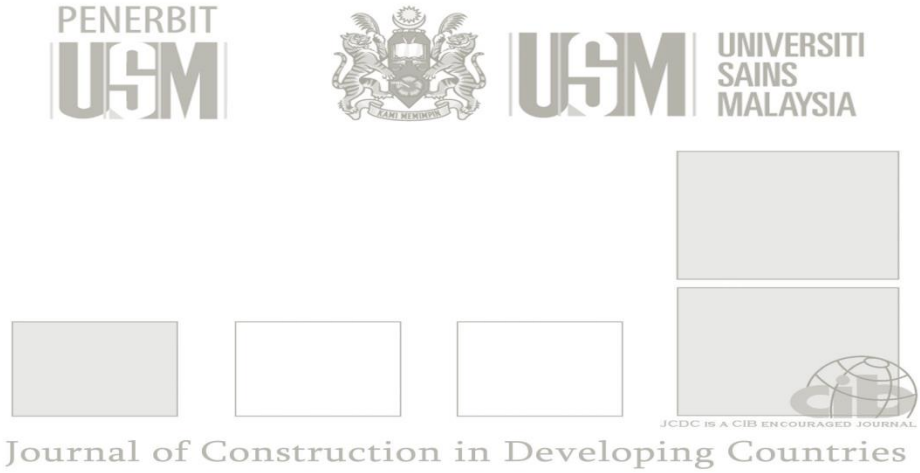

Manuscript Title	BIM Implementation Models in Thailand: Drivers, Benefits, Barriers and Lessons Learned
Authors	Francisco Sierra and Christayos Rodboonpha
Submitted Date	06-May-2022 (1st Submission)
Accepted Date	03-Sep-2022
DOI	https://doi.org/10.21315/jcdc-05-22-0091

BIM Implementation Models in Thailand: Drivers, Benefits, Barriers and Lessons Learned

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Abstract. This research is original and relevant as it provides for the first time an overview of the typical BIM implementation models in Thailand and a BIM implementation guide for contractors to avoid the repetition of current common mistakes. It also reveals that Thai private developers request the use of BIM for more than 60% of large projects. This is the main driver for contractors to use BIM. Most of them use BIM below its potential and receive limited benefits. In general, BIM is used to produce a 3D model, update technical drawings, detect clashes, quantity take-offs and create 3D visualizations. It was also found that the main barriers are the negative effect that the implementation of BIM has at the beginning on the schedule/productivity of the projects; high initial investment; lack of knowledge and information available about BIM; lack of leadership from government to promote the change; resistance to change of practice; and the long adoption period. This research makes suggestions to minimise each barrier.

Keywords: BIM; Contractors; Drivers; Benefits; Barriers; Lessons Learned

1. Introduction

In large cities, there is a growing demand for increasingly large and complex projects, and for them to be completed in increasingly shorter time frames. This, coupled with the endemic inability of the construction industry to control costs and time, has put contractors under great pressure in the last decade. Building Information Modelling (BIM) was developed with the purpose of minimising 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). In this way, the Thai BIM Association estimates cost reductions of 10-25% 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). The information available on how to implement BIM in Thailand is limited, and rarely takes into account the peculiarities of the contractors. This research aims to identify the barriers that prevent Thai

contractors from implementing BIM; establish, for the first time, the BIM implementation models followed in Thailand; and collect lessons learned from contractors and consultants already working in BIM, in order to develop a guide for its successful implementation. Additionally, this research aims to identify the current drivers, uses, and benefits that Thai contractors using BIM are experiencing. Therefore, this research is relevant, as it makes available novel and crucial information for Thai contractors to plan strategies to implement BIM, to avoid repeating common current mistakes, and to guide them to change their daily practice successfully.

Although this research is based in Thailand, the research could be applied to other countries at a similar stage of BIM pre-adoption, especially in South Asia, taking into account their local differences. The findings are expected to be of particular benefit to contractors, but since BIM is collaborative, it will also help any other stakeholders involved, especially developers, consultants, and policy makers.

2. Literature Review

This literature review identifies and extracts information from relevant research carried out on the adoption of BIM by contractors in Thailand included in the following databases for the period 2005-2022: Scopus; Google Scholar; Research Gate; Construction information service; Iconda; Emerald; DOAJ; Springer-Link; and JSTOR.

2.1. Theoretical benefits of BIM for contractors

By definition, 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 19650-1, 2018). BIM automates some operations, reduces errors, and cuts execution time. Therefore, in theory, BIM should improve the productivity of contractors who adopt it (McGraw-Hill Construction, 2009). But, the potential benefits that BIM can bring to contractors will depend on the quality and quantity of information integrated into the BIM model.

