Engineering Journal issn: 0125-8281

Article

A Case Study of BIM Application in a Public Construction Project Management Unit in Vietnam: Lessons Learned and Organizational Changes

Quoc Viet Dao[1,2,a] **and The-Quan Nguyen**[2,b,*]

1 Specialized Construction Investment Project Management Board of Ministry of Construction, Hanoi, Vietnam
2 National University of Civil Engineering, Hanoi, Vietnam
E-mail: [a]viet1010@gmail.com, [b,*]quannt@nuce.edu.vn (Corresponding author)

Abstract. Public construction projects in Vietnam are managed by project management units (PMUs). A PMU should consist of the board of directors, a project office, functional and project executive departments. Functional departments are in charge of investor's responsibilities, while project executive departments are in charge of project execution. This paper discusses the practice of BIM adoption in a case study of a PMU (SPMB) in a public project. Lessons learned include the fact that, while BIM could provide certain benefits to the project, it also extended the project's duration and increased project costs. The SPMB, previously departmentalized by project phases, has changed its organizational structure by establishing a task group made up of professionals from various project executive departments, leading directly by the SPMB leaders, to address BIM issues, though only some basic uses of BIM have been applied. The functions of the project executive departments have also been adjusted due to the application of a new procurement form and the emergence of new processes, and the requirements for a new type of capability (BIM). Subsequently, other elements of the organizational design have been changed accordingly. The lessons learned contribute to the current understanding that PMUs need substantially organizational restructuring for BIM implementation effectively and efficiently while also well-prepared for negative impacts.

Keywords: organizational design, public construction projects, BIM, project management unit (PMU), organizational change.

ENGINEERING JOURNAL Volume 25 Issue 7
Received 10 June 2021
Accepted 8 July 2021
Published 31 July 2021
Online at https://engj.org/
DOI:10.4186/ej.2021.25.7.177

This article is based on the presentation at The Construction Digitalization for Sustainable Development (CDSD 2020) International Conference in Hanoi, Vietnam, 24th-25th November 2020.

DOI:10.4186/ej.2021.25.7.177

1. Introduction

In order to facilitate the implementation of the Law on Construction 2014 (Law Code No. 50/2014/QH13), the Vietnamese Government issued Decree No. 59/2015/CP-ND on 18/6/2015. Three new models for public project management units (PMUs, or project management boards – PMBs) for managing construction investment projects (the popular term for "construction projects" in Vietnam) have been introduced and put into practice as a result of these laws and regulations. The new models for construction projects include specialized PMUs (also named field-based PMUs), regional PMUs (also termed area-based PMUs), and one-project PMUs [1, 2]. In the new regulations, the PMUs can play as the owners, owners' representatives (with less autonomy than the owners), or project management consultants in construction projects using public investment capital (or state capital), especially state-budget capital. They can also bid as consultants to manage other projects, including projects in other sectors. Since there was another model for PMU existed, with lots of units established before the Law on Construction 2014, the transformation from the old model to the new models has been promulgated with selected laws and regulations, not only the Law on Construction 2014, Decree No. 59/2015/CP-ND, but also the Prime Minister's Decision No. 134/QD-TTg dated 26/01/2015, Circular 16/2016/TT-BXD dated 18/6/2015 and Decision No. 953/QD-BXD of the Minister of Construction dated 14/8/2015. The new regulations aim to develop new PMUs which are more professional under the form of specialized and regional PMUs while promoting the application of modern technologies such as Building Information Modelling (BIM), Virtual Design and Construction (VDC) [3-5]. Circular 16/2016/TT-BXD dated 30/6/2016 also provides detailed guidelines for the forms, organizational structures and operation of the new models of PMUs. According to the Circular, a specialized or regional PMU must be composed of the board of directors, the project office, the functional departments and the project executive departments. Functional departments are responsible for the investor's responsibilities, while the project executive departments are the specialized unit implementing the project to run for each project as a whole or individual project phases [3].

Building Information Modeling (BIM) has been applied in the global construction industry to improve productivity and efficiency of construction projects for a while [6]. In Vietnam, BIM has recently been officially introduced to the construction industry, especially to the public sector, with a BIM Roadmap developed to promote BIM in Vietnam [7]. The Prime Minister issued Decision No. 2500/QD-TTg dated 22/12/2016 on the application of BIM in construction activities and management and operation of construction buildings and infrastructure in Vietnam. The goal of the application of BIM is to save at least 30% of the aggregate conversion cost from relevant entities implementing BIM, to enhance transparency and convenience in management and quality control of construction activities and the operation and management of construction works [8]. To put the BIM roadmap into action, the Minister of Construction issued Decision No. 362/QD-BXD dated 02/4/2018 on the announcement of 20 pilot projects/works applying BIM in different stages from design to construction and operations of construction works funded by various sources of capital [9]. This list then was extended with 12 additional projects (under Decision No 01/QD-BXD dated 03/01/2019 [10]). At this point, specialized and regional PMUs in Vietnam have started to apply BIM in their large projects. This paper calls into questions whether BIM application brings practical benefits to the PMUs and if these organizations need to change their organizational structures to adopt new processes and new ways of cooperation. Using the case study of the project "Headquarters of the Government and Government Offices", this article investigates the application of BIM in construction project management at the Specialized Construction Investment Project Management Unit - Ministry of Construction (SPMB, as its official abbreviation).

2. Background: PMUs in Public Construction Projects in Vietnam

In order to manage effectively the construction projects using public investment capital in general and state-budget capital in particular as required by the Law on Construction, the Vietnamese Government details the models of PMUs tailored to a specific type of projects based on size, nature, finance and some specific conditions, as follows [2]:

- Models of specialized and regional PMUs apply to construction projects using state-budget capital, specialized projects using off-state budget capital of state-run economic groups and corporations.

- One-project PMUs apply to projects using state capital of A-group projects with construction works at the Special grade; projects applying high technology as certified by the Minister of Science and Technology; projects on national defense and security that require state secrets.

- If no PMU is operating in the area, the owner can hire a PMU from another area as a project management consultant for their projects.

- The owner can use their in-house human resources to manage small-scale renovation and repair projects or projects with the participation of the community.

According to the above regulations and Circular 16/2016/TT-BXD, specialized PMUs can be established at ministries, ministerial-level agencies; provinces and state-run economic groups or corporations. Regional PMUs can be established in ministries, ministerial-level agencies; provinces, economic groups, or state corporations, especially districts where specialized PMUs have not been established. Summary of specialized and regional PMUs in State management agencies from central to local is shown in Table 1 (sources: [2, 3]).

Table 1. Form of specialized and regional PMU in State management agencies.

Models of PMUs	Ministries, ministerial-level	Provincial level	District level	In state-owned economic groups or corporations
Specialized PMUs	v	v		v
Regional PMUs	v	v	v	V

After several years since the Circular 16/2016/TT-BXD was put into effect, ministries and provinces have been restructuring the PMUs under their management to improve the effectiveness and efficiencies. Therefore, lots of new PMUs have been established by transforming or by merging existing ones. However, regarding their organizational structure, standards design must be applied according to the Circular. A PMU should consist of a number of important departments such as Director Offices, functional departments and project executive/operating units. The number of departments depends on the volume of works and functions of the PMU. Projects or investment stages can departmentalize the executive/operating units; the latter will lead to units being in charge of one or some project stages such as project preparation, site clearance, design and estimation, bidding and contract management, construction supervision, project acceptance and handover etc. [3]. The key personnel of a typical PMU include a Director, deputy Director(s), a Chief Accountant who manage the entire PMU. Each project will have a project manager who is appointed, dismissed and allocated to project operating unit by the PMU Director. The project managers shall have working license or relevant experience, as required by the current regulations [2].

