Benefits and challenges of BIM implementation for facility management in operation and maintenance face of buildings in Vietnam

G V Hoang\(^1\), D K T Vu\(^1\), N H Le\(^1\) and T P Nguyen\(^1\)
\(^1\)Faculty of Construction Economics and Management, National Civil Engineering University, 55 Giai Phong Street, Hai Ba Trung District, Ha Noi, Vietnam.

E-mail: gianghv@nuce.edu.vn, dungvtk@nuce.edu.vn, namlh@nuce.edu.vn, namtp@nuce.edu.vn

Abstract. Building Information Modelling (BIM) is regarded as a technological breakthrough that facilitates the modernization of construction industry, increasing the productivity and value across stakeholder groups. However, despite of BIM’s potential benefits towards the industry players, it seems that BIM is still not broadly implemented yet in the Vietnam construction industry, especially for facility management (FM) during the Operation and Maintenance (O&M) phase of buildings. This paper, therefore, investigate the status quo of BIM implementation for FM in O&M phase of buildings in Vietnam, exploring the benefits and also the challenges that construction practitioners in Vietnam need to overcome to fully exploit BIM potentials in O&M phase. The research results, on the basis of interviews with experts in Vietnam construction industry, show that BIM for O&M phase is still in its infancy in Vietnam and the most indicated challenges are: the cultural approach to adopt BIM in the FM industry; lacking or inadequate, misunderstanding information handover requirements.

1. Introduction
A study has shown that the life cycle cost of an asset can be 5-7 times higher than its initial investment costs [1] and more than 85% of the total costs of ownership are spent on FM [2]. These above figures imply the importance of optimizing the facility management activities during the O&M phase of a facility. In fact, facilities owners spend a lot of time and money sifting through a huge number of documents to deploy necessary information for facility management system, resulting from the incompatibility among the FM information systems and the fragmentation of the needed data. With the deployment of BIM, these above problems can be effectively addressed and the FM can be facilitated because BIM holds a potential of erasing the communication gaps and streamlining the exchange and interoperability of information in the digital form [2], [3].

In addition, the building is now the most popular type of building in crowded cities around the world as well as in Vietnam. With the outstanding advantages: saving land, integrating many uses, low-cost; the high-rise building has become an inevitable urban architecture trend. Therefore, the benefits of applying BIM in FM will be more replicated if it is applied to high-rise buildings.
In Vietnam, although BIM has been applied to many construction projects, its application is still mainly restricted to the design and construction phase. In order to facilitate the BIM application during the O&M phase of buildings in Vietnam, this paper, therefore, covers the following main contents: (1) Reviewing the BIM uses and benefits in buildings’ O&M phase; (2) Reviewing the challenges of BIM deployment in O&M phases and solutions to these challenges; and (3) Investigating the status quo of BIM application for FM in O&M phase in Vietnam construction industry, pointing out the benefits as well as the challenges of BIM adoption during this stage.

2. Literature review

2.1. Overview of literature on BIM for FM in O&M phase of buildings

Although in Vietnam BIM is still in its infancy, there have been many successful BIM projects as well as BIM literature around the world. This paper, with the above indicated objectives, examines related previous studies published on Web of Science database to get the current overview of literature, using search string of (“building information model*” OR “BIM”) AND “facility management”) within search field of abstracts, keywords and titles. The search result shows that, in the past decade, there has been a growing trend of research on BIM-FM in O&M phase of buildings with the total of 113 papers, starting from the year of 2008. Both the total publications by year and sum of cited by years have been increasing steadily, and the years of 2018 and 2019 have witnessed an impress growing with 32 and 29 published paper respectively.

![Figure 1. Total of BIM-FM publication by year in Web of Science database](image-url)
Figure 2. Sum of times BIM-FM publication cited per year according to Web of Science database

The following part of literature review will analyze and synthesize publications on BIM uses, BIM benefits and challenges as well as indicated solutions for these challenges during the process of applying BIM for FM in O&M phase of buildings.