2.1.1 Theoretical benefits and drivers for contractors in Thailand

Early studies by Sukkhi (2011) and Tangparitkul (2015) concluded that the main benefit of BIM for Thai contractors is the reduction of mistakes and conflicts between drawings and the subsequent re-drawing time. The second benefit is that BIM provides accurate and up-to-date information, quickly incorporating design changes (Sukkhi, 2011; Tangparitkul, 2015). Jongjit (2017) also states that

BIM manages more efficiently the "change orders", which is a significant benefit for contractors since these changes are inevitable in most Thai construction projects (Handayani et al., 2019).

In May 2013, two of the largest contractors in Thailand, Ritta Co Ltd. and Thai Obayashi, announced to the public the results of their BIM implementation. That was the point at which contractors in Thailand awoke to BIM (Virulrak, 2016), since these announcements showed the public how BIM was able to reduce the cost of their projects. Yet, few took the step. BIM is not yet common among Thai contractors (Sukkhi, 2011). The only driver for them has been that some private developers have started to require the use of BIM on certain complex projects. These Thai developers have seen in BIM a risk management method, useful for accurate calculation of construction costs, one of the biggest risks for their business (Virulrak, 2016).

2.2 Barriers to BIM implementation

The study by Jongjit (2017) found that the three main barriers for Thai contractors were the high economic investment needed, unclear leadership, and the lack of qualified personnel to work in a BIM environment. In their next study, Jongjit and Prasitsom (2018) reordered and expanded the list, starting with the lack of knowledge, difficulties in breaking with traditional organizational practices, the high investment needed, and the attitude of the staff against change. Finally, Pimanmas (2019) concluded that the costly annual fees to use BIM software are the highest 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. These studies allow us to outline six main theoretical barriers, which are discussed below.

2.2.1 The initial high cost of adoption

The literature shows how the adoption of BIM requires a large investment in hardware, software licenses, training of the existing workforce, and hiring of specialists. This barrier is greater in Thailand due to software prices, a real problem for SM contractors (Pimanmas, 2019). 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 should save time and money a few years later (Kiviniemi, 2010). However, SM contractors have minimal budgets and a mind-set of investing money only on quick-return investments (Hamada et al., 2016). Therefore, they prefer to continue using traditional systems instead of BIM, as this investment is difficult to assume (Hamada et al., 2016; Bataw et al., 2016; Criminale and Langar, 2017; NIBT, 2018).

2.2.2 The Thai construction industry does not fully understand BIM (Ngowtanasawan, 2016)

In countries that are in the early stages of BIM implementation, there is generally a lack of knowledge surrounding the steps to take for full implementation of BIM in the daily practice of an organization. Being "BIM-ready" is not about buying a simple piece of software, training your staff, and then flipping the switch (McPartland, 2016); it is also more than just a switch from 2D to 3D and clash detection. This lack of understanding of what BIM is, and the steps to unleash its full potential, leads to sub-optimization, limited implementation and use of BIM, frustration at not receiving the promised benefits (Kiviniemi, 2010; Hamada et al., 2016; Bataw et al., 2016). CICRG (2011) provides examples where, due to poor planning and unfamiliarity with BIM, it added little or no value to the project, and increased the cost of paying for external modelling services. Only if BIM is used correctly will it provide the expected benefits for the project and the company. As Kirkham (2015) stated, "In essence, it is only as good as the people using it".

We can observe a similar situation in Thailand. The early studies by Sukkhi (2011), and Panuwatwanich and Peansupap (2013) concluded that the Thai construction industry has many misconceptions about BIM and the real benefits it brings. Most Thai organizations simply send their staff to learn REVIT, and upon their return, corporations think they have entered the BIM era (Virulrak, 2016). In addition, contractors always have a limited time to finish projects, and they receive penalties if there is a delay. At first, implementing BIM requires time, due to the learning curve. This additional time affects the project timeline. Therefore, after a few months, some contractors go back to the traditional 2-D methods in order to comply with the deadlines of the project (Ruthankoon, 2015). Finally, there are two key areas that are part of this barrier that are barely covered in the Thai literature, and are covered below, using literature of countries in a similar situation.

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

- Each activity in a construction project has its own computer application. A common misconception is that BIM can import and export data to and

from all those applications in a fluid way. Most of the current software packages were developed to function as standalone applications, and they are not ready to exchange data with other applications. Bataw et al. (2016) identified the lack of interoperability between different pieces of software as one of the major problems for the efficient exchange of information during design and construction. Therefore, it is essential to establish at the beginning of the project a standard information exchange format for all partners and activities, to avoid duplication of tasks (Bataw et al., 2016; Criminale and Langar, 2017; NIBT, 2018).