3. Literature Review

3.1. Elements of Organizational Design

Newly created or restructured organizations have different functions, missions, and strategic objectives. Accordingly, each organization will choose a different organizational structure to ensure the realization of its strategic goals. In an organizational structure, its departments have interdependent relationships with specific tasks, powers and responsibilities. They are specialized and arranged at different levels and stages in order to perform activities of the organization and towards the identified goals [11]. Studies on organizational design propose six elements to form an organizational structure, including:

- *Work Specialization*: Work specialization shows the degree of dividing activities into relatively independent jobs to assign to individuals in order to increase labor productivity of the whole group [12]. Specialization creates many different jobs requiring different levels of expertise; each person can choose for themselves the jobs and positions suitable for their capabilities and interests. Specialization increases the efficiency of using the diversity of professional capacities and skills of workers; however, specialization also makes them bored easily and limits their creativity because they only perform one task again and again [11].

- *Departmentalization*: Organizational structure represents the structural form of the organization, including the overall separation into relatively independent departments that perform certain activities [11]. After making decision on who will be in charge of each job tasks, common work activities must be regrouped so that work can be completed in a coordinated and integrated manner. The way the jobs are grouped is called "departmentalization" [12]. The growing usage of customer departmentalization is one popular departmentalization trend. Because acquiring and retaining consumers is critical to business success, this strategy works successfully because it focuses monitoring and responding to changes in consumer demand [11]. Another prevalent trend is the employment of teams, particularly when work tasks have become more complicated and require a wide set of talents to complete [11]. A cross-functional team, which is a work team made of employees from multiple functional specializations, is one sort of team that more firms are utilizing [11].

- *Span of Control*: Span of control is the number of subordinate employees that a manager can efficiently and effectively manage or the number of subordinates that report directly to a specific manager [12]. Defining management is not only about determining the number of managers in an organization, but also about determining the number of management levels in that organization. The wide span of control will require few levels of management, narrow span of control leading to many levels. Factors affecting span of control include: the manager's skills, abilities and the characteristics of their job; clarity in defining duties, authorities and responsibilities; capacity of information systems [11].

- *Chain of command*: The chain of command is the line of authority connecting upper organizational levels and lower levels, which clarifies the reporting system. This helps employees with answers to questions such as "Whom do I report to?" or "Who do I go to if I have a problem?" [11] Three crucial concepts that need to be considered for the chain of command include authority, responsibility, and unity of command. Authority was a significant concept discussed by the early management writers; they viewed it as "the glue that held an organization together" [11]. The right to tell people what to do and expect them to do it that comes with being in a managerial position is referred to as authority. Managers in the chain of command had the authority to coordinate and supervise the activities of others. Lower-level managers might be transferred authority, which would grant them certain rights while simultaneously imposing certain restrictions. Responsibility should be understood as managers use their authority to assign work to their subordinates. Those subordinates then obligate to perform the duties assigned to them. The term "responsibility" refers to the obligation or expectation to perform. Employees should be held responsible for their work. Assigning job authority without establishing responsibility and accountability can lead to abuse. Similarly, no one should be held liable or accountable for work duties that he or she does not have the power to accomplish. The unity of command principle states that a person should report to only one manager. Without unity of command, conflicting demands from multiple bosses may create problems controlling difficultly on management [11].

- *Centralization and Decentralization*: The degree to which decisions are made at the highest levels of an organization is referred to as centralization. The organization is more centralized if top management make crucial choices with limited input from below. On the other hand, the more that lower-level employees provide input or make decisions, the more decentralized the organization is. Centralization-decentralization is actually not an "either-or concept". The level is always relative - that is, a typical organization is never fully centralized or decentralized [11].

- *Formalization*: Formalization refers to how organization's tasks are standardized and the extent to which employee behavior is guided by regulations, behavior rules, processes, procedures or templates. In highly formalized organizations, there are clear job descriptions, a variety of organizational rules, and well-defined procedures that cover workflows. Employees have little discretion over what, when and how tasks are being done. However, when formalization is low, workers have more autonomy in working [11].

3.2. BIM and the Application of BIM in Construction Project Management

- *BIM concept*: In the early 1970s, a new technology with the term Building Information Modeling (BIM) appeared in the construction industry, but the practical application started in the mid-2000s [6]. BIM uses three-dimensional (3D) models to generate, analyze and integrate information of the BIM-enabled projects [13]. BIM supports the exchange and sharing of building information by digitizing the information of each building element. Design consultants, as well as construction contractors, can use software such as Autodesk Revit Architectural, Revit Structure, Revit MEP to set up the BIM model of the work on the computer like the real building. This three-dimensional model is linked to the project's information database, showing all spatial and temporal relationships such as geometrical size, quantity, and materials of elements, building parts and the self-construction process of those elements and parts [14]. BIM is not just a 3D model but a process of creating and using digital models for the whole life-cycle of construction assets [15, 16]. By integrating the information from all construction activities throughout the life of a project, BIM can increase the efficiency and availability of information; the better usage of information then brings significant benefits to stakeholders involved in the life-cycle of construction projects [7].

- *BIM benefits*: Literature shows lots of benefits for the application of BIM. The most-reported practical benefits include cost estimation [17], cost reduction and control [17, 18], time savings and enhanced communication [18], productivity, clashes detection [19], efficient construction planning and management, and improvement in design and project quality [17]. Also, BIM brings in better collaboration and a good mix of product (software) and process innovation [20]. With the development of BIM uses and the integration of BIM with other modern technologies, more and more benefits with BIM can be practiced.

- *BIM maturity*: In order to measure the maturity of BIM, researchers and practitioners differentiate between BIM level 0, level 1, level 2 and level 3. Sometimes level 4 is discussed. Essentially, level 0 (low collaboration) signifies a lack of cooperation. Paper or electronic prints, or a combination of both, are used for production and distribution. BIM Level 1 (partial collaboration) focuses on the transition from CAD information to 2D and 3D, often using a Common Data Environment (CDE). Despite the presence of the CDE, the generated models are not shared among the different stakeholders. Therefore, Level 1 is often regarded as "lonely BIM". Level 2 (full collaboration) focuses on distributing information among the various project stakeholders, with the focal point is collaborative working. At this level, all team members work together to create a federated model that retains the unique characteristics of each design discipline. BIM level 3 (full integration) is not yet thoroughly developed, but its focal point is the complete collaboration between all disciplines through the use of a centralized, collaborative project model [21, 22]. Just being introduced recently, BIM level 4 discusses the concepts of improved social outcomes and wellbeing [22]. Though four levels of BIM maturity have been introduced, only BIM level 2 has been claimed to be the practically highest level of BIM maturity these years [23].

- *Applying BIM in construction project management*: similar to project management in general [24], construction project management can be considered as the application of knowledge, tools, techniques and skills to gather subjects to conduct new construction, repair, and renovation activities in the specific place to ensure the project is completed on time; within the approved budget; meeting specified technical and quality requirements; ensuring occupational safety and environmental sanitation through the functions of planning, organizing, checking and monitoring from start to finish within limited resources [25]. Objects of construction project management are construction works, including new, renovated and repaired works and are classified as civil, industrial, traffic, agriculture and rural development, technical infrastructure and other works [1].

According to previous studies, BIM application is a promising way for construction project management, throughout the building life-cycle, through optimizing construction design and construction activities, managing construction assets, and reducing excessive waste, among other things [26]. Specifically, BIM can be applied in cost estimation from early design to detailed design and construction stage [27, 28], structural design process [29], Mechanical, Electrical and Plumbing (MEP) systems design [30], design conflict detection [31], schedule management [32], quality control [33], safety risk management on construction sites [34], energy analysis [35], and facility management [36], etc. A complete list of BIM applications in all of the project life-cycle can be found in the work of Meng et al. [16]. These can be considered as basic/initial applications of BIM.

