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Applying Bim and Related Technologies for Maintenance and Quality Management of Construction Assets in Vietnam

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Abstract: Maintenance and quality management is an important task that aims to maintain the quality and performance of a construction asset under its design and requirements, to ensure the safety and the needs of its owner(s) and user(s). However, in reality, the uniqueness and complexity of construction assets along with the diversity of stakeholders involved are significant challenges that make the maintenance has not achieved the desired effect and goals, thus affect the construction assets quality. The paper studies application of Building Information Modelling (BIM), and related technologies such as Barcode, Radio Frequency Identification (RFID), Sensor, Internet of Things (IoT), Augmented Reality (AR) in many countries around the world; accompany with investigating into the readiness of these technologies in Vietnam. The study results show that all these technologies are available on the market in Vietnam. However, the technology readiness of the maintenance unit is narrow and needs to be improved. The study findings of the benefits and challenges of advanced technology adoption and the ability to implement them in Vietnam provide reliable ascertainment for researchers and construction asset managers in promoting the application of digital technologies to improve the quality and effectiveness of maintenance and quality management of construction assets in Vietnam.

Keywords: BIM and related technologies, readiness, maintenance, construction assets, Vietnam

1. Introduction

The related studies have indicated that operating expenses of construction assets account for over 70% of their life cycle cost (Kale et al., 2016). During the operation phase of construction assets, the maintenance and quality management is one of the most critical tasks, responses of ensuring and maintaining the quality and performance of construction assets under their design and requirements, to ensure the safety and the needs of its owner(s) and user(s) (The Vietnamese Prime Minister, 2015). In reality, premature degradation (especially unsafe incidents during the operation and exploitation period) of the construction assets is mainly because of failing to perform or the poor implementation of maintenance. In Vietnam, regulations on maintenance work are enhanced in the Construction Law as well as in the system of other legal documents (decrees, decisions), or standards related to each asset type, engineering systems, components that requiring assets' owners (or the users) to maintain the assets thoroughly and correctly. However, the uniqueness and complexity of construction assets that require maintenance and quality management and the diversity of stakeholders involved in this process are the significant challenges leading to failure in achieving the desired effects and objectives, thus affecting the quality of the construction assets (R&D Constech Viet Nam joint-stock company, 2019).

Researchers around the world had investigated these challenges to determine solutions based on advanced technologies that allow shifting manual maintenance/quality management tasks to automatic ones, as well as improving the quality

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of collaboration among assets' stakeholders (Gao & Pishdad-Bozorgi, 2019). The major tasks such as: Developing maintenance plan and requirement, performing maintenance activities (regularly, irregularly, upgrade), and evaluating maintenance results or building performance, will be coordinated by relevant parties (the construction asset management unit, the maintenance contractors) with the support of Building Information Modelling (BIM) technology (Aljer et al., 2017). Major maintenance activities (1) identifying and retrieving information about asset elements to be maintained; (2) conducting maintenance and (3) relevant advanced technologies that can be integrated with BIM technology will support archiving maintenance history. The mentioned technologies are: Barcode, Radio Frequency Identification (RFID), Sensor technology (Sensor), Internet of Things (IoT) and Augmented Reality (AR) (Parlikad et al., 2017). They have been studied and adopted in Vietnam recently; however, they have not been studied and applied widely to maintenance in particular and operation in general construction assets. Besides, these technologies have been studied to be used separately, not yet integrated to leverage the resonance efficiency of technologies in the Vietnam context.

The paper investigates the application of the advanced technologies mentioned above in countries worldwide based on the results and findings of relevant articles and reports hitherto. Other research methods such as surveying and interviewing (after the survey for further investigation) will also be integrated with the document analysis method to investigate the readiness of these technologies in Vietnam. The study results show the benefits and challenges of advanced technology adoption and implementation in Vietnam. The study findings provide reliable foundation knowledge for researchers and construction asset managers in promoting the application of digital technologies to improve the quality and effectiveness of maintenance and quality management of construction assets in Vietnam.

