the process and continue to embrace collaboration (McPartland, 2016). A two-way channel should be established to communicate the vision and receive feedback (Raza, 2019). Lessons learned should be identified and quick wins should be acknowledged to infuse energy into the transformation process (Kotter, 1996). BIM implementation is an iterative process that requires several years to complete. However, once BIM is positively tested, it follows a progression plan to consolidate old tasks and steadily introduce new tasks to achieve full BIM collaboration (Raza, 2019; Kotter, 1996).

6. Seek knowledge transfer: Barriers 1, 2 and 9

   Contractors must look for success stories and information to learn from. In countries with a lack of information, this can be achieved through local or international consultants or mentors with experience in the implementation of BIM to achieve the "first time right" process (Kiviniemi, 2010) and reduce errors, time and cost. In addition, the lessons learned during BIM implementation should be shared.

7. Government and universities: Barriers 1, 2, 3 and 9

   Government mandates are the most effective way to introduce BIM (Smith, 2014). The government should create a national standard and BIM protocol to avoid legal issues, establish a BIM fund to subsidise BIM implementation and create a BIM hub to deliver seminars and disseminate successful case studies (Smith, 2014; Zhou et al., 2019). Therefore, the Thai government should lead changes in practice because of the economic and social benefits that BIM could bring to Thailand. There is a need for a policy to request the mandatory use of BIM in public projects, incentives during the first years of implementation to overcome economic barriers and the establishment of a Thai BIM standard. The government could also subsidise continuous professional development courses at universities to reduce BIM knowledge gaps. These policies motivate and force more stakeholders to adopt BIM. The literature provides good examples of how these actions have successfully promoted the use of BIM in other countries.

   In addition, a common hub should be created, consisting of as many experts as possible from academia, professional bodies and industry members to lead the change and develop a Thai BIM standard aligned with BS EN ISO 19650. This creates a unique and clear path to work in BIM. Universities,

too, must become the biggest motivator for change and prepare a "BIM-ready" workforce to reduce the existing knowledge gap and solve the lack of qualified labour. More knowledge about BIM should be disseminated through seminars and workshops at universities, key documents should be translated to overcome the language barrier and more articles and case studies should be published to increase the available information.

CONCLUSIONS

BIM is generally used to produce a 3D model, update technical drawings, detect clashes, quantify take-offs and create 3D visualisations. Thai private developers request the use of BIM for more than 60% of large projects, but BIM will only become mainstream if the Thai government makes BIM mandatory for public projects, as seen in the case of other countries. Most contractors use BIM below its potential, thereby enjoying limited benefits.

The current study has discovered eight barriers and solutions to the implementation of BIM in Thailand. First, BIM requires high investment in money and time; hence, the need for better planning and incentives from the government, especially for SMEs. The second barrier is the lack of understanding of BIM, requiring Thai universities to train their workforce at all levels. The third is the lack of information regarding BIM. Contractors should publish successful case studies and academics should produce more research to equip the workforce with BIM knowledge. Next is the poor government leadership that calls for the creation of a Thai national standard and mandatory BIM for public projects. Resistance to collaboration is also another barrier to the implementation of BIM. Training in collaborative practice and agreement on file formats to exchange information is necessary to deal with this barrier. Also, the workforce is resistant to practical changes. This requires mandatory training and celebration of success. In addition, the lack of leadership in the company is another barrier to the implementation of BIM. It is suggested that the head of the organisation be trained in BIM and lead the change. Lastly, reduction in productivity. CEOs must integrate BIM in each department with a specific business plan for their company to improve productivity and obtain projects by creating information-rich 3D models, promoting collaboration and seeking the constant transfer of knowledge through mentors, consultants and seminars.

This research discovers three implementation strategies. The first strategy is having good practice. Executive directors should lead the change from top to bottom with a specific plan per department to train BIM tools to the entire organisation. It is an expensive process, but it promotes collaboration and the production of information-rich 3D models, accelerating processes, reducing errors and improving contractor productivity, all to become more competitive in the industry. In 2022, this was the primary model. The second strategy is to adopt the hybrid model. In the hybrid model, an external consultant leads the BIM process and supervises the projects. Even though this helps reduce implementation errors, failure to favour a complete cultural change within the company limits the benefits gained. The last strategy is the short-term solutions for accessing BIM projects. This strategy allows an external consultant to be hired to perform any BIM-related tasks. BIM is used only to create a basic 3D model and meet customer requirements.

However, the lack of contractors' involvement lengthens the BIM learning period and project completion, resulting in contractors receiving minimum benefits with reduced productivity and unrecovered investment. This model is not advisable.

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