Improving facility management of public hospitals in Iran using building information modeling

Amin Alvanchi 1,*, Abolfazl Seyrfar 2

1- Assistant professor, Department of Civil Engineering, Sharif University of Technology, alvanchi@sharif.edu

2- MSc Student, Department of Civil Engineering, Sharif University of Technology, abolfazl.seyrfar@gmail.com

* Corresponding author

Abstract:
Improving management of complex and congested facilities in hospital buildings is a potential point for both reducing money spent and enhancing quality level of the medical services provided in public hospitals of Iran. Although building information modeling (BIM) is identified as an effective tool for improving facility management (FM), use of advantages it offers to the FM processes of hospitals has been neglected thus far in the country. To address this issue, this research aims to investigate the BIM capabilities and the supporting organizational structure public hospitals in Iran can adopt to improve their FM processes. A comprehensive literature review was conducted on applicable capabilities of BIM to the FM processes. Hierarchical FM structure of public hospitals in the country was recognized through review of the related regulations. A public hospital case was chosen for an in-depth recognition of FM processes operations and validation of the proposed BIM-based improvements. It was argued the use of BIM capabilities can cause substantial improvements in the FM processes of the public hospitals.
Reduced duration of FM activities, improved facility layouts, enhanced communication and coordination, facilitated training, and improved emergency management are some expected outcomes.

**Keywords:** Building information modeling; Facility management; Public hospitals; Hospital building

1- Introduction

Hospitals are complex organizations with various stakeholders, facilities and materials closely linked and working together to accomplish their vital missions, i.e., curing patients in need and improving public health. The complex combination of people with different organizational roles and various types of materials and facilities working together in a variety of sensitive medical procedures makes operating costs of hospitals among the highest in the public service organizations [1] [2]. As World Health Organization [3] reports, government expenditure on health exceeds 14% of total government’s expenditure globally. Despite high cost spent on different hospital operations, a single slight flaw in any parts of this complex organization may cause dire consequences and create significant dissatisfaction. Efforts on improving different parts of hospital management resulting in quality enhancement and cost reduction are valuable to the society.

Meanwhile, a variety of medical and non-medical equipment used in hospitals and diversity of utility demanding medical services make hospitals utility systems among the most congested and complex utilities in public buildings [4]. Furthermore, the high pace of advances in medical equipment technologies in recent decade compels hospitals to continually install new medical equipment to maintain their operability and competitiveness in this highly competitive market. Cost consuming modifications to the utility systems become necessary to support new medical equipment. Poor hospital facility management (FM), though, can add to the costs of these modifications. Prolonged activities, frequent disruption to regular hospital operations and short or excessive supply of utility services are some examples resulting from poor FM during new equipment installation and utility modification [5]. A
proper FM not only considerably contributes to the final operational cost of hospitals, but it also improves the quality of medical services provided.

According to Gallaheer et al. [6], retrieving equipment specifications and its past records absorbs a considerable time in FM activities; expediting access to this information can improve FM performance. However, without a reliable tool, a considerable portion of valuable historical equipment records are lost or become difficult to access over the equipment’s lifecycle [6] [7]. Use of a dependable information management infrastructure can considerably improve FM processes [8]. Meanwhile, research efforts show building information modeling (BIM) expedites access to the building components information and assists hospital facility management team to promptly decide and respond to the problems occurred [9]. Research efforts indicate operation and maintenance phase of constructed structures absorbs the majority of costs spent over their lifecycles [10] [11]. Nevertheless, most BIM research efforts are focused on applications of BIM in design and construction phases [12]. Identified capabilities of BIM nominate it as a suitable tool applicable to various aspects of FM processes, such as quality control, energy management, maintenance and repair, and equipment installation and supervision [5]. With this perspective, the large building structure and congested utility system components of hospitals and delicate services provided in them justify efforts to properly incorporate BIM capabilities to improve FM processes in hospitals.