2. Applying Building Information Modelling –BIM, and related technologies into the Maintenance and Quality Management of Construction Assets

2.1 Building Information Modelling –BIM

There are various definitions of the Building Information Model (BIM) that are widely used in the world. However, these definitions all lead to the most common understanding: BIM is the process of creating and using digital information models within designing, constructing, managing and operating construction assets (Fig 1) (The Ministry of Construction of Vietnam, 2017). The application of the BIM throughout the life cycle of the assets will allow asset information data to be produced and achieved in a digital format facilitating the exchange and cooperation between the asset management participants.

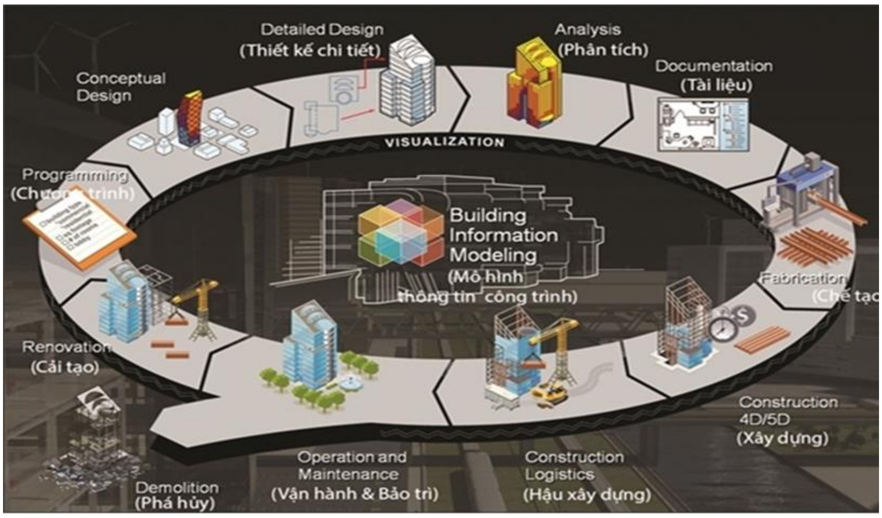


Fig. 1 - Building Information Modelling - BIM for the whole life cycle of construction assets (Arayici & Aouad, 2011)

The application of BIM technology for maintenance and quality management of construction assets has been studied and applied in many countries around the world, including developed countries such as the UK (Heaton et al., 2019), France (Alileche & Shahrour, 2018), the US (Guillen et al., 2016), China (Yin et al., 2020), Singapore (Shen et al., 2016) to developing countries like Malaysia (Ismail et al., 2020; Solla et al., 2020). BIM applies to manage, support the maintenance in particular and operation of many construction assets from buildings (Ismail et al., 2020),(Shen et al., 2016) to infrastructures (Jing, W., Hao, G., Li, C., Wei, W., & Cheng, 2019),(Yin et al., 2020). BIM adoption has significantly benefited all parties involved in this process (Arayici & Aouad, 2011). The application experience of countries around the world showed that the primary effect of BIM implementation in construction asset maintenance task is:

• (1) Providing a standard digital environment for storing and accessing quickly, thoroughly and accurately all the maintenance-related data for the whole asset life cycle;
• (2) Optimise time and cost to assign and perform maintenance tasks from predictive maintenance (regular maintenance) to emergency maintenance (repair maintenance) and upgrade or renovation if any;
• (3) Enhancing the collaborative working environment; increasing the interoperability and effective collaboration of stakeholders, increasing the maintenance process's labour productivity and efficiency.