Recently, several researchers have questioned the feasibility and efficiency of using BIM in isolation. To fully realize the efficiency of BIM application, especially the potential in enhancing data management and knowledge flows across the project life-cycle, a growing body of research calls for its integration with other advanced technologies [16]. With the advantages f rich geometric and semantic information through the building life cycle, BIM has been integrated with geographic information system (GIS), a broad field that includes decision-making centered on geo-visualization and geospatial modeling [37]. BIM-GIS integration brings in applications in visualization of construction supply chain management, emergency response, urban energy assessment and management, heritage preservation, climate adaptation and ecological assessment, then is strong support for smart sustainable city, as summarised by Song et al. [37]. BIM can also be integrated with Radio Frequency Identification (RFID) for greater visibility and traceability of real-time information, then can improve resource management, logistics and supply chain management, process tracking, safety management, facility management [16], with some specific usages such as collecting real-time data for the site assembly of premanufactured components [38], or tracking workers' location for safety reason [39]. When integrating with Virtual Reality (VR) and Augmented Reality (AR), the accurate superposition and visualization processing of a large number of models and data can be improved, which can facilitate user interaction and simulation in design, the visualization and traceability functions for monitoring the construction progress and cost information in real-time, also can enhance the visibility of hidden structures and pipelines for the purpose of operation management [16]. Other reported technologies to be used with BIM include laser scanning, cloud computing, semantic web technology, and mobile BIM equipment [17], bringing in new BIM uses and 3D printing that helps promote off-site construction [40]. Since 2008, the integration of BIM and IoT has been discussed [41]. Especially given the global movement towards Industry 4.0, the Internet of Things (IoT) well complements the capabilities of BIM on many fronts, which lead to new or enhanced applications such as off-site construction, facility management, maintenance management, environmental monitoring, health and safety management, emergency response, energy efficiency, indoor localization, structural health monitoring, lean construction and reuse of construction components [42-44]. These can be considered as newly emerged, and advanced BIM uses.

3.3. Organizational Structures and Changes for the Application of BIM in Construction Project Management

Organizations are structured in accordance with their functional and mandated systems and are streamlined to maximize their competitive advantages and organizational values [45]. Many studies have explored how information technology is reshaping the construction industry [46]; therefore, a significant change in technology direction will trigger some significant changes in the organization's response to current and future markets. Some studies agree that an appropriate way to simplify an organization's response to system changes is through organizational structures [47]. In the field of project management in general and construction project management in particular, functional organizational structure models, matrixes and project responsibility are often applied [25, 48]. Considering the functions, tasks, strategies and sizes and complexity of their projects, organizations decide on their organizational structure. The following section analyzes the pros and cons of three functional organizational models, project organizational structures and matrix organizational structure.

- *Functional organization structure*

The characteristic of this organizational model is that the project is assigned to a functional part of the organization, and members are temporarily mobilized from different functional departments, taking on their part of expertise within the project management group [25]. Research [25] has shown that the advantage of the functional organizational structure is to promote the flexibility in using staff and experts in many projects for maximum and effective use of their competency and experience. In addition, the continuity of processes, administrative procedures and policies are preserved; the specialization is high, and staff have the opportunity to be highly trained. The disadvantages of this model are that functional departments tend to orient specific activities associated with their activities instead of project activities; there were no individuals who responsible for the entire project resulting in a lack of coordinated efforts; the motivation of people working on the project tends to be weaker and weaker. This type of organization does not allow for complete access to the project and does not place the client in a central location; therefore, the functional organizational structure model is difficult to apply with complex project management organizations or multiple projects simultaneously.

- *Project organization structure*

Project organization structure is the form of organization in which project management members are entirely separated from the functional departments, specializing in managing and operating projects according to their assigned duties. In the project, one person is assigned to be the Project Manager; members are assigned tasks and report directly to this person. The Project Manager has full authority and is responsible for evaluating all project team members' effectiveness and career development. One advantage of this model is that it can react quickly to market requirements since the Project Manager has full powers to make project decisions [25]. In addition, this type of organizational structure can be more effective in the long term; the project management staff will develop the management skills needed and valuable for the following projects. Finally, management information is communicated faster, with higher efficiency than the functional organizational model. One disadvantage of the model is the inefficient use of staff in managing multiple projects at the same time, since each project needs recruiting sufficient staff for the designated positions. Another disadvantage is that when a project is completed, and there is a limited chance for a next project, the project team will be disbanded; this limits the opportunities for staff for continual developments and career opportunities. Research [48] shows that this model can be applied to construction contractors, while other studies show that this model is often applied in managing large, high-value or complex projects, rapidly changing environments, and uncertain technology.

- *Matrix organizational structure*

The matrix-based organizational model is a combination of the functional organizational model and the project organizational model. Depending on the relative level of power and influence between the functional managers and the project, the matrix-based organizational model is divided into three categories [25]: weak matrix, balanced matrix or strong matrix. In the strong matrix organizational model, all project managers are assigned in the same department, called the project management office - PMO [25, 48]. The matrix-based organizational model allows departments to focus on their competencies, and project staff are recruited from departments within the organization [25]. This model solves the disadvantages of the project organizational model when the project management members are appropriately distributed and can return to work in functional departments at the end of the project. In addition, this model enables the organization to react faster and more flexibly to customer requests and market changes [25]. This model has also been found to be effective for the human resource allocation of multiple projects because it meets the cost constraints and industry requirements [49]. The model's weakness is that it prevents project implementation progress if the decentralization of decisions in project management is not transparent or overlapping. A functional department manager may have different goals, subjects, and priorities than the project manager; this leads to goal conflicts and delays in getting work done. This project management model violates the principle of centralization in management when an employee has two managers, so it is difficult to decide which task to perform in case two orders from two level managers contradict each other [25]. Research [48] suggests that investors or construction project management organizations should choose matrix organizational structure model with the role of Project Manager and project team are clearly assigned.

In order to adopt BIM to manage their projects, organizations must apply changes. However, at the conceptual level, there is still a lack of understanding about the types of changes that are needed [50]. Literature shows a limited number of changes, such as changes to the routines for project initiation and implementation with the integration of BIM activities [50], establishing a BIM team, and altering the organizational structure with BIM roles and responsibilities [51]. Other changes at the project level include the standardization of processes and procedures, better communication management, raising the responsibility of project parties to verify works rather than relying solely on automated processes to determining accuracy [52].

4. BIM Application Practice in Vietnam

As an inevitable trend, BIM is being applied more and more in the construction field to improve the productivity and efficiency of construction activities in general and construction project management in particular [6]. In the Vietnamese context, the application of BIM to manage construction projects throughout the project's life cycle has been vigorously promoted. The Prime Minister issued Decision No. 2500/QD-TTg dated 22/12/2016 on the application of BIM in construction activities, and management of construction works in Vietnam to create a legal corridor for the application of BIM. Among the 32 pilot projects/buildings to apply BIM as pilot projects, there are projects from public and private sectors [9]; among the public projects, there are projects funded by state-budget capital, the off-budget state capital even

Government loans and bonds (Fig. 1).

Figure 1 shows that most of the projects in the pilot lists are buildings (18 projects, 56.25%), then transport projects (7 projects, 21.88%). There are some projects from the industrial and agricultural, and rural development sectors. Regarding the capital sources, 21/32 of the projects (65.63%) are public projects or being managed as public projects, 11/32 of the projects (34.38%) are from the private sector (Fig. 2).