2.2. BIM uses for FM in O&M phase of buildings

According to [4], the applications of BIM, in general, can be seen in throughout the life cycle of facilities with various potential uses such as design visualization, site planning and site utilization, scheduling and sequencing, cost estimating, systems coordination, layout and fieldwork, and operations and maintenance. In the O&M phase, as indicated by [5], facilities management departments can make use of BIM for renovations, space planning, and maintenance operations. More detailly, [6] specifies the functions of BIM for FM as: (1) Synchronously providing information related to building's service condition or performance, owners and capacity, service time and financial situation; (2) Delivering data update records, and perfecting relocation plan and management; (3) Physical information of the building and important financial data about area available to lease, rental income and interdepartmental financial distribution. Also follow https://www.bim.psu.edu/bim_uses/BIM uses in operation phase are: (1) Record modeling (2) Maintenance scheduling, (3) Building system analysis; (4) Asset management (5) Space management; (6) Disaster planning and management. To see the applicability of BIM in building operation, it is necessary to put BIM's use within the scope of O&M phase. Follow [7] Operational management covers these areas:
Figure 3. Operational management covers these areas

Through the BIM use in FM mentioned above, it can be applied in all O&M jobs from technical activities to administrative activities. Such as:

| O&M areas                                      | BIM use                                                                                     |
|------------------------------------------------|--------------------------------------------------------------------------------------------|
| (1) Daily operation of the building.           | We can judge whether or not the equipment runs smoothly by using the BIM model to do real-time monitoring on the equipment's operational parameter. After a long-term information accumulation, operation organization can build an information base of equipment maintenance to promote management level, improve building's safety performance and reduce the occurrence of emergencies in building's operation stage. |
| (2) Energy management                          | BIM can help measure energy consumption and the amount of waste. Then BIM can help facilitate the analysis and comparison of various energy alternatives to help facility managers reduce environmental impacts and operating costs. |
| (3) Hazardous waste management & recycling     | By integrating building data with BIM, organization can manage space like area available to lease; control rental income; reduce vacancy and ultimately achieve major reductions in real estate expenses. |
| (4) Real estate management                     | For BIM, the database is the most important factor which not only relates to the quality of the information entered but also the ability to transmit information, so this is a prerequisite for applying BIM, so it is also a good resolution of the job communication management. The application of BIM technique can also promote emergency response abilities in building management. It can accurately locate where the problem is, and rapidly provide relevant information. Even if it deals with the emergencies, it also can control the problem within the minimum range. |
| (5) Relocation management                      |                                                                                             |
| (6) Wired and wireless communications management|                                                                                             |
| (7) Emergency preparedness and business continuity|                                                                                             |
Information about building mechanical equipment stored in BIM models can be valuable in creating a database needed for ongoing preventive maintenance.

Many administrative functions related to organizational support and building. The most outstanding feature of BIM is that it provides a complete, accurate, up-to-date database and most importantly, everyone can exploit this database: from the owners, operators, contractors... Therefore, it helps to solve quickly and effectively when problems occur, including security or administrative functions.

Table 2: Benefits of BIM to FM in O&M phase

| Benefits of BIM to FM in O&M phase | [8] | [9] | [5] | [6] | [10] | [11] | [12] | [4] |
|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Collaboration improvement         | x   | x   |     |     |     |     |     |     |
| More accurate information from a  |     |     |     |     |     |     |     | x   |
| data-rich asset                   |     |     |     |     |     |     |     |     |
| Automatically updated model       |     |     |     | x   |     |     |     |     |
| Improved interoperability         |     |     |     |     |     |     |     | x   |
| Increased employees’ productivity|     | x   |     | x   |     |     |     |     |
| and efficiency                    |     |     |     |     |     |     |     |     |
| Easier data retrieval;            |     | x   |     |     |     |     |     |     |
| Reduced response time in operations; |     |     |     | x   |     |     |     |     |
| More proactive maintenance        |     |     |     |     |     |     |     | x   |
| Increased level of emergency      |     |     |     |     |     |     |     |     |
| preparedness.                     |     |     |     |     |     |     |     |     |
| Workforce engagement              |     | x   |     |     |     |     |     |     |
| Evaluate energy efficency         |     |     |     |     |     |     |     | x   |
| Reduce operational cost           |     |     |     |     |     |     |     | x   |
| Better customer service           |     |     |     |     |     |     |     | x   |
| Clearer FM requirement definition |     |     |     |     |     |     |     |     |
| & construction                    |     |     |     |     |     |     |     | x   |

Obviously, BIM facilitates the FM tasks in a more sustainable way by optimizing FM tasks, reducing time, energy and workforce required.