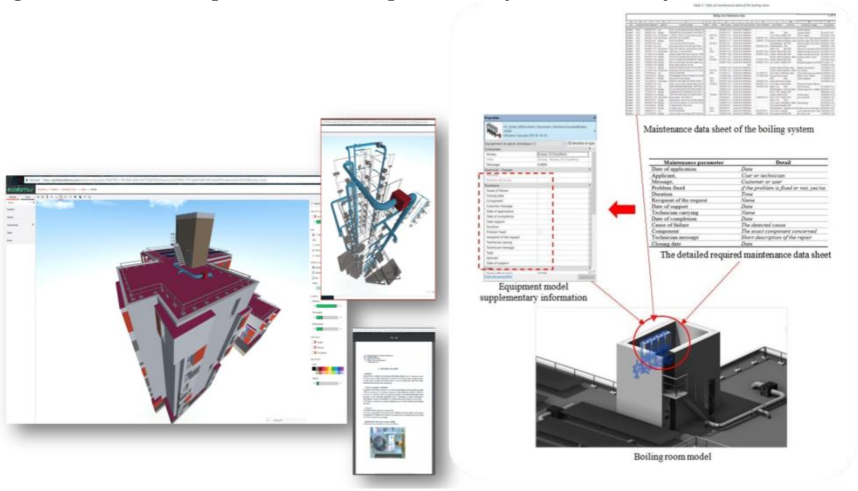


Fig. 2 - An example of the BIM 7D model (Alileche & Shahrour, 2018)

However, dissimilar to the BIM models used in the design and construction phase, the 7D BIM model used for Facility management - which maintenance is a core and significant task- requires more specific information and data that regarding characteristics, technical requirements, and maintenance history of construction asset components to develop asset information database (Fig 2). Asset information needs to be updated to the database after each maintenance work, not only for the asset component that has been maintained but also the relevant parts. Therefore, the challenges and barriers to the BIM implementation for the maintenance and quality management of construction asset have been identified in several studies: (1) Technology point of view: the study on BIM application is incomplete, needs to have further research on many aspects such as optimising the size of asset database to reduce the "load" of the BIM model, integrating information from the exit asset management model to BIM; (2) The cost and time to develop the 7D BIM model point of view: Return of Invest (ROI) BIM has not been straightforward yet, that lead to the concern and controvert of the operation managers in applying BIM technology; (3) Employee and management framework point of view: the asset management participants have not had enough knowledge and experience on BIM implementation, conventional management framework and behaviour contradicts the activities and collaborations in the BIM environment.

2.2 Related Technologies

Besides leveraging BIM for the operation and maintenance management of construction assets, diverse advanced technologies that might be integrated with BIM also attract researchers. Their application in the BIM environment could improve the automation of operational activities. More specifically, the technologies are popular ones such as Barcode technology (Barcode), Radio frequency identification (RFID), Sensor technology (Sensor), Internet of Things (IoT), or more advanced ones like Augmented Reality technology (AR). These technologies support automatically identify assets, structures, elements, equipment that encoded in BIM (such as Barcode, RFID technologies); automatically update or aide for faster manually update real-time information about the status asset more quickly, easily and conveniently (like Sensor, IoT technologies); and visualise hidden construction assets (such as AR technology).