2.2.3 There is a lack of qualified professionals to work in a BIM environment

This problem affects all levels of the organization. Tangparitkul (2015) revealed that many professionals, especially engineers, have never used BIM and have a very limited understanding of it. This is worrying for a country like Thailand, where the majority of contractors are civil engineers (Virulrak, 2016).

2.2.4 Resistance to change of practices at different levels

At industry level, it is difficult to change the traditional practices (Jongjit and Prasitsom, 2018). The Thai construction industry is reluctant to collaborate. It follows a fragmented practice, where duplication of tasks is a constant. There is a lack of trust between designers and contractors; they work in isolation and aim towards different goals due to Thai design-bid-build practice. Traditionally in Thailand, when a contractor wins a bid, they re-do all of the drawings and documentation from scratch, due to a lack of trust in the designers (Virulrak, 2016), insufficient consideration during the design stage of constructability, and of the specific conditions of the site (Son et al., 2015). Sukkhi (2011) confirmed that, in Thailand, the design drawings that contractors receive are not easy to build and rarely match the as-built drawings. Contractors are forced to constantly review, redesign, and rework those documents (Sukjaroen, 2016). The traditional practice is slow to illustrate any alteration, generating inaccuracies and differences in drawings and documentation. The same happens when contractors calculate the impact of these changes on the cost and schedule (Handayani et al., 2019). This ends in misunderstandings between parties that will eventually lead to errors during construction. Construction managers and field workers in Thailand spend a significant amount of time on non-value-adding activities, such as duplicating drawings, transcribing records, and 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, which leads to errors, and increases construction time and cost exponentially. BIM could be a solution for these endemic problems. However, instead of changing practice, Thai contractors assume that these problems will

occur, and so accept the cost of adding additional labour to detect clashes and re-draw details manually (Sukjaroen, 2016; Handayani et al., 2019).

At project level, the Thai industry works following a 2D compliance system (Pimanmas, 2019). The documents to be submitted to receive building permission are still based on conventional 2D drawings (Hamada et al., 2016). Therefore, contractors feel that they can continue to work in the traditional way (Hatmoko et al., 2019).

Employees resist change (Jongjit and Prasitsom, 2018). "Old habits die hard" (NIBT, 2018). The process of learning a new technology and becoming comfortable takes time and always involves resistance from those who have to change habits. Therefore, a lack of enthusiasm is common when adopting new methods.

2.2.5 Insufficient CEO leadership and BIM integration at organizational level

The implementation of BIM is a business decision that should be led by the head of the organization, using a well-documented strategy. However, it is very rare to find contractors in Thailand implementing BIM at the corporate level; most organizations see BIM as an external activity to commission to an external BIM modeller (Virulrak, 2016).

2.2.6 Insufficient government leadership and lack of national standard (Udomdech et al., 2021)

In Thailand, the Government has not implemented BIM policies, standards, or incentives. It has been proven that, in countries where BIM is mandatory for public projects, the adoption of BIM has been accelerated (Smith, 2014; Zhou et al., 2019). Since the Hong Kong government established these incentives, BIM implementation has flourished (Chan, 2014,). In contrast, Sawhney (2015) points out that one of the key reasons for the low level of adoption of BIM in India is that the government does not mandate its use for public projects.

In addition, Chan (2014) explains how the lack of local standards in Hong Kong to guide the implementation of BIM also delayed the adoption of the new technology. In countries where the government does not set standards, clients tend to set their own standards, to not set them on time, or even not set BIM standards at all. This bad practice creates constant misunderstandings and

problems during the construction stage (Zejnilović, 2017; NIBT, 2018). In the last three years, in Thailand there have been some initiatives to fill this deficit. In 2019, the BIM Institute of Thailand was created by The Engineering Institute of Thailand, to promote the implementation of BIM in Thailand. They have published highly valuable documents to reduce this lack of Thai standards. such as the "Building Information Modeling Guide" (EIT, 2019a); "BIM Adoption Guide" (EIT, 2019b); or the "BIM Standard" (EIT, 2020). In the same way, in 2021 the Thai Building Information Modeling Association (TBIM), published the "Thailand BIM Object Standard Guideline" (TBIM, 2021).

3. Methodology

The literature review reveals that further research is needed to clarify the actual current drivers, use, benefits, and implementation methods that Thai contractors follow, as well as the barriers that prevent them from implementing BIM. It also reveals the need of information about BIM in Thailand in general (Udomdech et al., 2021) and the steps to follow for a smooth and fruitful implementation for contractors in Thailand in particular. For this purpose, a qualitative study was undertaken in two stages. Qualitative research is valuable for this study, as it provides rich descriptions of complex phenomena and the lessons learned from experts in the implementation of BIM in Thailand, which allows us to refine and expand the knowledge currently existing in the literature and develop a BIM implementation guide for Thai contractors.