2.4. Challenges of applying BIM for FM in O&M phase

Despite of potential benefits of BIM application in O&M phase, BIM application for FM is just at the beginning [25]. BIM potentials for this area are still not fully realized, although some projects has witnessed some positive results in applying BIM for FM [22], [23], [24].
The limited application of BIM in FM results from some challenges that can be classified into six categories attributed to six core “BIM planning elements” proposed by [14] as strategy, uses, process, information, infrastructure and personnel.

| BIM planning elements | Challenges |
|-----------------------|------------|
| Strategy              | – Construction industry does not understand FM [11]  
                        | – The cultural approach to adopt new processes and technologies in the FM industry [24] |
| Uses                  | – Great effort required to build a new or modify an existing BIM models for the building(s) [15] |
| Process               | – The management of information transfer between real-time operations and monitoring systems and the BIM model [15] [11]  
                        | – Lack of Legal and organizational issues that prevent BIM implementation [24], [16], [11]  
                        | – Lack of alignment between people, processes and systems, particularly in the manner that agrees with the basis principles of BIM [17]. |
| Information           | – Misunderstanding of information handover requirements [13], [11], [15], [26], [24]  
                        | – BIM data for FM is either lacking or inadequate, [11] |
| Infrastructure        | – Lack of interoperability between BIM technologies and current FM technologies, how the relevant information included in the BIM models could be integrated with the existing FM information systems and software tools in use [13], [11], [18], [24], [27] |
| Personnel             | – A general lack of technical skills and software knowledge required to utilize the BIM deliverables [13], [26], [9]  
                        | – Staff acceptability of changes to the organization. [9], [19] |

3. Methodology

3.1. Background for choosing research methodology

The Law on Construction, which was issued in 2014, became the first legal document regulating BIM application in Vietnam, opening a strong era of BIM development in the country. However, the adoption of BIM in Vietnam construction industry mostly occurs in design and construction phases, not in the O&M phase. According to the Decision No. 01/BXD-VP dated Jan, 03rd 2019 by the Ministry of Construction, 22 pilot projects are expected to implement BIM. However, only 09 projects are required to apply BIM for operation management:
Table 4. The list of pilot projects/buildings which are required to apply BIM in the operation phase (attached to the Decision No. 01/BXD-VP dated Jan, 03rd 2019 by the Ministry of Construction)
(Source: The Ministry of Construction)

| No. | Project name | Location         | Owner                                             | Financial source                      | Project scale (Billion VND) | Project schedule | BIM is expected to be applied for |
|-----|--------------|------------------|--------------------------------------------------|----------------------------------------|----------------------------|------------------|----------------------------------|
| 1   | Expansion of the Headquarter for Authority of Radio Frequency Management | Hanoi             | Authority of Radio Frequency Management          | The Government’s extra-budgetary resources | 1.040                | From 2018          | Operation management              |
| 2   | Construction of the Headquarter for Authority of Telecommunication | Hanoi             | Authority of Telecommunication                   | The Government budget                 | 1.000                | From 2018          | Operation management              |
| 3   | Cua Dai Bridge, Quang Ngai | Quang Ngai        | Quang Ngai Project Management Unit of Transport Construction works | The Government budget                 | 2.250                | 2017-2020         | Design, Construction, As-built drawings, Operation management |
| 4   | Development of the green transport for Ho Chi Minh city | Ho Chi Minh city | Urban – Civil works Construction Investment Management Authority of Ho Chi Minh city | ODA and Reciprocal capital           | 2.036                | 2018-2024         | Construction, As-built drawings, Operation management |
| 5   | Highway tunnel through Cua Luc bay | Quang Ninh        | Project Management Unit of Highway tunnel through Cua Luc bay | The Government budget                 | 10.000               | 2018-2024         | Design, Construction, As-built drawings, Operation management |
| 6   | Son La hydroelectric power plant | Son La            | Son La Hydro Power Company                        | The Government budget                 | Form 2019            |                 | Operation management              |
| 7   | Tra Khuc river Spillway | Quang Ngai        | Quang Ngai Project Management                     | The Government budget                 | 1.498                | 2018-2021         | Design, Construction, As-built    |
Based on this above table, we can see that 07/09 projects are infrastructure investment projects. Only 02/09 projects are buildings investment projects, including “Expansion of the Headquarter for Authority of Radio Frequency Management” project (building no.1) and “Construction of the Headquarter for Authority of Telecommunication” project (building no.2). This paper, which focuses on BIM application for FM of buildings, examine the two above building projects to explore the current infancy status of BIM application for FM in Vietnam.