Regarding the size of the projects, except for four projects without this type of information, projects in the pilot lists have total capital budgets ranging from 165 VND billion to 10,000 VND billion (Fig. 3). Twenty projects belong to national importance or A-group (with investment capital of 800 VND billion or more), accounting for 62.5%; 9 projects belong to B-Group (from 80 to 800 VND billion), accounting for 28.13%. The figures show that among the public projects, BIM is mainly proposed to be used for construction projects of national importance and A-group projects, which are considered large and very important projects.

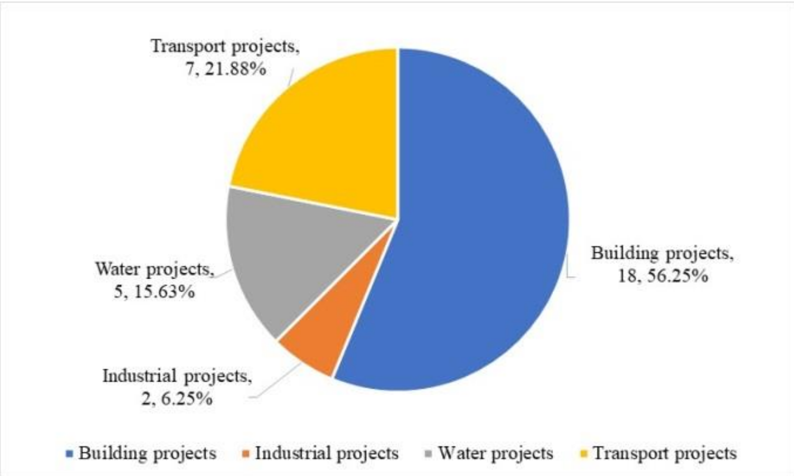

Fig. 1. BIM pilot projects by types of construction works (developed from [9]).

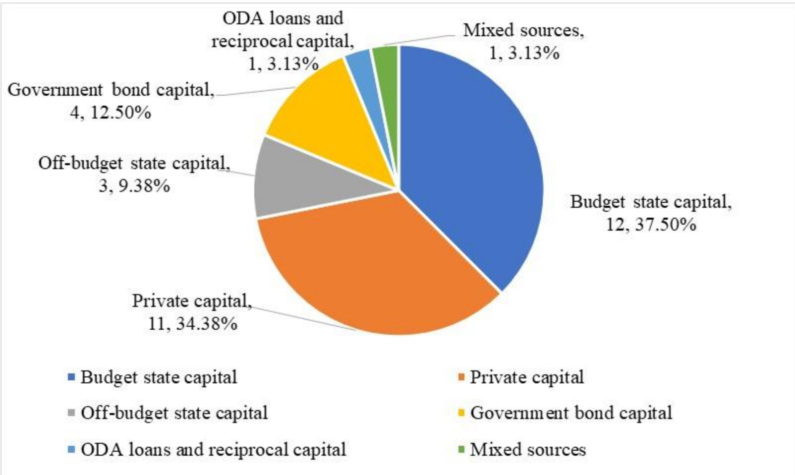

Fig. 2. BIM pilot projects by capital sources (developed from [9]).

The proposed lists of pilot projects show that the Vietnamese Government is very interested in applying BIM to improve productivity and efficiency in construction activities in general and construction projects using state capital in particular. Regarding the BIM uses, 3D models are developed to detect design conflicts, provide a visual perspective for parties or some of the project documentation services, bidding, or manipulating work volumes [7, 31]. Fig. 4 shows that BIM services are proposed to be delivered in many different project stages from surveying, project formulation (development), design, construction, completion and operation management. Among that, the stages of design, construction and completion attract more interests. This shows that Vietnam is not only interested in applying BIM in many different construction activities but with a master plan to apply BIM in a synchronous, unified process from preparation to completion of the project, bringing the building into operation and exploitation.

DOI:10.4186/ej.2021.25.7.177

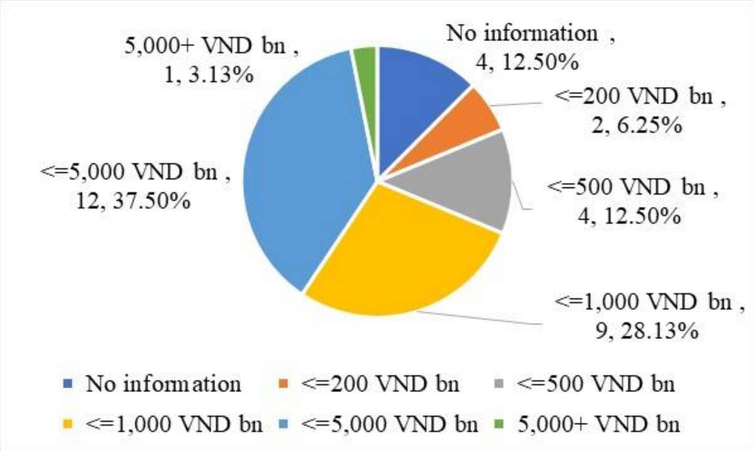

Fig. 3. BIM pilot projects by the size of investment capital (developed from [9]).
Note: 1 VND billion ~ 43,000 USD (as of 13th September 2020, at https://www.xe.com/).

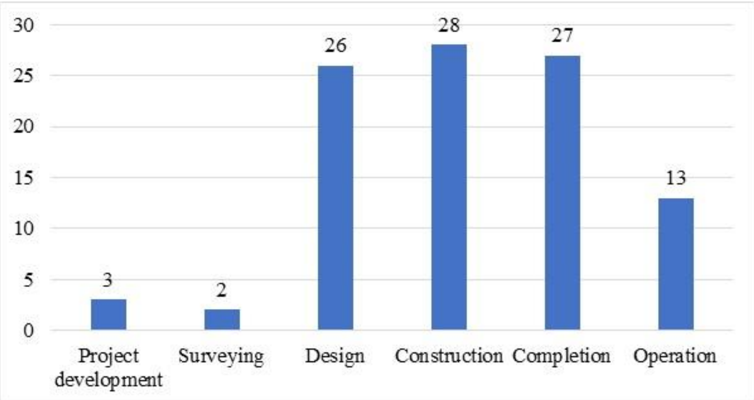

Fig. 4. BIM pilot projects by size of investment capital (developed from [9]).

Considering the BIM maturity levels, the application of BIM in Vietnam, where applicable, is at Level 1, or the level of creating "separate information sources that cover the entire range of information of assets in semi-structured electronic documents" [53, 54]. However, most of the construction industry is still at Level 0, with 2D drawings and paper documents stored on "giant" bookshelves.

5. The Case Study

At the Ministry of Construction, the first and only specialized PMU was established based on merging the Construction Investment Project Management Unit of National Assembly House and Ba Dinh Hall (new) and Investment Project Management Unit and renamed as the Specialized Construction Investment Project Management Board - Ministry of Construction (SPMB). This is a specialized PMU under the Ministry of Construction and operates as a public non-business unit. This PMU became the sole representative of the Ministry of Construction to manage its key critical national importance and A-group projects. The SPMB can play as an investor or represent the investors of construction projects using state budget capital; they can also provide project management consultancy services to the construction market.