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

In the second stage, structured interviews were conducted in order to refine and expand the theoretical background created in the literature review. This method provides not only answers, but also the reasons for those 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: (i) Current drivers and benefits; (ii) barriers (internal and external); (iii) implementation models; and (iv) good practice and lessons learned to minimise these barriers.

Nine interviews were conducted face-to-face by the author between June 2019 and January 2020. In July 2022, the nine interviewees were contacted again to provide an update on their answers, to add any significant changes that occurred in the last 3 years. A large Thai contractor (10) was added to the sample. The updates have been included in the analysis and conclusions. All of the interviews were recorded in digital audio and transcribed verbatim and anonymised by the researcher.

Potential participants were selected using a purposive sampling method to generate a robust set of expert opinions from which good practice could be stablished. Participants were selected based on their experience in the BIM implementation process in Thailand, as well as their ability to generate rich, reliable, and generalizable information. The participants have more than five years of experience on the subject and cover three slightly different points of view on the same problem. The sample included executive directors of four Thai contractor companies, referenced as (1, 2, 3, 10). 1,2 and 10 are large contractors and 3 is a medium-sized contractor, and all use BIM in their daily practice. (4, 5, 6) are professors and associate professors with a record of publications on BIM in Thailand. Finally, (7, 8, 9) are three BIM consultants who provide their BIM services to contractors. There is a limited number of experts with the required extensive practical knowledge of BIM implementation by contractors in Thailand. However, the sample size was proved appropriate since saturation of themes was achieved.

A thematic analysis was used to organise and analyse in detail the data collected in the interviews. The results of the interviews were analysed, comparing experiences, establishing and explaining the patterns and associations found. The results were also subjected to a validation / comparison process with the findings in the literature.

4. Results and Analysis

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

4.1 Implementation rates and drivers

While the literature shows a low BIM implementation rate, the interviews reveal a recent increase in this rate. In 2019, large contractors who work daily on large private projects declared that they use BIM in 30% of these projects (1, 2). This percentage was also supported by the academics (7,8,9). The three BIM consultants gave percentages around 50% (4,5,6). However, they always work on BIM projects because their business is BIM consultancy, so their data can probably be considered somewhat optimistic. Finally, the mid-size contractor uses BIM in less than 20% of the projects (3). In the 2022 update, it was found that the process of adopting BIM in Thailand by contractors has accelerated considerably in the last two years. Today, the Thai market is completely familiar with BIM (1,2). 80% of large contractors have the ability to use BIM in Thailand, sometimes with limited understanding, but they have the ability (10). The three large contractors (1,2,10) agreed that today about 60% of large private

projects in Thailand use BIM. Finally, the medium-sized contractor still uses BIM in less than 30% of the projects, but is very interested in accelerating the incorporation of BIM into its daily routine, because "If you're not using BIM, you're already outdated or dead" (3).

Private developers are clearly the responsible for Thai contractors starting to use BIM in projects (1, 3, 4, 5, 6, 7, 8, 9, 10), as they require BIM to bid on large projects. Interviewee number seven clearly 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" (7). In principle, it could be thought that the benefits that BIM provides should be the driver to implement it. However, the results show that Thai contractors implement BIM only because they need to do so to stay in the market. Only contractor (2) claims that BIM was implemented to improve the "efficiency" of its organization.

4.2 Benefits

The experts agree with the literature, and acknowledge that Thai contractors primarily use BIM to improve the re-development and updating of technical drawings. Thai contractors need to rework all the construction details they receive from designers, because of buildability issues (7,10). Therefore, BIM helps to automate the updating of technical drawings, and facilitates access by the rest of the team to more precise (6) and updated information (9), avoiding errors (3). In the same area, respondents (3) and (5) also perceived an 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 is 3D visualization (1, 2, 3, 4, 6, 7, 9). At the same level, BIM is also used for faster and more accurate early detection of clashes between different elements and trades before construction, which reduces field errors and cost (1, 2, 3 4, 7, 8, 9, 10). In the 2022 update, it was found that most of the large contractors already use BIM during the tender process (1,2,4,7,10), since it improves the accuracy of quantity take-offs and subsequently the budget is 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" (10).

Thai contractors with a better understanding of BIM use it to improve the efficiency of a greater number of processes, such as structural analysis (5, 8), construction progress monitoring on site (1,6), and site analysis (2).

The contractor and other parties in the project should integrate 4D (time) and 5D (cost) data into the 3D geometric model and work in collaboration for BIM to deliver the full benefits promised in the literature. However, only the contractors who integrated BIM into the core of the organization (1, 2, 10) reported an increase in their collaboration levels. A good example is

contractor two, who developed a holistic plan and created a BIM society to promote collaboration within the organization, with debates and exchange of ideas on BIM between departments (2). This is the contractor who receives the most benefits from the investment. Unfortunately, most SM Thai contractors prefer to externalise BIM.