Annually about 6.6% of Iran’s GDP is spent on healthcare. 40.4% of this amount is spent by the government which constitutes 17% of the total annual governmental budget [3]. A major part of this budget is spent on 537 public hospitals, funded and managed by the government [13]. Despite the huge money spent on public hospitals, satisfaction level from the healthcare system in the country is still low. For example, hospitals satisfaction level of 20.7% was reported by Farzadi et al. [14] and 32.8% was reported by Maharlouei et al. [15]. Despite reported capabilities of BIM for improving FM processes, there is no research found in the country to incorporate BIM in the FM processes of the hospitals. To respond to this shortfall, this research assessed the possibility of incorporating different capabilities of BIM in the FM processes of public hospitals in Iran. Following, in Section 2, research methodology and
different steps taken in the research is presented. In Section 3, different aspects of research efforts conducted for using BIM in FM processes are discussed. Current hierarchical structure of public hospitals and the way it affects FM processes of hospitals is briefly introduced in Section 4. An in-depth recognition achieved and analysis made in the public hospital case of HashemiNejad, in Tehran, Iran, is presented in Section 5. In Section 6, the recommended implementation architecture which supports the proposed BIM-based FM processes of the public hospitals in the county are presented. The research is concluded in Section 7.

2-Methodology

The research was conducted in five main steps. First, a comprehensive literature review of various advantages and disadvantages identified for using BIM in FM processes was performed. In parallel to the first step, the hierarchical structure of public hospitals and the way it affects the FM processes in these hospitals in Iran was recognized. The case of HashemiNejad public hospital in Tehran, Iran, was studied in step three to recognize operational details of FM processes in a sample public hospital. In step four, various BIM capabilities in FM processes were analyzed and capabilities found suitable for the current situation of the hospital were proposed. A pilot implementation, then, was conducted to verify the applicability and appropriateness of the proposed modifications in connection with the FM crew in the hospital. Finally, in step five a supporting architecture for implementation of the proposed improvements in public hospitals was recommended. The proposed recommendations were based on the current implementation methods found in the literature and the current condition of the FM processes in the public hospitals in Iran. Figure 1 summarizes different steps taken in the research.

3- Use of BIM in FM processes

FM is defined by the International Facility Management Association [16] as “the practice of coordinating the physical workplace with the people and work of the organization; it integrates the principles of business administration, architecture and the behavioral and engineering sciences”. Working commission on facilities management and maintenance in the international council for research and innovation in
building and construction (CIB) considers four main scope areas for facility management. These scope areas include financial management, space management, operational management, and behavioral management [17] which cover a wide range of activities for FM during the operation phase of a building.

In this perspective, in hospital buildings with complex medical services provided during the operation phase, FM is a key support for the sensitive medical procedures performed. Facility managers need to handle and utilize a broad range of information from the buildings, operations, equipment, patients, and employees [18]. A comprehensive literature review conducted on the FM of the hospitals by Yousefli et al. [19] identified the use of information technology as a main trend in the recent research for developing cost-efficient and reliable FM processes. Here, BIM is seen as the main platform for facilitating the communication and maintenance of the information [19].

In many past research efforts identified potential applications of BIM were tested, analyzed and improved. Implementation challenges of BIM-based FM were also reported. Among a variety of constructed structures, incorporation of BIM in FM of public buildings, e.g., educational building [20] [21], city hall complex [22] [23], and hospital [4] [9] [18] [24] [25] [26] has been followed the most. Here, different benefits and challenges of using BIM in FM processes were reported. It was reported that use of BIM can improve FM processes in multiple directions including, 1) shortening work order durations, 2) analyzing multiple possible modification scenarios through three dimensional models of buildings, 3) facilitating training process of various FM stakeholders, 4) analyzing emergency conditions, 5) facilitating real-time data access by storing equipment maintenance history on model, 6) attaching statutory compliance data and work standards, and 7) controlling and Monitoring energy.