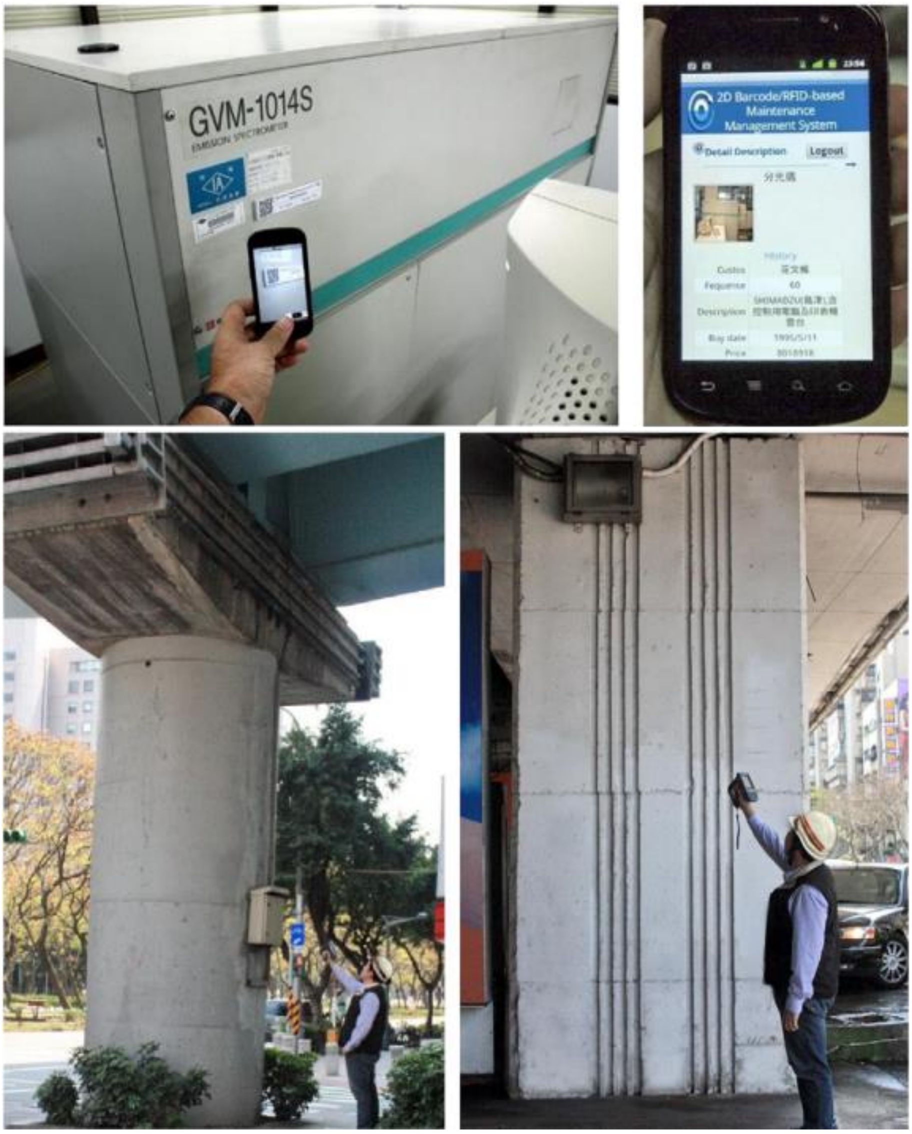
2.2.1 Applying Barcode Technology (Barcode), Radio frequency Identification (RFID) to automatically Identify Construction Assets

Automatically identifying construction assets in BIM for tracking, collecting or capturing and visualising their information or even their components, elements, and equipment information can perform by leveraging Barcode and RFID technologies (Farghaly et al., 2018). The methodology and strategy of implementing these technologies have been thoroughly studied for both individual applications for asset maintenance management (Lin et al., 2014),(Wang et al., 2014), as well as in combination with other technologies for maintaining and operating the construction assets (To et al., 2020),(To, 2019).

Barcode technology has been studied and applied widely in many fields since invented in the 1950s. Started from the one-dimension (1D) tags with a maximum storage capacity of only 28bite, Barcodes have been upgraded to two dimensions (2D) tags - which have been mainly used since 1990 - with larger storage capacity. The 2D barcodes can store a wide variety of information (such as image, sound, text) and quickly recover data even if they are partially damaged. Furthermore, Barcode technology is a low-cost technology because users can design barcode tags and store information on the code themselves. After that, they can read these barcode tags by open-source software installed easily on a computer or mobile devices. Hence the barcode technology can identify many equipment and components within a small budget (Lin et al., 2014).

Radio Frequency Identification – (RFID) technology uses radio waves to identify, track or manage assets. RFID tags include active tags and passive tags. These two RFID tag types have chip and antenna; however, active ones are supplemented with batteries to operate automatically. With a more complex structure, RFID tags are more expensive than Barcode. Still, they have many advantages over barcode ones, such as a much more considerable amount of information stored, read from a distance and better durability. Active RFID tags also can track asset status (such as measuring subsidence of structural elements) and automatically transmit information to the asset information database or server. Although RFID technology contains various benefits, it costs much higher than Barcode one; therefore, it can only be used in identifying important or hidden assets or in positions where Barcode one cannot be applied (Fig 3) (Lin et al., 2014).