Based on the answers above, it is possible to see two clear strategies:

A) BIM is used to create a 3D model to meet customer requirements, and improve mainly three processes; the development of technical drawings, 3D visualization, and clash detection. This strategy leads to using BIM below its potential so that it produces minimal benefits and, consequently, leads to dissatisfaction.

B) BIM is implemented with the aim of improving the efficiency of as many processes as possible, integrating cost and time information into the geometric model, and aiming for collaboration. This strategy is good practice and gives the expected benefits. Unfortunately, it "occurs less than expected in Thailand" (6).

4.3 Barriers

The literature review produced a preliminary identification of barriers that prevent the implementation of BIM. In a second phase, experts were interviewed to validate, refine/enrich and rank the barriers identified by the literature. Each contractor will face these barriers to a greater or lesser extent, depending on their size and budget, implementation model, and their level of knowledge of BIM. The barriers are arranged in descending order of importance. At the end of the list, an extra theme was added as a result of the sum of all the other themes. This extra barrier does not appear in the literature but is of great relevance to Thai contractors.

[B1] BIM requires a large and constant investment in time, money, resources, and training.

In Thailand, the hardware, software licenses, and training entail a large initial investment (1, 3, 4, 8, 9). In addition, it is essential that organizations understand that the implementation of BIM is a non-finite process, since BIM is a very dynamic environment that requires constant updates and training (7). This barrier is not so accentuated for large contractors, who can also purchase servers in the cloud and internal servers for storage and quick access to information (1, 2). In contrast, SM contractors have difficulty in meeting these

expenses (8). An example of this is that most only have sufficient budgets to back up information on hard drives (3).

[B2] Limited knowledge about BIM at every level.

Many contractors do not understand BIM (4, 7), or have a very limited understanding about how to implement BIM to receive the full benefits (5, 6). This leads to constant misunderstandings about the actions to take during the implementation process, which generates great losses of time and money, and limited benefits (1, 3, 6). For that reason, many early adopters work in parallel in 2D-CAD in order to finish projects on time [3]. Four sub-barriers were identified in relation to this main barrier, which are barely covered in Thai literature.

B.2.1 The review shows that, in Thailand, there is minimal information available about implementation of BIM for contractors, and most is in English (1). Tutorials and forums online are in English. In this way, Udomdech et al. (2021) noted "lack of English proficiency" as the first barrier to BIM adoption by Thai designers. Since 2019, the Thailand BIM Institute by EIT, the TBIM and few universities have published documents in Thai and held workshops and seminars where they have disseminated really valuable knowledge about BIM in Thai. This has facilitated the current acceleration of BIM adoption in Thailand by contractors. However, contractors in Thailand still lack "examples of successful implementations to learn from" (7).

B.2.2 Few Thai professionals have working experience in a BIM environment (8, 9). The information is starting to become available, but the experience is what really matters (10). It is hard for contractors to find "BIM-ready" workers, with experience, even at a basic level, like BIM modellers (5, 9). But more worrying is the low level of knowledge at the decision-making level of the companies (7, 9).

B.2.3 Knowledge gap and disagreements between parties. If part of the organization or some of the stakeholders in a project do not have the necessary competence to work in BIM, it becomes very difficult to change to the new way of working (5, 6). This happens widely in Thailand, where some stakeholders, especially subcontractors and the supply chain, do not use BIM at all (6). Others do not fully understand it. For instance, some Thai developers simply ask for a 3D model to visualize the development of the project (7, 8, 10). Finally, some developers specify "Employer Information Requirements" (EIR) of maximums. This can lead to disagreements on, for example, the LOD specified by the developer. “There is no value in detailing pipes up to level 500 for clash detection, but it does take additional work for the contractor” (10). In other occasions, some responsibilities are not entirely clear. Once the clashes are

detected, deciding who is responsible for the additional work becomes a conflict as no one wants to spend more time/money (1,2,3,10). Nowadays is very rare to find projects were there are no Employer Information Requirements (EIR) (1,2,10). In those cases, problems appear when the contractor starts building, as there is no clear BIM plan. The contractor is forced to complete the project in the traditional way, using CAD, due to the high cost of construction delays (1, 2, 3, 8).

B.2.4 Interoperability issues. BIM is used to exchange information more efficiently. Therefore, it is essential to understand and agree common information exchange formats or the use of Industry Foundation Classes (IFC) to facilitate collaboration between parties. Otherwise, key information will be lost when trying to combine models, and information will have to be re-added manually (1, 2, 6). Limited knowledge led some Thai contractors to start implementing Archicad, but soon after, they were forced to switch to Revit, at additional cost, when they encountered interoperability issues when trying to exchange information, since most of the construction industry in Thailand works nowadays in an Autodesk environment (1, 9, 10).

