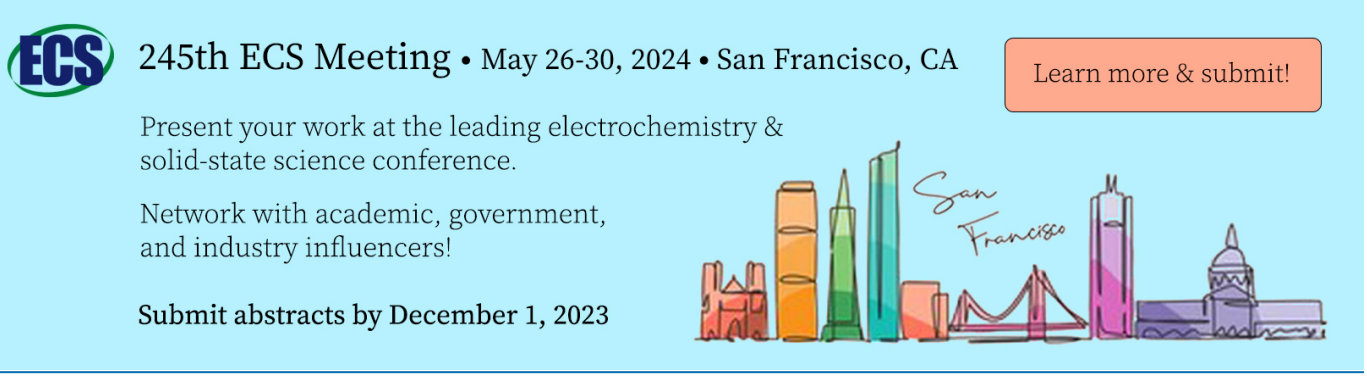
The changing role of BIM-facilitated facilities management in the post-COVID era: A systematic literature review



The changing role of BIM-facilitated facilities management in the post-COVID era: A systematic literature review

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Abstract. COVID-19 has become a long-term pandemic and pushed the re-interpretation of normality. Fighting against the pandemic and building a new normal in the post-COVID era requires constant and innovative approaches. Building information modeling (BIM) facilitated facilities management (FM) has been advocated as a powerful method to overcome the huge public health-related challenges. However, studies investigating the role of BIM-facilitated FM in the pandemic era are fragmented, and holistic knowledge is limited. Research objectives of this study are twofold: (1) to identify varying FM requirements after the outbreak of COVID-19, (2) to investigate how BIM-facilitated FM copes with changing requests in the pandemic period. To achieve the objectives, a systematic literature review was conducted. Currently, FM tends to be public health-centric, and highly emphasized requirements encompass the flexibility of space transformation for emergency purpose, effective and sufficient ventilation, reliable biosecurity, and strict anti-infection management. Based on centralized database and visualized model, BIM-facilitated FM enables space optimization, simulation and prediction of infection risk, monitoring and managing equipment operation, and effective information management, which enhances both hard and soft FM. This paper sheds light on the applications and directions of future BIM-facilitated FM research in protecting public health in the post-COVID era.

1. Introduction

With the rapid outbreak and worldwide spread, COVID-19 has become a long-term pandemic and posed a threat to public health throughout the world. People spend most of their time in buildings. Facilities management (FM) of buildings is closely relevant to humans' daily life. It is established that the infection risk is high in indoor spaces but can be reduced and controlled by effective FM measures [1]. The pandemic places enormous burdens and challenges on both soft and hard FM. FM is of great importance in combating COVID-19 and forming a new normal.

Constant and innovative approaches are demanded to facilitate FM and protect public health during tough time. As advanced information technology, building information modelling (BIM) is anticipated to facilitate FM, because of its centralized model, increased utility and speed for data retrieval, and visualization ability [2]. It can enhance information handover, increase data accuracy, improve data access and update, increase work efficacy, and benefit analysis and simulation in previous BIM-facilitated FM practices [3][4]. It is evidenced that BIM has also been adopted in anti-pandemic FM after the outbreak of COVID-19 [5][6][7]. However, related studies are fragmented, and the changes of

FM requirements and the role of BIM in facilitating FM under the pandemic era are not clear. There is a dearth of a systematic and comprehensive review.