Fig. 3 - Applying Barcode (Barcode), Radio frequency identification (RFID) technologies to identify equip-



ment and structural elements automatically (Lin et al., 2014)

2.2.2 Sensor and Internet of Things (IoT) Technologies Enable Tracking Real-Time Information of Construction assets

Sensor and Internet of Things (IoT) technologies presented in many studies which have objectives of managing and exploiting construction assets effectively (Wang et al., 2014), (Alileche & Shahrour, 2018; Astier et al., 2017), (Lynch & Sohn, 2014). BIM plays as a hub to enable these technologies to update real-time information of construction equipment, elements, component during the asset life cycle (Astier et al., 2017; To, 2019). This information is collected or captured follows a strategy built and installed on sensor devices - considered a "**thing**" in the Internet of **things** system. After that, the collected information will be sent directly or be processed before delivering to the asset database –BIM environment. The efficiency of supported technologies in real-time asset information update has helped asset managers reduce an extensive amount of expense on labours work.

Because of the development of information and communication technology (ICT) and the Internet, IoT technology has been considered a low-cost technology recently (Tushar et al., 2018). However, sensor technology requires a higher investment expense because of spending for procurement, installation of sensor equipment, as well as building and programming the data processing system and database storage to avoid overload of the BIM environment along with the maturity of construction assets (Fig 4). Indeed, the sizeable amount of asset information transferred by sensors or other "things" to the BIM model may increase the cost of maintaining the BIM model. This problem is still under prime consideration and ongoing study (Heaton et al., 2019). Therefore, sensor technology is mainly applied for maintaining inaccessible elements but required care (such as underground infrastructure assets) (Yin et al., 2020); or equipment that required regularly and continuity updated status (such as essential machine rooms or equipment related to assets' safety like fire-safety, lift system) (Solla et al., 2020).

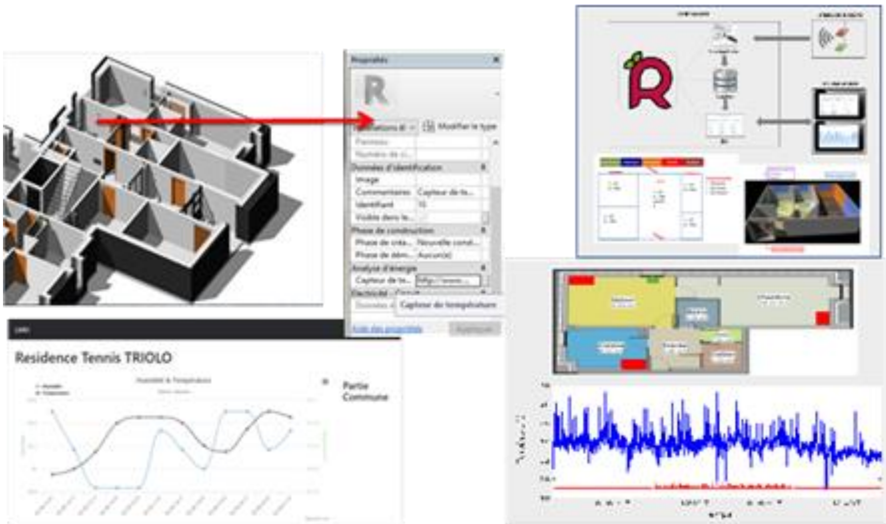


Fig.4 - Processing information delivered by the sensor system and storing into the BIM model (To, 2019)

2.2.3 Augmented Reality (AR) in Visualising Assets

Augmented Reality (AR) technology has been studied and considered a technology to visualise the construction assets that need to be maintained. Right to the name of this technology, AR supports maintenance workers to "see" hidden components or elements installed inside other parts such as air conditioning equipment (inside ceiling system on Fig 5), plumbing piles (inside walls or ceiling system on Fig 6). AR technology has been integrated with BIM and could be installed on mobile devices to facilitate the maintenance and operation of construction assets more flexible and more accessible (Charles et al., 2020), (Kuula et al., 2012), (Diao & Shih, 2019).