[B3] Insufficient government leadership.

There is no national policy or Thai standard to create a clear and unique path (6, 7, 9). This creates a regulatory gap. Each organization follows different standards, from Singapore, US, UK, Japan, etc., or creates custom standards. Therefore, contractors often find that each project requires different action protocols, which is a source of misunderstandings, confusion and delays, even for well-trained contractors in BIM (1, 2). Moreover, Thailand does not require BIM for public projects. Therefore, Thai contractors know that they have access to these projects without the need to implement BIM (4, 7).

[B4] Resistance to practice change.

Some contractors, especially SMEs, see the traditional way as a "more efficient and less expensive" method to work that perfectly complies with building regulations (3).

There is a resistance to change from working in isolated bubbles (1, 2, 5, 6, 9) to collaboration. The different stakeholders are reluctant to share information, as they have different objectives and goals (3, 7, 8). Contractors who outsource BIM or add minimal information to the BIM model do not create the right environment to receive the benefits that emerge from information sharing and collaboration.

There is a resistance to change of practices at employee level. The workforce of the three contractors (1, 2, 3) was reluctant to attend any BIM

training, since they preferred to continue using CAD (4, 6). The executive team of each company had to make the training mandatory. However, after the training was completed, the staff of contractors (1) and (2) began to agree to work in the new BIM environment. In contrast, in the case of the contractor (3), where a very limited number of staff received the training, reluctance towards BIM persists. The lesson from this is that all employees should receive training on BIM.

[B5] Lack of leadership in some companies.

The CEOs of the contractor companies in Thailand tend not to get fully involved in the change of practice (3, 4, 5). The experts agree that, in these cases, the opposition of their employees to the change was greater (3) and the benefits minimal (7, 8, 9). Most of these managers have limited knowledge about BIM and often outsource it, rather than integrate it into the organization (3, 4, 9). Some senior management may also have a generational problem of low capacity/will to adopt new technologies. Others are used to looking for short-term financial gains, and they do not see that BIM must be a core skill for the business, in order to continue operating in the long term (10). However, when leaders have a clear vision and lead the change, they motivate the staff and this accelerates the change (1, 2). There are very good examples in Thailand of innovative CEO/senior management teams that have implemented BIM, such as Ritta Co Ltd. and Thai Obayashi Corporation. Therefore, a key factor for the success of BIM implementation is that the head of the organization understands, leads and supports the change.

[B6] Reduction of productivity.

"BIM delays all of our daily tasks" (3). Little is said about this in the literature, but this problem affects all contractors in Thailand and is especially costly for SM contractors. The sum of the previous barriers to a greater or lesser extent lengthens the normal BIM learning curve (2). The BIM implementation process slows down the construction of the building and adds new tasks, related to planning and the generation of models. The urgency with which a project must be completed is not compatible with simultaneously learning BIM, and contractors who do not know how to use BIM at the beginning of the project have serious problems meeting deadlines (8). If we assume that implementing BIM is mandatory to survive in the construction industry, we can say that the main barrier that Thai contractors encounter in the first projects where they use BIM, is the negative effect it has on the schedule / productivity of those projects. Traditionally the schedule of a project does not take into account, the learning curve to deal with BIM processes, especially 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" (10).

During the early stages of the implementation process, or when contractors hire an external BIM consultant to create the BIM model (3), many contractors continue to work on CAD in parallel to speed up resolution of technical problems. Once construction begins, the developer and contractor just want the building to be finished and the lack of experience on BIM makes them get into the habit of working in parallel in the traditional way. This habit lengthens the implementation period even more (3, 8) and causes more duplication of tasks, which further reduces productivity (3). For these contractors BIM reduces their productivity, without receiving any benefit, only complaints from staff and customers. "Our company still does not see any of the benefits attributed to BIM" (3).

4.4 BIM implementation models and lessons learned to minimise the barriers

The collected responses show that each Thai contractor tends to customize its implementation strategy to align it with the culture of the organization, as well as its needs and budget. Generally speaking, there are three completely different approaches in Thailand. Large contractors (1, 2, 10) integrate BIM within the organization. The second type of contractor chooses to hire an external BIM consultant (4) to lead the implementation of BIM in the organization. Finally, most SM organizations (3), due to their size, resources and budget, hire external consultants that produce the BIM model and complete the tasks required by the client (5, 6). The 2022 update revealed that Thai contractors are more often developing internal BIM teams. Outsourcing BIM is not used as much anymore (1,2,3,10).