Besides, based on information provided by practitioners in construction industry, another project, Viettel Headquarter (building no.3), is also put into this research as the owner of this building has a plan to continue applying BIM in O&M phase, not only in design and construction phases.

Figure 4. Viettel Headquarter: The 09-storeys building with the center as a large square surrounded by office blocks. Total construction area is 32 hectares, of which 19 hectares’ area is designed for water surface.
3.2. Choosing research methodology
Based on the limited number of buildings in Vietnam having plans for applying BIM for FM in O&M phase as indicated above, the authors take advantage of 09 semi-structured interviews [20] with 09 experts, hoping for a greater depth understanding of status quo of BIM application in Vietnam. These experts include experts in charge of operation management of the two above indicated building projects (building no.1 and building no.2) and other BIM experts in construction industry. This number of interviews satisfies the required number of interviews to ensure the reliability of the data for phenomenological study (from 5 to 25 interviews) according to Cresswell [21].

The interview questionnaires consist of 24 questions which are designed so that the respondents can express their opinions and experiences freely during the interviews. The detail questions are divided into 3 parts: Part I: 6 questions about interviewee’s profile; part II: 6 questions about status quo of BIM implementing in building O&M stage; part III: 12 questions about specific BIM’s project in building O&M stage. Part II and III are concentrated 4 main tasks: (1) The current BIM uses deployed for FM in O&M phase of buildings in Vietnam; (2) Outstanding benefits that BIM brings to the FM tasks during O&M phase of buildings; (3) Challenges of BIM application for FM in O&M phase of buildings in Vietnam and (4) Factors that can facilitate BIM adoption for FM in O&M phase in Vietnam.

The detail questions are divided into 3 parts: Part I: 6 questions about interviewee’s profile; part II: 6 questions about status quo of BIM implementing in building O&M stage; part III: 12 questions about specific BIM’s project in building O&M stage. Part II and III are concentrated 4 main tasks: BIM uses, BIM’s benefits, BIM’s challenges, BIM’s solution in building O&M stage.
4. Result

4.1. The profile of the interviewees

| Interviewees no.1 | Organization        | Years of experience with BIM | Roles                  | Notes                                                                 |
|-------------------|---------------------|------------------------------|------------------------|----------------------------------------------------------------------|
| State owner       | > 5 year            | BIM Manager                  |                        |                                                                      |
| Interviewees no.2 | Private owner       | > 5 year                     | BIM Manager            | Member of owner’s BIM team, taking part in both designing and         |
|                   |                     |                              |                        | construction phases of building no.3                                 |
| Interviewees no.3 | Private owner       | > 5 year                     | BIM Coordinator        | Members of facility management board of building no.3                |
| Interviewees no.4 | Contractor          | > 5 year                     | BIM Coordinator, BIM   | Member of general contractor’s BIM team, taking part in the          |
|                   |                     |                              | Technician             | construction phase of building no.3                                  |
| Interviewees no.5 | Contractor          | > 5 year                     | BIM Coordinator, BIM   |                                                                      |
|                   |                     |                              | Technician             |                                                                      |
| Interviewees no.6 | Contractor          | > 5 year                     | BIM Coordinator, BIM   |                                                                      |
|                   |                     |                              | Technician             |                                                                      |
| Interviewees no.7 | Research organization| > 5 year                     | BIM Manager            |                                                                      |
| Interviewees no.8 | Research organization| > 5 year                     | BIM Manager, BIM       |                                                                      |
|                   |                     |                              | Coordinator            |                                                                      |
| Interviewees no.9 | Facility management company | 0 year             | CEO of facility management company | CEO of facility management company in charge of FM for building no.1 and no.2 |

These profiles of respondents both provide a balance view from practitioners having technical basis as well as practitioners having managerial basis. Besides that, these respondents, excluding the CEO of the facility management company in charge of managing the two buildings also had a relative significant year of experience with BIM which ensure the trustability of their answers.
4.2. General status quo of BIM application for FM in O&M phase of buildings in Vietnam

On the basis of answers from experts, the authors can conclude that BIM application for FM in O&M phase of buildings in Vietnam is still in its infancy.

The facility managers of the two-building project no.1 and no.2, in fact, do not apply BIM for FM tasks as planned. They deploy iBMS (Intelligent Building Management System) as an alternative solution for BIM in operation phase and they also indicated that they do not have any experience and knowledge on BIM.