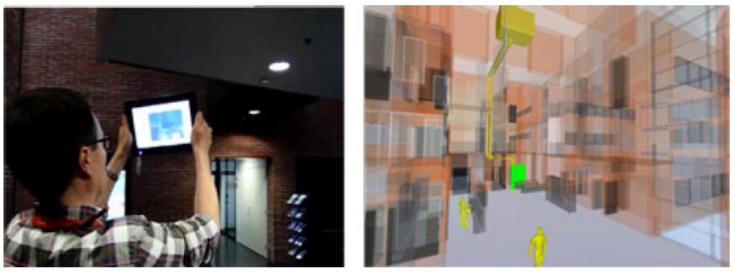


Fig. 5 - Using mobile devices to access the air-conditional system problem on AR interface (left) and coloured notification of the problem on BIM (right) (Charles et al., 2020)

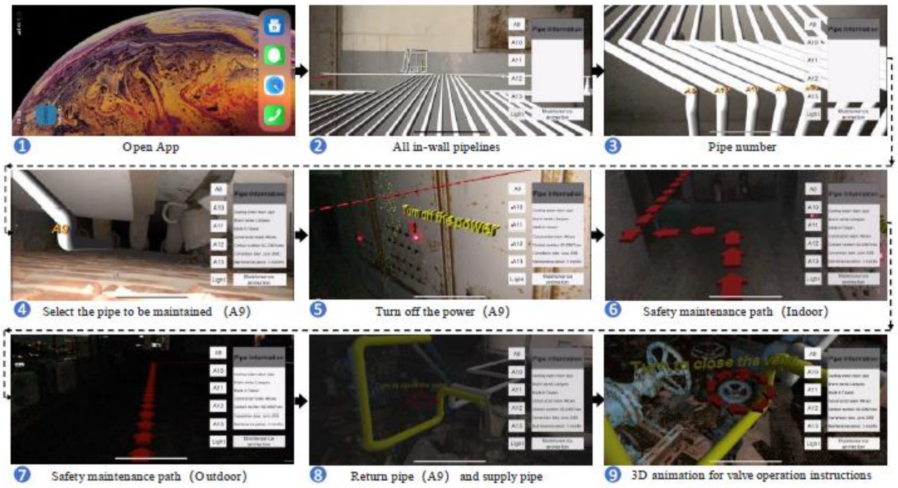


Fig. 6 - Maintenance system develop base on BIM and AR (BARMS) for plumbing system (Diao & Shih, 2019)

3. The Readiness of BIM and Related Technologies in Viet Nam

Among those, as mentioned earlier, applicable advanced technologies to maintain and manage the quality of construction assets, BIM technology has been no more unpopular in Vietnam's construction industry since the Prime Minister issued "The approval of the BIM adopting plan in construction implementation and operation" (The Vietnamese Prime Minister, 2016) in 2016. By 2017, the Ministry of Construction released decision No. 1057 / QD-BXD, which provided provisional application guidance during the pilot phase of BIM implementation in Vietnam (The Ministry of Construction of Vietnam, 2017). The two documents are the instrument to enlarge BIM implementation diffusion in Vietnam's construction industry. However, after four years of adoption the decision No. 2500 / QD-TTg and three years of adoption the decision No. 1057 / QD-BXD, the study about BIM-enabled pilot projects shown the difficulty in applying BIM to manage construction assets by the tiny number of projects that develop BIM model for asset operation phase (G V Hoang, D K T Vu, 2020), (Nguyen et al., 2018). This situation is the new and emerging area of research on BIM-enabled facilities operation and maintenance model in Vietnam in particular and in the world in general, as well as the implementation challenges (Gao & Pishdad-Bozorgi, 2019).

Nevertheless, the benefits delivered by BIM adoption to the pilot projects during the construction phase are the foundation and base for implementing BIM in the operation phase of these projects and existing construction assets in Vietnam. Besides, the cost of establishing a BIM-enabled facilities operation and maintenance model could be much cheaper in developing countries with an abundant and inexpensive labour force. Indeed, based on the experiences in developing a BIM model for support maintenance activities for an existing school building in Vietnam (Fig.7), establishing an asset information database in the BIM model (Fig. 8) is the most tedious task but consumes much time. However, the job does not need to be done by qualified engineers. Even workers that have short training for implementing this work can perform it without mistakes. Therefore, the BIM implementation for construction asset maintenance and quality management is realisable and workable for all the above reasons.