Before the transformation and BIM adoption, the SPMB consisted of the Board of Directors, Administrative and Organizational Department, Financial and Accounting Department, Economics and Planning Department, Construction Management Department and Design Management Department (Fig. 5). It is noted that the projects are put under the Construction Management Department directly; however, other departments still involve in the project management in other stages. In 2018, the Government assigned the SPMB to perform the task of managing the construction project of Headquarters of the Government and Government Offices. This project is assigned to the Government Office as an investor with nearly 500 billion VND from the state budget capital. This is one of the projects that the Minister of Construction decided to pilot the application of BIM in construction project management with an implementation period of 8 months. It is the underground car park built on the area adjacent to Hoang Hoa Tham street, Hanoi, to exploit underground space to accommodate the real needs of about 150 car parking places serving the Government's activities and 450 motorbike parking spaces for staff. The land area is about 3,000 m2, the building includes three basements, each floor is about 3,000m^2, the total construction floor area is about 9,000m^2. The project is equipped with many complex technical systems such as power supply system, lighting system and lighting control system; air conditioning, ventilation, smoke escape system; fire prevention and fighting system; information and electronics system; parking management system; water supply and drainage systems to meet the requirements of the usage. Above the underground car park, flower gardens, trees, lawns and miniature landscapes are built to serve the resting needs of Government office employee and create a unified landscape with the general landscape of the whole area.

In order to assess the BIM adoption in this BIM pilot project, desktop research was applied. Official documents of the SPMB and also project documents, project reports are collected for analysis. As one member of the research teamwork in this SPMB, he has a chance to observe the BIM application in practice. Also, minutes of meetings and reports from the BIM consultant and the contractors are collected and reviewed to dig for relevant information. Research results have been discussed among the project team to ensure the reliability and validity.

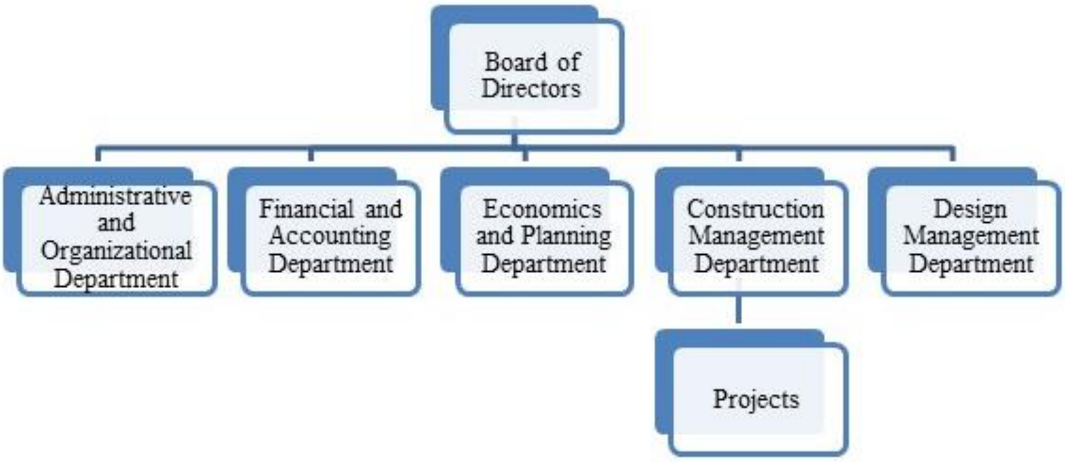

Fig. 5. The former organizational structure of the SPMB.

The project was implemented for eight months and applied BIM in the design to the handover stage. The objectives of applying BIM are [55]:

- Minimize unintended design conflicts or the mismatch between design requirements and actual construction sites; to save time and money;
- Improve the management, monitoring, implementation coordination, and exchange of project information among stakeholders from the design stage, design adjustment to the handover of the project;
- Provide complete information about installed equipment on the project, integrate the user's existing management systems;
- Simplify the handover of design and construction documents related to the project, optimize the operation and maintenance of works;
- Increase transparency and convenience in management and control of construction quality and operation activities.

BIM uses applied in the project implementation phases are summarized in Table 2. The BIM implementation involved many key stakeholders of the project, including the SPMB itself, the design consultants, the construction supervision consultants and the general contractor. Detailed BIM-related activities of each stakeholder are illustrated in Table 2. Apparently, in this case study, only some primary BIM uses have been implemented. As in the objectives, this project was expected to approach BIM level 2. However, the fundamental BIM uses application brought in some new processes for key project stakeholders to collaborate in a completely new way using the BIM model. Also, a new procurement form was adapted for selecting capable construction consultants and contractors in terms of BIM. What is more, SPMB had to seek assistance from external BIM experts to develop criteria for contractor selection and assess the outcomes from BIM-related activities.

Table 2. BIM applications in project implementation stages [55].

Implementing agencies	Project preparation phase	Project implementation phase	Project completion phase
SPMB	Set up a team in charge of BIM, participate in BIM activities; Establish rules in digitizing project documents, applicable product specifications of BIM; To contribute comments on basic design plans	Organize and coordinate design consultancy, verification consultant to approve construction drawing design; Organize and coordinate design consultant, supervision consultant and construction contractor to approve design adjustments; Organizing and coordinating supervision consultants, construction contractors to ensure construction progress and quality	Organizing and coordinating project parties to take over and complete the works; Acceptance of the project and hand over the project to the investor to operate and exploit the 3D model
Design consultants	Making basic design plans of 3D models using Revit software; Identify conflicts between disciplines	- Designing construction drawings of 3D models using Revit software; - Update adjusted design during construction of 3D models by Revit software	Acceptance of construction items, the whole works in 3D model
Construction supervision consultants		Tracking construction progress and quality on the construction site according to 3D models; Acceptance of construction works according to 3D models	Acceptance and acceptance test of work items, the whole project
Contractor General		Deploying 3D detailed construction drawings using Revit software Deploy 3D construction method drawings using Revit software	Deploying 3D finishing drawings using Revit software

6. Discussions

6.1. Advantages and Disadvantages of Applying BIM in the Case Study Project

In comparison with traditional methods applied in previous projects, the application of BIM brought in some benefits for the SPMB. The significant advantages in the conceptual design stage, belonging to the "project preparation phase" as in Vietnamese regulations, include the ease in evaluating design options and the speed in the internal design approval process. During the project implementation phase, BIM shows its effectiveness in the phased-evaluation of detailed design because of the improvement in the clarity and visualization of each equipment system, pipe system, cable tray, etc. Apparently, BIM allowed SPMB to approach the 3D model clearly and consistently. In the design coordination process, multi-disciplinary coordination showed the advantages of BIM when it was easy to make decisions and select the most reasonable solutions according to requirements. During the construction phase, BIM showed benefits in timely detection of design conflicts, capturing the functional conditions of the site before construction works started on-site, especially leading to the potential of reducing future design changes.

Applying BIM in the project also showed some shortcomings compared to benefits that BIM can bring, such as the time prolonged and cost increased for other processes and activities, new investment. For example, in the conceptual design stage, more time is needed to export a BIM model to get 2D drawings submitted to government agencies for government appraisal and approval. The design duration and the design adjustment/changes were longer than the traditional approach, not to mention the additional time spent for evaluating BIM proposal and inspecting BIM-related results. Other factors including the volume extraction or the visual arrangement of the construction site and the construction volume management have not been evaluated during application process.

Table 3. Comparison of benefits of BIM compared to traditional methods in the project.

Project phases	Comparing aspects	Advantages	Dis-advantages	Notes
Project preparation phase	Creation and evaluation of design plans	x		
	Approved design plans	x		
	Determination of major volume			Benefits not clear due to manual check still applied
Project implementation phase	Creation and evaluation of design plans	x		Intuitive; clear each system; high precision; reduce conflicts
	Design duration		x	Longer time due to coordination of subjects
	Design adjustment/changes, assessment		x	Longer time due to coordination of subjects
	Design coordination process, multi-disciplinary coordination	x		Easily make decisions and choose the right solution
	Determination of major volumes			Not fully applied due to those quantities generated not compliant with the current national construction norms
Construction phase	Promptly detect design conflicts before construction	x		
	Reduce design adjustment time	x		
	Intuitive ground layout	x		Better visualization with 3D models
	Management of quantity take-off		x	Quantities generated not compliant with the current national construction norms
Overall	Project cost increase		x	Contingency cannot cover newly emerged costs
	Project time slightly prolonged		x	Additional time for BIM authoring and a variety of BIM-related assessments

Source: [55]

Also, for BIM application in this project, an additional investment amount was added to estimating the total project investment budget to deal with new construction activities related to BIM, such as design and collaborative activities. The added value is used to cover the increase in the construction design package budget, the investment for equipment such as desktops and CDE, and time for hiring BIM experts to evaluate the BIM proposal and assess BIM results. The results of the application of BIM in the project evaluated in comparison with traditional methods are summarized in Table 3.