This paper aims to identify varying FM requirements after the outbreak of COVID-19 and investigate how BIM-facilitated FM copes with changing requests in the pandemic period. To achieve the objectives, a systematic literature review is conducted. This study summarizes existing work and sheds light on the applications and directions of future BIM-facilitated FM research in protecting public health.

2. FM and BIM-facilitated FM

2.1. Definition, and Responsibilities of FM

Over the development of FM, the term has been identified in various ways, which reflects a dynamic nature and an increasing recognition of FM [8]. Diverse definitions of FM cover part or all of the three factors, including business environment (e.g. business objectives, company culture), building and facilities characteristics (e.g. facility type, location, and size), and external interventions (e.g. legislation, market, interrelationships with other stakeholders) [2]. The widely recognized definitions of FM are from the International Facility Management Association (IFMA) and International Organization for Standardization (ISO). It is defined by IFMA as a profession that encompasses multiple disciplines to ensure functionality, comfort, safety, and efficiency of the built environment by integrating people, place, process, and technology [9]. This definition mainly focuses on projects and facilities. While, ISO defines FM as the organizational function which integrates people, place, and process within the environment with the purpose of improving the quality of life of people and the productivity of the core business [10], which also considers business strategies and is wider.

According to IFMA, FM provider contributes to maintaining what are usually the largest and most valuable assets of an organization, and its basic responsibilities are listed in Table 1.

Table 1. Basic responsibilities of FM [11].

No.	Responsibilities
1	Impacting operational efficiencies
2	Supporting productivity of facilities and personnel
3	Managing risks to facilities and personnel
4	Mitigating environmental impact
5	Promoting sustainable tactics for long-term cost management
6	Leveraging technological solutions
7	Reducing or overcoming effects of natural disasters
8	Guaranteeing compliance
9	Leveraging security

2.2. BIM-facilitated FM Practices

BIM is viewed as a facilitator for FM efficiency. The information collected through a modelling process and a BIM-compliant database promise to input initial data to FM systems, and advanced visualization and analysis abilities of BIM are beneficial to support and enhance a variety of FM practices [3]. BIM and FM integration is called “6D BIM” which refers to offering integrated facility management solutions by utilizing BIM information from 3D, 4D, and 5D to integrate into the operation, maintenance, and future renovation of projects [12].

As presented in Table 2, the widely adopted BIM-facilitated FM practices consist of locating building components and real-time data access, maintainability checking, space management, emergency management, and energy and sustainability management. There are also some potential BIM-facilitated FM practices, such as creating and updating digital assets, facility condition assessment, and personnel training, etc. In sum, BIM’s contributions to FM stem mainly from

improvement in the current manual process of information handover, increase in FM data accuracy, improvement in data access and update, increase of work execution efficiency, and advanced analysis and simulation abilities [3][4].

Table 2. BIM-enabled FM practices.

BIM-enabled FM practices	Sources
Locating building components and facilitating real-time data access	[13] [3] [14] [15]
Creating and updating digital assets	[3] [16]
Maintainability checking	[17] [3] [18] [19] [20] [21]
Facility condition assessment	[3]
Space management	[16] [3] [22] [23]
Emergency management	[3] [24] [25]
Energy and sustainability	[26] [3] [19] [27] [28]
Planning and feasibility studies for non-capital construction	[3]
Personnel training	[25] [3]
Budgeting and value trade-off and life-cycle cost management	[3]

However, there are also technical and organizational barriers hindering BIM implementation in FM, for instance, lack of interoperability between BIM solutions and FM systems, lack of standard, unclear BIM deliverable demand, lack of clarification about responsibilities of stakeholders, and unquantified benefits, etc. [2] [3].