The mentioned BIM-related advanced technologies have been widely used in everyday life in Vietnam. Barcodes are used everywhere, from identifying merchandise in shops or supermarkets to providing extra and detailed flyers. The logistics industry uses RFID tag technology to track containers' location during transportation or storage (Hoa et al., 2017). Sensor technology is used to measure the temperature, humidity, brightness and displacement of devices or space. Many mobile devices and computer accounts connected on the broadband internet platform are a specific example of the application of IoT technology in Vietnam (Nha et al., 2019). AR technology is also widely exploited on mobile platforms to build games or software for teaching, learning and online shopping. AR has even been studied to operate a mechanical and electrical system of an existing building in Vietnam (Binh et al., 2019).

The above analysis shows that BIM and related advanced technologies are ready in the Vietnamese technology market. However, the readiness of the maintenance unit on these technologies implementation to maintaining and managing quality construction assets is narrow. This conclusion is evidenced through the multiple-choice online survey results of 30 randomly selected asset maintenance staff and managers from 30 large and small, medium-maintenance organisations. They are engineers who have at least five years of experience involving directly in operating and maintaining construction assets in Vietnam. The participants' answers were given after studying the application of BIM and related advanced technologies in the maintenance and quality management of construction assets. As a result, all the participants agree that the benefits and challenges of BIM and associated technologies adoption in construction asset maintenance and quality management might be unchanged in the Vietnam context.