6.2. Lessons Learned from the Practical Application of BIM at SPMB

Since this is the first BIM-enabled project of the SPMB, it has become one of the PMU's focal projects. The managers' involvement and supports have created favorable conditions to facilitate BIM adoption and implementation of BIM-related activities. The support from the Vietnam BIM Steering Committee in delivering initial training courses and policy advice were significant. All of these have contributed to the success of BIM implementation in the project.

The application of BIM in this case study project also experienced specific difficulties. Firstly, in terms of the legal system regulating the construction industry, the guiding documents, standards, technical regulations and economic norms related to BIM have not been fully completed. BIM concepts and terminologies have not been used consistently; the goals and benefits of BIM have not been identified clearly [55]. Secondly, similar to what some studies have pointed out [56, 57], the organizational structure and culture were an obstacle to the implementation of BIM. Initially, the arrangement of personnel for BIM deployment was intricate due to lack of qualified human resources, and conflicts between the specialist tasks and the BIM tasks frequently occurred. Before BIM adoption, SPMB adopted functional organizational structure with the Administrative and Organizational, Financial and Accounting, Economics and Planning, Construction Management, and Design Management departments. The current organizational structure (after transformation as required by Circular 16/2016/TT-BXD, see Fig. 6) could facilitate better the BIM adoption.

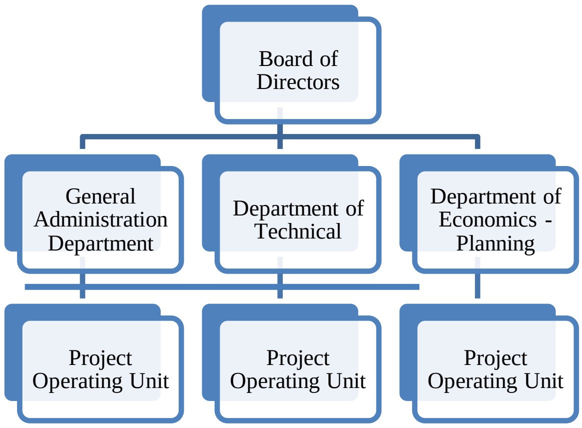

Fig. 6. The new organizational structure of the SPMB [58].

The project implementation team was formed based on mobilizing staff from all departments and led by the leaders of SPMB; the leaders of the departments still managed and supervised their employees at various projects. The coordination between the project activities and functional activities was overlapping. Besides the BIM working group had not been specific, so conflicts often occurred during the operation process. As a result, the project objectives had not been achieved as expectation, especially the factors related to customers had not been interested in. Accessing to new processes and technologies had a significant impact on the organization's performance. Staff were skeptical of the effectiveness of using BIM while the benefits of testing were not seen; therefore, BIM is considered a risky investment because its economic values were not clear, and employees were not ready to change [57]. Thirdly, lack of experience in projects applying BIM technology and lack of skilled staff were two factors that affected project effectiveness. This result had also been reflected in Vietnam and in countries with the development of BIM technology [56, 59, 60].

Fourthly, the high cost of BIM software and hardware investment and the lack of the parties' technology was seen as the biggest obstacle from BIM application in construction project management. Finally, the case study also supports the discoveries from previous studies that there were difficulties and disadvantages in sharing information among parties [56] and updating information and transferring existing data into BIM. Table 3 shows that the design development and adjustment were longer than in the traditional approach; this is different from previous studies [7, 61] that BIM helps reduce project time. This can be partly explained by learning theories when the case study was in its period of practical application. When BIM application can be more mature and widely adopted, and improved outcomes can be expected.

Several lessons for ensuring the success in BIM implementation can be concluded from the case study:

- *Clearly defined goals*: right from the beginning of the pilot implementation of the application of BIM in construction activities, SPMB leaders have identified the benefits that BIM brings to the construction industry in general and construction project management activities in particular. SPMB's goal is to master BIM to put it into operation; all staff directly involved in the management of construction projects must know and understand BIM in their activities. Therefore, SPMB has proactively adjusted its organizational structure to accommodate the changing environment outside. From the functional organizational structure with the project assigned to the Construction Management Department or Design Management Department; project management members are temporarily transferred from different functional divisions to a strong matrix organizational structure with the combination of Construction Management Department and Design Management Department into the Technical Department. In the new organizational model, Project Steering Committees are formed with members mobilized from different departments and led by the Project Manager, who comes from the Technical Department. Accordingly, a strong matrix organizational structure model has been initially seen at SPMB.

- *Influencing factors recognition and assessment*: This is a crucial aspect in applying BIM because this is the application stage, and without evaluation of the influencing factors, it is possible to lead to failure. From there, the factors that directly affect the project and the difficulties are forecasted and overcome. The problems of machines and means used in SPMB are gradually overcome. The mentality of the SPMB's staff is stable and the financial issue such as salaries and bonuses of the BIM research staff is also concerned and arranged.

- *The willingness of the stakeholders in the project*: this is the most difficult task in the process of pilot application of BIM because there are many stakeholders in the construction project during the construction process. For example, state management agencies, investor/user, project management consultant, design consultant, supervision consultant, construction contractor and others. Each subject has different roles, responsibilities, facilities, and people. Therefore, it is very difficult for all parties to be willing to participate in the testing of BIM application. If they are not gathered together, the application of BIM implementation is susceptible to phase difference and leads to unexpected results.

- *Closely coordinating in the implementation process and unified implementation*: right from the project preparation stage, SPMB has established the process, agreed with the Design Consultancy in implementing step by step, required schedule and output products for implementation. The reality of BIM implementation showed that the closely coordination between organizations and departments involved in the implementation of construction projects contributes to the initial success in applying BIM. SPMB held weekly meetings with stakeholders to share, coordinate and agree on the implementation process, required progress, and goals needing to be achieved. Even online meetings were regularly held to timely inform and ensure project progress and objectives.

6.3. Organizational Changes Applied at SPMB for BIM Adoption in the Case Study Project

As discussed above, SPMB has applied a significant change in the organization structure to transform according to the requirements of Circular 16/2016/TT-BXD and for BIM adoption. The new design of SPMB consists of the Board of Directors, General Administration Department, Department of Technical, Department of Economics - Planning and Project Operating Units (POU) [58] (Fig. 6). The Department of Economics - Planning is tasked with implementing the investor function next to the Department of Technical tasked with running projects. Operating units are established by individual projects to act on behalf of SPMB in mandating contracts with investors. The Project Operating Units are led by the Project Managers, who belong to the Department of Technical, and the project members are mobilized from different departments. One POU has been established to manage this BIM piloting project.

The key stakeholders of this project include the SPMB as the project management consultancy, the design consultancy, the general contractor and one company working as a construction supervision consultant. Among all of the stakeholders, only the SPMB did not have BIM competency at the project approval. Therefore, some initial BIM training was delivered to them, and some more new members of staff recruited. This applies some changes in their working styles as well as collaboration processes.