3. Research Methodology

A systematic literature review was adopted to achieve the objectives of this research. Publications were retrieved in November 2021. Three databases were chosen for paper retrieval, namely Web of Science, Scopus, and Google scholar. BIM, COVID-19, and FM were used as keywords to retrieve publications. The following search schemes were applied to verify a paper's title, abstract and keywords on Web of Science and Scopus: 'BIM' AND 'COVID-19' AND 'FM' OR 'facilities management' OR 'facility management'. The search results were screened by limiting the topic-related subject categories, including Engineering, Computer science, Engineering and civil, Social science, and Information management. The same search logic was conducted in the retrieval on Google scholar. All articles are published after 2020. After two-step selection, that is, scanning the title, abstract, and keywords of a paper firstly and scanning the full text of a paper secondly, the authors removed the publications that have no relevance to the topic. 14 papers with high relevance were left in the final. All of the journals have architecture, engineering and construction backgrounds, for example, Building and Environment, Sustainability, Automation in Construction, Journal of Facilities Management, International Journal of Architectural Technology and Sustainability, Journal of Management in Engineering, and International Journal of Civil and Environmental Engineering.

4. Findings and Discussion

4.1. Changes of FM Requirements after the Outbreak of COVID-19

According to their practical contributions, the selected studies can be roughly divided into two groups, as shown in Table 3. The majority of studies contribute to exploring and shedding light on how to form a new normal and manage public venues under the post-pandemic period. The rest of the studies learn lessons from the development and operation of isolation hospitals and emergence healthcare hospitals and provide insight into how to fight against the outbreak of pandemic.

Table 3. Practical contributions of selected studies.

COVID-19	Sources	No. of Papers
Form a new normal — Public venue management	[1] [29] [30] [31] [32] [33] [34] [35] [36]	9
Fight against outbreak of COVID-19 — Isolation hospital/ Emergence healthcare hospital	[5] [37] [6] [7] [38]	5

Based on the literature review, FM encounters enormous challenges and trends to be human-centric. FM practices emphasized in the existing studies are summarized in Table 4.

The outbreak and rapid spread of COVID-19 add to the urgency of effective means to control and reduce infectious disease outbreaks and pathogen transmission. Compared with traditional practices of FM management, some anti-pandemic measures of soft FM attract much attention, including keeping social distance and reducing crowding (e.g. [29][31][32]), waste management [5][6][7], and temperature check and record [29][31].

As for hard FM, space management and ventilation system are repeatedly highlighted. The outbreak of pandemic calls for rapid response and real-time management, and the flexibility of space management is of growing importance [5][37]. Blurred boundary of space definition enables establishment of multifunctional venue to satisfy emergence and special purposes [6]. In addition, ventilation plays an important role in air transmission inside buildings. Under the pandemic context, it is expected to reduce the risk of infection through proper ventilation solutions, such as recirculation, pressure regime, and ventilation rate [5][33][36].

Isolation hospitals and emergence healthcare hospitals are built and operated for clinical purposes. Especially, there are essential healthcare facilities and FM measures to treat patients and protect both patients and medical staff members, for instance, decontamination, sterilization, strict separation of pathway arrangement, ventilation systems following the principle of negative pressure, U-shaped airflow inside the isolation ward, and reliable mechanical systems [5][6][7][38]. Both soft and hard FM systems are needed to fully meet such special clinical requirements.

Table 4. FM practices emphasized in the pandemic period.

FM Management	Sources	No. of Papers
Keeping social distance and reducing crowding	[29] [31] [32] [33] [34] [35] [36]	7
Space management	[5] [30] [6] [7] [36]	5
Clinical and medical management	[5] [6] [7] [38]	4
Waste management	[5] [6] [7]	3
Ventilation system	[5] [33] [36]	3
Temperature check and record	[29] [31]	2