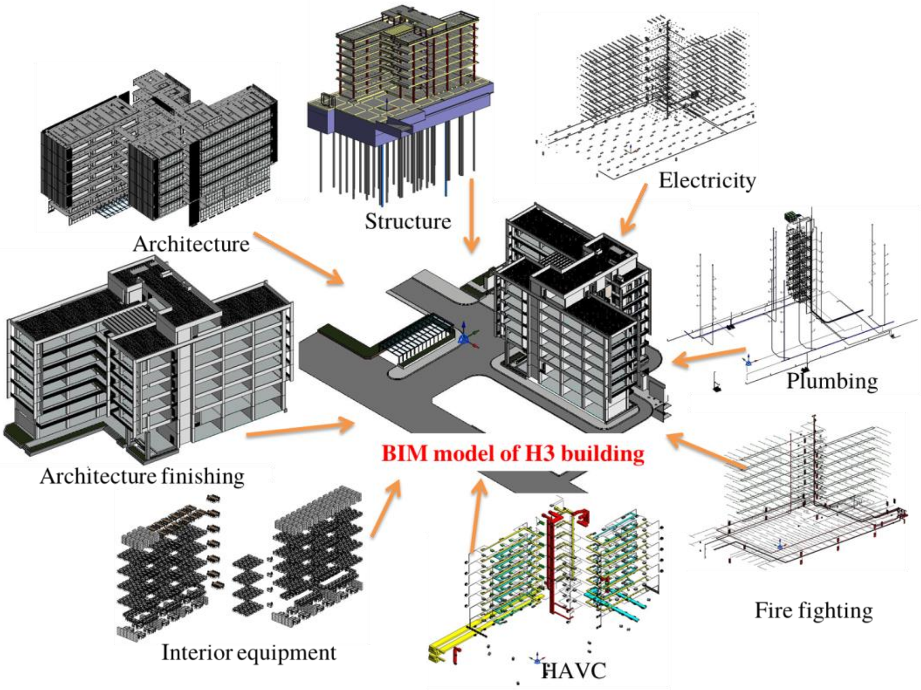


Fig. 7 - The BIM model of an existing school building in Vietnam

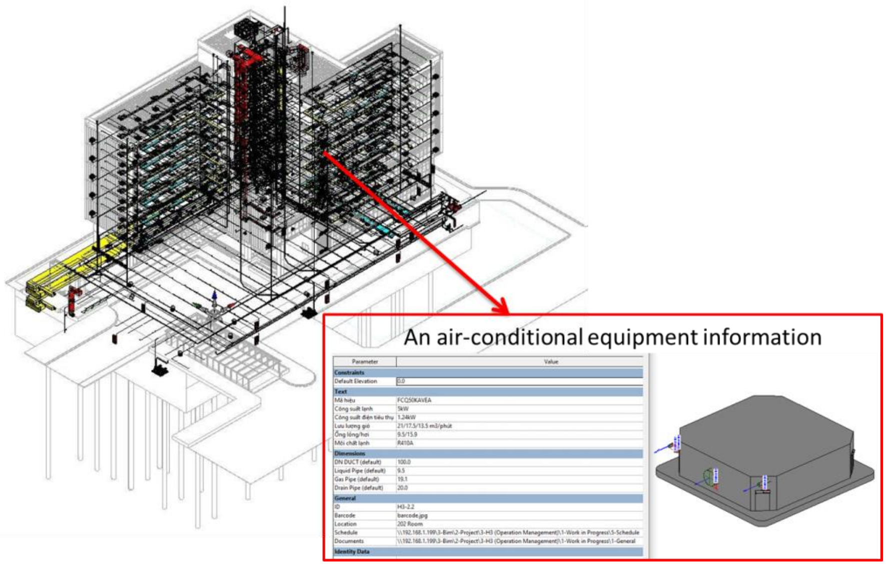


Fig. 8 - The air-conditional equipment information presented in the BIM model (Fig.7)

The answering results of the question "How well do you know of the technologies mentioned" show that all the survey participants have a specific understanding of the technology (Fig. 9). The participants also agree that the BIM and related advanced technologies implementation will deliver higher effectiveness in maintaining and managing the quality of construction assets in their organisation than the traditional approach (Fig.10). The asset maintenance staff and managers' opinion on "the desire to apply BIM and related advanced technologies for the maintenance and quality management of construction assets in their organisation in case staff training and technology transferring" has appeared different. More specifically, only 15/30 participants think that their organisation will be willing to apply. Answer the interview after the online surveying. The other half of the participants consider that barriers related to investment costs, training requirements on novel technologies or adaptation to modified workflow would restrain their organisation from innovating.

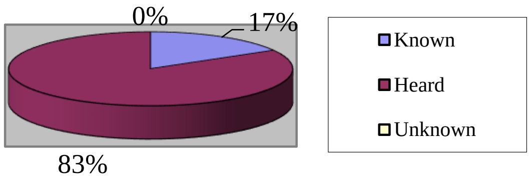


Fig. 9 - Knowledge on BIM and related advanced technologies of asset maintenance staffs and managers participated in the survey

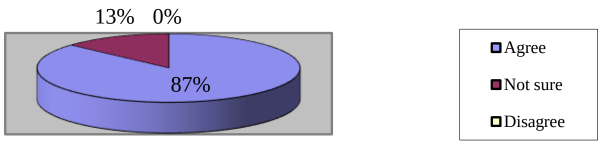


Fig. 10 - The opinion of the asset maintenance staffs and managers on the statement: the implementation of BIM and related advanced technologies will deliver effectiveness to the maintenance and quality management of construction assets in their organisation

Fig. 11 - The opinion of the asset maintenance staffs and managers on the desire to apply BIM and related advanced technologies for the maintenance and quality management of construction assets in their organisation

4. Conclusion and Discussion

The study's results present remarkable efficiency in applying BIM and related advanced technologies like Barcode, RFID tags, Sensor, IoT, AR technologies in the maintenance and operation of construction assets worldwide. Implementing these technologies provides a collaborative, visualised work environment based on the BIM platform and replaces many manual maintenance activities with automated ones. These results are an essential foundation to encourage stakeholders to apply the advanced technologies to improve the quality and effectiveness of maintenance and quality management of construction assets in Vietnam.

The study also demonstrates the applicability of these technologies in Vietnam through surveying human resources and technology readiness. The research findings are an essential scientific foundation for researchers and construction asset managers to continuously study to deal with outstanding problems such as (1) Lack of guidance on the application of advanced technologies in the maintenance and quality management of construction assets in Vietnam's context; (2) Solution to improve the human resources readiness of construction asset management organisations. Addressing these challenges will promote digital transformation in the construction industry and enhance the maintenance performance and quality of construction assets in Vietnam.

Besides the achieved results, the study remains some limitations. The first one is the non-large volume of survey and interview (post surveying) participants (They are from only 30 construction asset maintenance organisations were investigated among around 250 ones in Vietnam). The second one is that the paper has just concentrated on significant barriers and challenges of BIM and relevant technologies implementation but not yet thoroughly studied solutions for all the obstacles. These limitations will be considered in the authors' future works.

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