Interestingly, the owner of building no.3, decides to continue applying BIM in operation phase, after receiving some BIM benefits in the designing and construction phase. However, until now, they still do not actually make use of BIM in operation phase; they are still in the process of putting FM-necessary data into their BIM model. They have a plan to deploy BIM together with iBMS for the following FM tasks: MEP systems management, maintenance and space management.

4.3. Expected benefit of BIM for FM in O&M phase of buildings in Vietnam

Although practitioners are in the beginning stage of applying BIM for FM in O&M phases of buildings or just have experience with BIM in designing and construction phase, based on their experience with BIM, they show their expectation with BIM, the benefits that they think BIM can bring to owners and facility management staffs in O&M phase of buildings. Their opinions can be accumulated in the following table:

| Benefits of adopting BIM for buildings FM in O&M phase | Agree | Uncertain | Disagree |
|-------------------------------------------------------|-------|-----------|----------|
| Collaboration improvement                             | 7/8   | 1/8       |          |
| More accurate information from a data-rich asset;     | 8/8   |           |          |
| Automatically updated model                           | 6/8   | 2/8       |          |
| Improved interoperability                             | 8/8   |           |          |
| Increased employee productivity and efficiency        | 8/8   |           |          |
| Easier data retrieval;                                | 5/8   | 3/8       |          |
| Reduced response time in operations;                  | 8/8   |           |          |
| More proactive maintenance                            | 8/8   |           |          |
| Increased level of emergency preparedness             | 8/8   |           |          |
| Workforce Engagement                                  | 7/8   | 1/8       |          |
| Evaluate energy efficiency                            | 8/8   |           |          |
| Reduce operational cost                               | 6/8   | 2/8       |          |
| Better customer service                               | 8/8   |           |          |
| Clearer FM requirement definition for design & construction | 8/8   |           |          |

The above responses show that interviewees, based on their knowledge and experience with BIM, have high confidence in BIM for FM in Vietnam. As an expert indicated, "The benefits of BIM in FM inherit all the benefits from the previous stages: design and construction. In addition, when being
applied in operation phase, BIM also can bring long-term benefits such as: saving life cycle cost of buildings”.

Moreover, these experts believe that Vietnam has an advantage over other countries when construction practitioners apply BIM for FM because their practitioner have the opportunity to learn from the mistakes of other BIM projects and can have a better preparation for BIM.

4.4. Challenges of BIM application for buildings’ operation phases in Vietnam

When interviewees are asked about the immediate challenges that the application of BIM in operation, they answered based on their experience and personal views on this issue. However, as analyzed through the status quo, the knowledge and experience of the interviewers about BIM in FM is not much and lack. Thus, collecting the answers of all interviewer, authors compared them with the challenges already gathered in the table 3. The result is presented in the following table:

| Challenges                                      | Inter no.1 | Inter no.2 | Inter no.3 | Inter no.4 | Inter no.5 | Inter no.6 | Inter no.7 | Inter no.8 |
|-------------------------------------------------|------------|------------|------------|------------|------------|------------|------------|------------|
| **Strategy**: The cultural approach to adopt BIM in the FM industry | x          | x          | x          | x          | x          | x          | x          | x          |
| **Uses**: Great effort required to build a new or modify an existing BIM model for the building(s) | x          | x          | x          | x          | x          | x          | x          | x          |
| **Process**: Transfer between real-time operations and monitoring systems and the BIM model; Lack of Legal and organizational issues that prevent BIM implementation; Lack of alignment between people, processes and systems | x          | x          | x          | x          | x          | x          | x          | x          |
| **Information**: lacking or inadequate, misunderstanding information handover requirements | x          | x          | x          | x          | x          | x          | x          | x          |
| **Infrastructure**: Lack of interoperability between BIM technologies and current FM technologies, how the relevant information included in the BIM models could be integrated with the existing FM information systems and software tools in use | x          | x          | x          | x          | x          | x          | x          | x          |
| **Personnel**: A general lack of technical skills and software knowledge required to utilize the BIM deliverables | x          | x          | x          | x          | x          | x          | x          | x          |

There are two elements that’ve got the high agreement of experts: strategy and information. Specifically, according to interviewee no. 1, 2, the obstacles are not merely due to the limited BIM technology knowledge and experience, but also due to the hesitation of the owner. Besides, the interviewee no. 4 indicated that the specific characteristics of operation management also hinder BIM application for FM.
The next one is the process element. This challenge needs to be directly operated in order to realize what the difficulties are to overcome, so the contractor interviewees agreed highly with this element. The interviewee no.5 indicated that challenges come from the requirements on the accuracy and detailed level of BIM models and the interoperability between BIM and applicable operation tools; Additionally, the interviewee no.2 supposed that the operation agencies do not have enough understanding on BIM, impeding the way of BIM implementation.