4.2. BIM-facilitated FM in the Pandemic Period

As advanced information technology, BIM is anticipated to facilitate FM. Multiple BIM features have been well adopted in FM practices in the pandemic period, as shown in Table 5. Visualization is the most widely adopted BIM feature, since it can provide a concrete and information-rich model and is beneficial to form a common understanding. For instance, in order to support rapid response to infectious disease outbreak, a visualization tool is developed to enhance communication in an interactive manner for occupants and facility managers [1]. Moreover, as a digital representation of all physical and functional properties of a building, BIM is viewed as a centralized database that enables reliable information exchange [29] [30] [31]. BIM can also integrate project information of various stages of the project life cycle and benefit information processing and data transfer from previous stages to the operational stage [38]. Additionally, with the aid of BIM simulation, facility managers are

able to make decisions effectively. For example, in the case of specialty field, a route simulation of patients and clinical personnel simulated clean supplies and waste flows and facilitates the decision of medical and buffer space allocation; results of ventilation simulation validate and verify whether the commingling of fresh air and polluted air was effectively avoided [7]. Finally, various participants with different backgrounds and interests are involved in the operational stage. Zhou [38] argue that BIM provides an avenue to cross-disciplinary collaboration and information sharing at the operational stage in a Fangcang Shelter hospital case.

Table 5. BIM features emphasized in the selected studies.

BIM Features	Sources	No. of Papers
Visualization	[1] [29] [5] [37] [31] [34] [35] [7]	8
Centralized data and model	[29] [30] [31] [33] [6] [35] [38]	7
Data storage, retrieval, transfer	[1] [29] [5] [37] [31] [38]	6
Simulation	[30] [37] [34] [7] [36] [38]	6
Information sharing and collaboration	[33] [6] [7] [38]	4

Apart from BIM, various advanced technology is adopted in FM practices under the pandemic period, such as Internet of Things [6][33], 5G technology [32] [37], and robot and cloud computing [38].

4.3. Research Methods of the Selected Studies

Research methods conducted by the selected studies are shown in Table 6. Almost half of the studies propose technical methods and then adopt them in actual cases. For instance, Li et al. propose an assessment framework for room-level outbreak risks in public buildings and demonstrate its efficacy by a case [1]. Delval et al. develop a COVID risk analysis tool to analyse infection risks in schools based on their ventilation and pedestrian movements and test it in two schools as a trial [36]. Then, researchers are also keen to learn lessons from typical cases, such as the Wuhan Thunder God Mountain/Leishenshan hospital [7][37] and the Optics Valley Fangcang Shelter Hospital [38]. Moreover, literature review [32][5], questionnaire and Analytical Hierarchy Process (AHP) [6] were conducted in existing studies. Limited research methods restrict our perception towards the pandemic and solutions to combat it and further build a new normal, which calls for various research methods and rich investigation.

Table 6. Research methods of the selected studies.

Research Methods	Sources	No. of Papers
Proposing technical methods and adopting in cases	[1] [29] [30] [31] [35] [36]	6
Describing specific cases	[37] [34] [7] [38]	4
Literature review	[32] [5]	2
Other methods	[33] [6]	2

5. Conclusions and Further Research

With the aim to identify varying FM requirements and to investigate how BIM-facilitated FM copes with changing requests in the pandemic period, a systematic literature review was conducted. The majority of studies focus on anti-infection operation management in public buildings, which indicates that the focus of existing studies trends to shed light on how to form a new norm and co-exist with the pandemic in a long term. Also, it is necessary to learn lessons from past experience, for example, development and operation of hospital for special purposes, to summarize and reflect how to fight against the outbreak of pandemic well.

Compared with previous operation management, current FM becomes more public health-centric and anti-pandemic. For soft FM, measures to reduce infection risks are stressed, including keeping social distance and reducing crowding, waste management, and temperature check and record. For hard FM, flexibility of space transformation for emergency purpose and effective and sufficient ventilation have been repeatedly emphasized. In hospitals for special purposes, a large number of clinical requirements need to be satisfied and supported by both soft and hard FM. BIM is viewed as a facilitator for FM efficiency. It is evidenced that various BIM features have been adopted in FM practices under the pandemic period, such as information management, visualization, and simulation. BIM indeed facilitates FM, especially space allocation and ventilation optimization, in real cases. However, it is observed that few innovative BIM adoptions appear, which calls for more technology innovation or innovative usage in the future. Additionally, research methods conducted in existing studies are limited. Various research methods and rich investigation are expected.

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