A BIM Task Group in SPMB was established in accordance with the size and complexity of their projects. In this project, the BIM Task group consists of three members who have qualifications in relevant disciplines. with the competency requirements of each member as follows: (a) The BIM team leader is a member of the organization and has at least five years of experience in the field, a university degree or equivalent in a construction major and have at least three years of practical experience in the management of BIM projects. (b) The BIM coordinators have at least three years of experience in the field and at least one year of practical experience in BIM projects. The team leader is the Deputy Director of SPMB. The BIM team leader will assign work to members to handle exchanging information between stakeholders, updating changes in a unified model. Since only that project implemented BIM at that time, the BIM Task Group only worked in this project, but their duties coverage will be expanded when more BIM projects are delivered.

Ever since the project preparation stage, SPMB has set BIM application goals for the project; established and standardized project documentation specifications, project codes; unified technical criteria in BIM. Significant changes have been made in the process of tendering. New criteria have been added to the bidding invitation documents to assess the BIM competencies of the bidders. In the design and construction stages, SPMB regularly urged and organized meetings for design departments to exchange, coordinate and unify in the BIM implementation. The BIM Task Group of SPMB has been working closely with the Project Stakeholders, especially the design consultancy, the general contractor and one company working as a construction supervision consultant. Their collaboration approach then was changed with the adoption of BIM. Instead of working on the 2D drawings, 3D models were developed for phased reviews, and coordination sessions were organized. SPMB also controlled and evaluated the design plan and reports to the investor to approve the investment project. During the project implementation phase, SPMB organized to coordinate among project participants to evaluate detail drawing designs and design adjustments during the construction process and report to the investor for approval. As regard to the contractor's construction activities, SPMB urged the implementation of detailed construction drawings, construction methods using 3D models and timely detecting conflicts between the design and the actual construction on site.

7. Conclusions

This article used a case study on the application of BIM in managing a construction project at the specialized PMU under the Ministry of Construction, Vietnam. The case study shows the massive potential for BIM application in construction activities in general and management of construction projects using state capital in Vietnam, though both benefits and shortcomings have been experienced.

Lessons learned include the fact that, while BIM could provide certain benefits to the project, it also lengthened the project's duration and increased project costs. The SPMB, previously departmentalized by project phases, has applied some organizational structure changes to facilitate BIM adoption and implementation. With the establishment of a task group comprised of professionals from various project executive departments, leading directly by the SPMB leaders, BIM issues have been identified and addressed. Though only some uses of BIM have been applied, it still leads to a different procurement form with new criteria for assessing the BIM capacity of construction consultants and contractors and evaluating the outcomes of BIM-related activities. The functions of the project executive departments have also been adjusted due to the application of the new procurement form and the emergence of new processes for collaboration based on the BIM models. Also, other elements of the organizational design have been changed accordingly. The lessons learned contribute to the current understanding that PMUs need substantially organizational restructuring for BIM implementation effectively and efficiently while also well-prepared for negative impacts.

This research study has some limitations. Firstly, the cost increment, the time extended, and financial benefits of BIM implementation could not be assessed due to the confidentiality of internal figures. Secondly, it did not discuss the collaboration among the project stakeholders in detail due to the lack of information collected while the project was in progress. Further research should be done broadly at specialized PMUs under other ministries, ministerial-level agencies and provinces, and at regional PMUs to obtain an overall perspective on the BIM application for these types of organizations.

Acknowledgement

The authors would like to thank Professor Dr Christopher Preece, Abu Dhabi University, UAE and the reviewers, the guest editors, for their valuable comments, which helped improve the manuscript.

References

[1] The National Assembly (Vietnam), "The Construction Law, No 50/2014/QH13 dated 18th June 2014, in 50/2014/QH13," 2014.

[2] The Government (Vietnam), "Decree 59/2015/ND-CP on construction project management, in Decree 59/2015/ND-CP," 2015.

[3] Ministry of Construction (Vietnam), "Circular 16/2016/TT-BXD guidance on application of a number of articles of the Government Decree No 59/2015/ND-CP dated June 18th, 2015 on construction project management, in Circular 16/2016/TT-BXD," 2016.

[4] The Prime Minister (Vietnam), "Decision No. 134/QD-TTg dated 26th January 2015 on the approval of the project on restructuring of construction sector in association with conversion of growth model toward enhancement of quality, efficiency and competitveness in 2014-2020 period, in Decision No. 134/QD-TTg," 2015.

[5] The Minister of Construction (Vietnam), "Decision No. 953/QD-BXD dated 14th August 2015 on the issuance of the action plan to implement the project on restructuring of construction sector in association with conversion of growth model toward enhancement of quality, efficiency and competitveness in 2014-2020 period as in Decision 134/DQ-TTg dated 26/01/2015 of the Prime Minister, in Decision No. 953/QD-BXD," 2015.

[6] S. Azhar, M. Khalfan, and T. Maqsood, "Building information modelling (BIM): Now and beyond," *Construction Economics and Building*, vol. 12, no. 4, pp. 15-28, 2012.

[7] T.-N. Dao, P.-H. Chen, and T.-Q. Nguyen, "Critical success factors and a contractual framework for construction projects adopting building information modeling in Vietnam," *International Journal of Civil Engineering*, vol. 19, no. 1, pp. 85-102, 2021.

[8] The Prime Minister (Vietnam), "Decision No. 2500/QD-TTg dated 22nd December 2016 on the approval of the project to apply Building Information Modelling in construction activities and the operation management of construction works, in Decision No. 2500/QD-TTg," 2016.

[9] The Minister of Construction (Vietnam), "Decision No. 362/QD-BXD dated 02 April 2018 announcing the list of piloting projects to implement Building Information Modelling in construction activities and operation management of construction works, in Decision No. 362/QD-BXD," 2018.

[10] The Minister of Construction (Vietnam), "Decision No. 01/QD-BXD dated 03 January 2019 announcing the additional list of piloting projects to implement Building Information Modelling in construction activities and operation management of construction works, in Decision No. 362/QD-BXD," 2019.

[11] S. P. Robbins and M. Coulter, *Management*, 11th ed. Pearson Education Limited, 2012.

[12] S. P. Robbins and T. A. Judge, *Essentials of Organizational Behavior*. Pearson, 2018.

[13] X. Xu, L. Ma, and L. Ding, "A framework for BIM-enabled life-cycle information management of construction project," *International Journal of Advanced Robotic Systems*, vol. 11, no. 8, p. 126, 2014.

[14] M. R. Kannan and M. H. Santhi, "Constructability assessment of climbing formwork systems using

building information modeling," *Procedia Engineering*, vol. 64, pp. 1129-1138, 2013.

[15] D. K. Smith and M. Tardif, *Building Information Modeling: A Strategic Implementation Guide for Architects, Engineers, Constructors, and Real Estate Asset Managers*. John Wiley & Sons, 2009.

[16] Q. Meng, et al., "A review of integrated applications of BIM and related technologies in whole building life cycle," *Engineering, Construction and Architectural Management*, 2020.

[17] D. W. Chan, T. O. Olawumi, and A. M. Ho, "Perceived benefits of and barriers to Building Information Modelling (BIM) implementation in construction: The case of Hong Kong," *Journal of Building Engineering*, vol. 25, p. 100764, 2019.

[18] D. Bryde, M. Broquetas, and J. M. Volm, "The project benefits of building information modelling (BIM). International journal of project management," vol. 31, no. 7, pp. 971-980, 2013.

[19] Y. Y. Al-Ashmori, et al., "BIM benefits and its influence on the BIM implementation in Malaysia," *Ain Shams Engineering Journal*, vol. 11, no. 4, pp. 1013-1019, 2020.