The remaining factors are infrastructure, uses and personnel which were mentioned by the interviewers but not as much as strategy, information, process. This can be explained: these challenges will arise after BIM in FM projects are implemented. In Vietnam, there are no projects so it is reasonable for lessly mentioning on these difficulties.

5. Discussion
The results obtained in this paper are consistent with the issues raised in the introduction. The order of the results presented in the paper follows a logical thinking: The application of BIM in FM is very necessary but not implemented in practice in Vietnam, so what is the reason for this situation. That’s why the result is presented in order: 4.1. BIM uses in operation and maintenance building continued; 4.2. The superior benefit of BIM in building operation management; 4.3. Status quo on BIM application for the operation and maintenance phase in Vietnam; 4.4. Challenges of BIM application for buildings’ operation phases in Vietnam.

Stemming from the fact that in Vietnam there is no BIM project in operation period yet, while there are some BIM projects implemented in this period, so the method of analysing data from previously published works and the method of interviewing BIM’s experts in Vietnam are chosen. However, the paper is not only a pure inheritance from previous researches but also a filtration. The benefits and difficulties synthesized by the authors were refined again through the opinions of BIM’s experts. This increases the reliability and realisticity of the study’s results.

The article helps answering current topical questions in Vietnam: which projects have implemented BIM in FM, what benefits does BIM bring when it is applied in operation period, and the difficulties faced when applying BIM in this period. The article will become a useful document for those interested in BIM in Vietnam: Policymakers rely on the challenges in this paper to devise mechanisms and policies to help Vietnam gain a head start by taking a shortcut in applying BIM in operation period. Owners realize the immediate and long-term benefits that BIM brings when operating their projects, thus motivating them to make BIM decisions in operation. On the basis of benefits and difficulties BIM brings, BIM contractors or building operators get the best preparation for this new technology.

6. Conclusion
At the beginning of the article, the authors have confirmed the importance of BIM in FM by pointing out the applications of BIM in FM: BIM uses in 10 operation and maintenance areas Moreover, the application of BIM also brings more advantages than the traditional technology: (1) shorter time to solve when an incident occurs; (2) saving life’s cycle cost in all activities of building.

However, compared with the potential that BIM brings, the application of BIM in FM is still very limited. Through the collected data and interviews with BIM experts in Vietnam, the authors have made the opinion that the application of BIM in operation in Vietnam is almost not available.

To find the answer to this paradox, the authors conducted an interview with BIM’s experts in Vietnam according to the difficulties has listed in the table 7. Thereby, the initiating challenge that BIM’s implementors in Vietnam must overcome to apply BIM in FM is: Strategy for BIM application in the operation phase.
The fact that BIM has not been applied in FM in Vietnam is both a challenge and an opportunity if BIM practitioners in Vietnam can take a leap forward from the experience of BIM-FM projects in the world. This is one of the pioneering researches on BIM in FM in Vietnam.

From the initial results that the research brings, the authors will continue to solve more in-depth problems in subsequent studies: factor analysis affecting the application of BIM, propose solutions to promote BIM application network in FM in Vietnam.