[M1] First model

In the first model, the senior management creates a vision and leads the change from top to bottom (1, 2,10), through an internal team that prepares, supports, and supervises the implementation of BIM. This team is responsible for studying the available standards, guides, and case studies, in order to understand how to work in a BIM environment, how to integrate it into the workflow of the organization, and to identify specific uses of BIM that can benefit their organizations. Then, they plan the implementation milestones and the required workforce resources and training (1, 2). Then, a trial and error strategy is followed, where progress is monitored and success is measured until BIM progressively expands within the organization (1, 2, 7).

This first model has variants. Contractor (1) studied BIM independently, and established a central BIM implementation department that set global goals and managed the integration across the organization. Therefore, this

contractor only trained a few draftsmen and engineers to cover the global goals. On the other hand, contractor (2) sought foreign mentors, contacting two similar companies with experience in BIM adaptation; one was in Japan, the other in Australia. As a result, contractor (2) learned from the lessons previously identified by their mentors. This is why they worked at department level, with a BIM leader within each department, responsible for determining the uses of BIM in the department and inspiring their staff to learn BIM. Once the uses of BIM for each department were 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, scheduling, etc. 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, where staff could discuss and exchange ideas about BIM.

Consequently, contractor (1) revealed in the interview that "the organization 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, etc..". On the other hand, contractor (2) confirms that they feel very confident in the BIM environment, and that "collaboration between departments has increased and more information is being shared".

It is possible to learn to model in 3D quickly, but it takes much longer to build collaborative habits and use BIM to its full potential (8). Each contractor ends up creating a 3D model, but each one of them adds to it more or less dimensions of information, depending on the strategy they have used. Contractor (2) is one who adds more dimensions of information, ending with 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 who followed the first model (1 and, especially, 2) improved their productivity, and in the long term, they reduced costs in both money and time. Therefore, model one is good practice, and the investment becomes worthwhile.

[M2] Second model

It consists of hiring an external BIM consultant (4), as an expert to speed up the implementation process. The consultant studies the company and establishes basic implementation goals, identifying what BIM will be used for in the organization. The consultant also provides training to a small, selected part of the organization (primarily the draftsmen), creates the BIM Execution Plans (BEP), and assists the contractor with their expertise to build the BIM model. It is an intermediate implementation model, allowing 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 during projects,

but does not favour a spirit of cultural change within the company, since it is not led by the executives. In addition, it is hard to find external consultants in Thailand with solid experience in BIM (8), and another company may hire your external consultant, thus leading to the loss of a good team that already understands your internal culture (8). Finally, there is less integration of BIM into the core of the organization; the implementation process takes longer, and the contractor receives less benefits from using BIM than using the first strategy. Therefore, model two is not the best possible practice.

[M3] Third model

Finally, there are organizations that fully externalise BIM (3). They hire external consultants to produce the BIM model and any BIM task required by the client (5, 6, 7). This type of contractor does not implement BIM in the organization; they simply hire an outside party which provides basic REVIT training to a very limited number of senior engineers or draftsmen (3,6), without following any long-term strategic plan. The external consultant performs most of the 3D modelling for the contractor, following the specific requirements of the client. They add hardly any information, and so do not really exploit the benefits that this model could provide them. Contractors following this strategy do not feel "safe in the BIM environment, at all" (3) and, consequently, they continue in parallel, "executing the construction process in the traditional way, because it is more efficient and less expensive" (3). This is a short-term solution to continue in the market that does not integrate BIM in the company. The investment is not recovered, the tasks are duplicated instead of being reduced, and none of the expected benefits of BIM are received. This is not an advisable practice.

5. 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 chapter aims to provide a set of recommendations for Thai contractors on how to implement BIM. These recommendations are based on the steps suggested by key authors on how to lead changes at the organizational level, the contextualization of successful actions carried out in other countries, found in publications, and what the Thai experts interviewed advised.

BIM implementation should be a top-down process [B1,B4,B5,B6]

Top management is responsible for the culture of the organization and therefore must lead any change in practice; without their leadership, success is likely to be elusive (McPartland, 2016; Pimanmas, 2019). The process should

start with the education of the senior management about BIM, so that they can establish the correct vision (Qadeer, 2016) and not waste dedicated resources.

Each contractor should have a personalized plan based on needs and resources [B1,B5,B6]

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

Plan to update hardware, software and staff training [B1,B2,B4,B5,B6]

First, decide which BIM tools and data storage are required to support your BIM practice (Qadeer, 2016). Then, investigate which BIM tools your potential business partners use to facilitate interoperability and information exchange. Next, a group of motivated champions should be selected to be trained and start testing the implementation (McPartland, 2016). It is also crucial to understand that BIM implementation is a never-ending process. BIM is constantly growing and evolving. Therefore, it is necessary to engage with BIM networks and attend conventions and seminars to stay on track.