[20] M. C. Georgiadou, "An overview of benefits and challenges of building information modelling (BIM) adoption in UK residential projects," *Construction Innovation*, 2019.

[21] NBS Enterprises Ltd. *BIM Levels Explained*. (2021). Accessed: Jan. 22, 2021. [Online]. Available: https://www.thenbs.com/knowledge/bim-levels-explained

[22] Designing Buildings Wiki. *BIM Maturity Levels*. (Jan. 13, 2021). Accessed: Jan. 22, 2021. [Online]. Available: https://www.designingbuildings.co.uk/wiki/BIM_maturity_levels

[23] NBS Enterprises Ltd., "NBS' 10th National BIM Report," 2020. [Online]. Available: https://www.thenbs.com/bim-report-2020/

[24] Project Management Institute, *A Guide to the Project Management Body of Knowledge*, 6th ed. Project Management Institute, 2017.

[25] Project Management Institute (PMI), *Project Manager Competency Development Framework*. Project Management Institute, 2017.

[26] J. Li, et al., "A project-based quantification of BIM benefits," *International Journal of Advanced Robotic Systems*, vol. 11, no. 8, p. 123, 2014.

[27] J. Choi, H. Kim, and I. Kim, "Open BIM-based quantity take-off system for schematic estimation of building frame in early design stage," *Journal of Computational Design and Engineering*, vol. 2, no. 1, pp. 16-25, 2015.

[28] A. Monteiro and J. P. Martins, "A survey on modeling guidelines for quantity takeoff-oriented BIM-based design," *Automation in Construction*, vol. 35, pp. 238-253, 2013.

[29] T. Hamidavi, S. Abrishami, and M. R. Hosseini, "Towards intelligent structural design of buildings: A BIM-based solution," *Journal of Building Engineering*, vol. 32, p. 101685. 2020.

[30] R. Parti, S. Hauer, and M. Monsberger, "Process model for BIM-based MEP design," in *IOP Conference Series: Earth and Environmental Science*, IOP Publishing, 2019.

[31] T.-Q. Nguyen, Q.-P. Luu, and V.-Y. Ngo, "Application of BIM in design conflict detection: A case study of Vietnam," *IOP Conference Series: Materials Science and Engineering*, vol. 869, p. 022038, 2020.

[32] X. Li, J. Xu, and Q. Zhang, "Research on construction schedule management based on BIM technology," *Procedia Engineering*, vol. 174, pp. 657-667, 2017.

[33] R.-R. Dong, "The application of BIM technology in building construction quality management and talent training," *EURASIA Journal of Mathematics, Science and Technology Education*, vol. 13, no. 7, pp. 4311-4317, 2017.

[34] M. A. Hossain, et al., "Design-for-safety knowledge library for BIM-integrated safety risk reviews," *Automation in Construction*, vol. 94, pp. 290-302, 2018.

[35] M. M. Singh and P. Geyer, "Information requirements for multi-level-of-development BIM using sensitivity analysis for energy performance," *Advanced Engineering Informatics*, vol. 43, p. 101026, 2020.

[36] M. R. Hosseini, et al., "Integrating BIM into facility management: Typology matrix of information handover requirements," *International Journal of Building Pathology and Adaptation*, 2018.

[37] Y. Song, et al., "Trends and opportunities of BIM-GIS integration in the architecture, engineering and construction industry: A review from a spatio-temporal statistical perspective," *ISPRS International Journal of Geo-Information*, vol. 6, no. 12, p. 397, 2017.

[38] C. Z. Li, et al., "An Internet of Things-enabled BIM platform for on-site assembly services in prefabricated construction," *Automation in Construction*, vol. 89, pp. 146-161, 2018.

[39] S. Dong, H. Li, and Q. Yin, "Building information modeling in combination with real time location systems and sensors for safety performance enhancement," *Safety Science*, vol. 102, pp. 226-237. 2018.

[40] J. Teizer, et al., "BIM for 3D printing in construction," in *Building Information Modeling*. Springer, 2018, pp. 421-446.

[41] U. Rueppel and K. M. Stuebbe, "BIM-based indoor-emergency-navigation-system for complex buildings," *Tsinghua Science and Technology*, vol. 13, no. S1, pp. 362-367, 2008.

[42] A. Ghosh, D. J. Edwards, and M. R. Hosseini, "Patterns and trends in Internet of Things (IoT) research: Future applications in the construction industry, *Engineering, Construction and Architectural Management*, 2020.

[43] S. Tang, et al., "A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends," *Automation in Construction*, vol. 101, pp. 127-139, 2019.
[44] Z. Ye, et al., "Cup-of-Water theory: A review on the interaction of BIM, IoT and blockchain during the whole building lifecycle," in *ISARC Proceedings of the International Symposium on Automation and Robotics in Construction*, IAARC Publications, 2018.
[45] D. Nadler, et al., *Competing by Design: The Power of Organizational Architecture*. Oxford University Press, 1997.
[46] S. Mihindu and Y. Arayici, "Digital construction through BIM systems will drive the re-engineering of construction business practices," in *2008 International Conference Visualisation*, London, United Kingdom, IEEE, 2008.
[47] R. L. Daft, *Organization Theory and Design*. Cengage learning, 2015.
[48] Project Management Institute (PMI), *Construction Extension to the PMBOK Guide*. Project Management Institute, 2003.
[49] T.-H. Chien, Y.-I. Lin, and K.-W. Tien, "Agent-based negotiation mechanism for multi-project human resource allocation," *Journal of Industrial and Production Engineering*, vol. 30, no. 8, pp. 518-527, 2013.
[50] H. Lindblad and S. Vass, "BIM implementation and organisational change: A case study of a large Swedish public client," *Procedia Economics and Finance*, vol. 21, pp. 178-184. 2015.
[51] S. MacLoughlin and E. Hayes, "Overcoming resistance to BIM: Aligning a change management method with a BIM implementation strategy," in *Proceedings of the 8th International Congress on Architectural Technology (ICAT 2019): Architectural Technology, Facing the Renovation and Refurbishment Challenge*, 2019, p. 103.
[52] K. B. Blay, M. M. Tuuli, and J. France-Mensah, "Managing change in BIM-Level 2 projects: Benefits, challenges, and opportunities," *Built Environment Project and Asset Management*, 2019.
[53] *Specification for Security-Minded Building Information Modelling (BIM), Digital Built Environments and Smart Asset Management*, PAS 1192-5:2005, British Standards Institution, London, 2015.
[54] B. N. Nguyen, et al., "The content of BIM short courses in Vietnam: Current approaches and recommendations," in *42nd AUBEA Conference 2018, Educating Building Professional for the Future of the Globalised World*, 2018.
[55] Vietnam BIM Task Group, "Report on the pilot projects implementing BIM in Vietnam," 2018.
[56] H. Aladag, G. Demirdögen, and Z. Isık, "Building information modeling (BIM) use in Turkish construction industry," *Procedia Engineering*, vol. 161, pp. 174-179, 2016.
[57] N. Bui, C. Merschbrock, and B. E. Munkvold, "A review of Building Information Modelling for construction in developing countries," *Procedia Engineering*, vol. 164, pp. 487-494, 2016.
[58] SPMB. *About the SPMB*. (2020). Accessed: July 16, 2020. [Online]. Available: https://spmb.vn/en/aboutus/
[59] K. Ku and M. Taiebat, "BIM experiences and expectations: The constructors' perspective," *International Journal of Construction Education and Research*, vol. 7, no. 3, pp. 175-197, 2011.
[60] S. Jones, et al., "The business value of BIM for infrastructure 2017," SmartMarket Report, 2017.

Quoc Viet Dao, photograph and biography not available at the time of publication.

The-Quan Nguyen, photograph and biography not available at the time of publication.