References
[1] Lee K S, An K H, Yu H J 2012 An Extension of the Technology Acceptance Model for BIM-Based FM Construction Research Congress (Indiana: West Lafayette) pp 602–611
[2] Akcamete A, Akinci B, and Garrett H J 2010 Potential utilization of building information models for planning maintenance activities In Computing Civil and Building Engineering Proceedings of the International Conf. (Nottingham: Nottingham University Press) p 151
[3] Golabchi A, Akula M and Kamat R V 2013 Leveraging BIM for automated fault detection in operational building Proceedings of the International Symposium on Automation and Robotics in Construction (Canada: Montréal) vol 48109 pp 187-197
[4] Nur S and Mohd A 2018 Adoption of building information modelling (BIM) factors contribution and benefits Proceeding International Conference on Global Business and Social Sciences (Malaysia) pp 239–255
[5] Azhar S 2011 Building Information Modeling (BIM): Trends, Benefits, Risks, and Challenges for the AEC Industry Leadership and Management in Engineering vol 11 pp 241-252
[6] Liao C, Tan D and Li Y 2012 Research on the Application of BIM in the Operation Stage of Green Building Applied Mechanics and Materials (Switzerland: Trans Tech Publications) vol 174-177 pp 2111–14
[7] Roper O K, Payant P R 2014 The Facility Management Handbook Fourth Edition (New York) American Management Association p 367
[8] Terreno S, Anumba J C, Gannon E and Dubler C 2015 The Benefits of BIM Integration with Facilities Management: A Preliminary Case Study International Workshop on Computing in Civil Engineering pp 675–683
[9] Tereno S, Anumba J C, Anumba, and Dubler R C 2016 BIM-Based Management of Building Operations Construction Research Congress (Puerto Rico: San Juan) p 1855
[10] Abbasnejad B and Moud I H 2013 BIM and Basic Challenges Associated with its Definitions, Interpretations and Expectations International Journal of Engineering Research and Applications vol 3 no 2 pp 287–294
[11] Naghshbandi N S 2016 BIM for Facility Management: Challenges and Research Gaps Civ. Eng. J. vol 2 no 12 pp 679–684
[12] Aziz D N, Nawawi H A and Ariff N R M 2016 Building Information Modelling (BIM) in Facilities Management: Opportunities to be Considered by Facility Managers Procedia - Soc. Behav. Sci. vol 234 pp 353–362.
[13] Giel K B, Mayo G, and Issa A. R. R 2015 BIM use and requirements among building owners Building Information Modeling: Applications and Practices American Society of Civil Engineers (ASCE) pp 255–277.
[14] Lopez J 2013 BIM Planning Guide for Facility Owners Computer Integrated Construction Research Program (PA: The Pennsylvania State University)
[15] McArthur J J 2015 A Building Information Management (BIM) Framework and Supporting Case Study for Existing Building Operations, Maintenance and Sustainability Procedia Engineering vol 118 pp 1104–11
[16] Sacks R, Eastman C, Lee G, and Teicholz P BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers Third Edit Hoboken New Jersey: John Wiley & Sons, Inc.
[17] Bosch A, Volker L and Koutamanis A 2015 BIM in the operations stage: bottlenecks and implications for owners Built Environ. Proj. Asset Manag. vol 5 no 3 pp 331–343
[18] Miettinen R, Kerosuo H, Metsälä T and Paavola S 2018 Bridging the life cycle: a case study on facility management infrastructures and uses of BIM J. Facil. Manag. vol 16 no 1
[19] Anderson A, Marsters A, Dossick S C and Neff G 2012 Construction to Operations Exchange: Challenges of Implementing COBie and BIM in a Large Owner Organization Construction Research Congress no. Cic 2011 pp 688–697
[20] Zakaria B et al. 2013 Exploring the adoption of Building Information Modelling (BIM) in the Malaysian construction industry: A qualitative approach International Journal of Research in Engineering and Technology vol 2 iss 8 pp 384-395
[21] Creswell W J 2014 Research Design: Qualitative, Quantitative, and Mixed Methods Approaches Fourth Edition SAGE Publication, Inc p 183
[22] Codinhoto R and Kiviniemi A 2014 BIM for FM: A Case Support for Business Life Cycle International Conf. on Product Lifecycle Management (PLM) (Yokohama) pp 63–74
[23] Arayi C, Onyenobi T, Egbru C 2012 Building Information Modelling (BIM) for Facilities Management (FM): The Mediacity Case Study Approach International Journal of 3-D Information Modeling vol 1 pp 55–73
[24] Kassem M, Kelly G, Dawood N, Serginson M and Lockley S 2015 BIM in facilities management applications: a case study of a large university complex Built Environment Project and Asset Management vol 5 iss 3 pp 261-277
[25] Gao X, Bozorgi P P 2019 BIM-enabled facilities operation and maintenance: A review Advanced Engineering Informatics vol 39 pp 227-247
[26] Tristan A, Kiriti G, Malcolm R, Mark C, Mark J and Christine P 2017 BIM application to building energy performance visualisation and management: Challenges and potential Energy Build vol 144 pp 218-228
[27] Heaton J, Kumar A, and Schooling J 2019 Computers in Industry Design and development of BIM models to support operations and maintenance Comput. Ind. vol 111 pp 172–186