Implement an integral cultural change in the company [B2,B4,B5,B6]

All employees should receive training on BIM, and how to think and perform tasks in a collaborative BIM environment. Contractors should follow the first implantation model, integrating BIM in every department and not outsourcing it.

- This is not simply a change from 2D to 3D. A BIM model only generates benefits if as many information dimensions as possible are added: 3D, 4D, 5D, 6D and 7D. The more information that is included, the more BIM will be able to automate and improve processes that the contractor has to carry out, especially to control time, costs and errors.
- Leaders must inculcate in their teams the value of collaboration as a transformative resource. Collaboration facilitates access to accurate information to make better decisions and reduces duplications.

Test BIM in a small pilot project and then expand it to its full potential [B1,B6]

Regular performance reviews should be established to monitor that traditional processes have been properly adapted to the BIM methodology (Kotter, 1996). These reviews also help determine what is working and what is not, to refine the process and continue to embrace collaboration (McPartland, 2016). A two-way channel should also be established to communicate the vision and receive feedback (Raza, 2019). Identify lessons learned and acknowledge quick wins, to infuse energy into the transformation process (Kotter, 1996). Once BIM has been positively tested, follow a progression plan to consolidate old tasks and steadily introduce new tasks to achieve full BIM collaboration (Raza, 2019; Kotter, 1996). BIM implementation is an iterative process that takes several years.

Seek for knowledge transfer [B1,B2,B9]

The contractor 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 a 'First Time Right' process (Kiviniemi, 2010), reducing errors, time and cost. Then share the lessons learned during your BIM implementation.

Government and universities [B1,B2,B3,B9]

Government mandate has been shown to be the most effective way to introduce BIM (Smith, 2014). The government should create a national standard, a BIM Protocol to avoid legal issues, establish a BIM fund to subsidize BIM implementation, and create a BIM-hub to deliver seminars and disseminate successful case studies (Smith, 2014; Zhou et al., 2019).

- The Thai government should lead this change of practice, due to the economic and social benefits that it would 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 the economic barrier, and the establishment of a Thai BIM standard. The government could also subsidize CPD courses in universities to reduce the BIM knowledge gap. These policies will motivate / force more stakeholders to adapt BIM. The literature provides good examples where these actions successfully promoted the use of BIM in other countries.
- A common hub should be created, including as many experts from academia, professional bodies, and industry members as possible to lead the change in a holistic way, and develop a Thai BIM standard aligned

with BS EN ISO 19650, to create a unique and clear path to work in BIM. Since 2019, this has started to happen.

- Universities have to become the biggest motivators for change and generate 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, translate key documents to overcome the language barrier, and publish more articles and case studies to increase the information available.

6. Conclusion

Thai private developers request the use of BIM for more than 60% of large projects, but BIM will become mainstream only if the Thai government makes BIM mandatory for public projects, as has happened in most countries. Most contractors use BIM below its potential and receive limited benefits. In general, BIM is used to produce a 3D model, update technical drawings, detect clashes, quantity take-offs and create 3D visualizations.

The following barriers and possible solutions (*in italics*) were stablished:

(i) High investment in money and time. *Better planning and Incentives from the government, especially for SMEs.*

(ii) Lack of understanding about BIM. *Thai Universities to train workforce at every level.*

(iii) Lack of information about BIM. *Contractors should publish successful case studies, and academics produce more research*

(iv) Insufficient government leadership. *Creation of a Thai national standard and mandatory BIM for public projects.*

(v) Resistance to collaboration. *Training in collaborative practice and agreement on file formats to exchange information.*

(vi) Workforce resistance to practice change. *Mandatory training and celebration of success.*

(vii) Lack of leadership in the company. *The head of the organization has to be trained in BIM and lead the change.*

(viii) Reduction on productivity. *CEOs must integrate BIM in each department with a specific business plan for their company, with the aim of improving productivity, not just to get projects. Aim to create information-rich 3D models and promote collaboration. Seek constant transfer of knowledge through*

mentors, consultants and seminars.

This research found three implementation strategies:

(i) Good practice. The executive director leads the change from top to bottom with a specific plan per department to train the entire organization on BIM tools and collaboration. It is an expensive process, but it promotes collaboration and the production of information-rich 3D models, which accelerates processes, reduces errors and improves contractor productivity, becoming more competitive. In 2022, this is becoming the main model.

(ii) Hybrid model. An external consultant leads the process and supervises the projects, reducing implementation errors, but without favouring a complete cultural change within the company, so it provides limited benefits.

(iii) Short-term solution to access BIM projects. An external consultant is hired to perform any BIM-related task; the contractor hardly gets involved in the process. BIM is only used to create a basic 3D model and meet customer requirements. This lengthens the BIM learning period and project completion. The contractor receives minimum benefits, with a reduction in its productivity and the investment is not recovered. This is not an advisable practice.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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