Despite numerous benefits reported, past research [27] [28] [29] found BIM applications in FM still at the initial and emerging stages and encouraged further research to address the existing implementation challenges. Challenges found in these research efforts for incorporation of BIM in FM can be summarized as: absence of structured method for incorporating BIM in FM processes; lack of proper tools for demonstrating BIM benefits to FM; limited knowledge on types of information to be collected and
methods and tools to be used for applying BIM in FM; too much detailed specifications required for BIM development; lack of expertise for working with BIM in public organizations; resistance to change previously adopted methods; and challenges for linking BIM to the current tools used in FM. Furthermore, the past research conducted on incorporation of BIM in FM processes of hospitals was mainly focused on single hospital cases rather than the network of hospitals. To address the existing gaps and challenges, this research aimed to propose an implementation method of BIM-based FM processes for the networks of public hospitals in Iran while the existing technological and organizational challenges are accounted.

The global acceptance of BIM as an efficient tool for managing different phases of the building project lifecycle has urged development of an open data format interoperable between various contributing disciplines. The industry foundation classes (IFC) developed by buildingSMART, a non-profit organization, aimed to create this open file format [30]. Since 2013, the IFC has become an international standard of ISO 16739 for data sharing in the construction and facility management industries [31]. Currently, IFC is supported by the majority of BIM software applications and it is considered as the main file format in the development of the BIM-based FM processes [32] [33]. Specification of the information items in different parts of the BIM models is another challenging aspect in the development of the BIM-based FM processes. The construction operations building information exchange (COBIE) [34] is a major step taken to define standard information items applicable in BIM-based models of FM processes. The COBIE has a lifecycle view to the integration of BIM and building projects with regard to the design, construction, and operation and maintenance phases. Ever since the COBIE has become a standard information items structure in many developed BIM-based FM processes (e.g., [35] [36] [37]).

Proper set up of a 3D model is the initial step for employing BIM in FM processes. New 3D model development is required when BIM-based FM processes are being employed in existing buildings with no 3D model available. 3D model development for such buildings starts with collecting spatial data of the buildings using either existing as-built 2D drawings [38], direct measurement and observation, or new
technologies such as laser scanning and photogrammetry [39]. Initial spatial data are processed to form a 3D model with meaningful objects [40]. Gradually, a variety of information required for FM is embedded within the object-oriented BIM model, forming the BIM cloud accessible for different FM contributors [39]. Here, a major challenge is capturing spatial data of various concealed building components adapted during the building’s operation phase [41]. Setting a proper security management is vital to assure right people access data in the appropriate circumstances [42]. A proper security management is also required to avoid different project contributors lose interest in incorporating their related data into the BIM cloud [43]. Facilitated access to various building components is one of the major capabilities of BIM-based FM processes. To improve this capability, BIM models benefit from new technologies such as mobile augmented reality [44], radio frequency identification (RFID) tags [45] and even smartphones and tablets [46].

4-FM Structure of Public Hospitals in Iran

Before identifying the operational details of FM processes in the public hospitals a holistic view to the hierarchical structure and current condition of FM processes in public hospitals was obtained. Related regulations and references were studied and discussed with people working in the public healthcare system. The healthcare system in Iran has a unique hierarchical structure. In this structure medical universities, under supervision of the Ministry of Health and Medical Education (MOHME), are responsible for providing health services, managing public hospitals, monitoring the private sector, and conducting medical research and education [47]. The dean of a medical university is the highest authority for all public hospitals in a specified geographical area, e.g. a province, and must report to the MOHME [48]. About 75% of Iran’s hospital beds are in the public hospitals owned by MOHME, 16% are owned by other governmental bodies, and only 9% of them are privately owned [49]. It was estimated that more than 50% of hospitals in the country are worn out, many of which are poorly maintained [50], resulting in the high maintenance and repair costs. Public hospitals are highly demanded because of their low medical service prices [51]; high deterioration rates are seen as results. Given the ownership of MOHME on
public hospitals and its responsibility in making health-related policies, MOHME has recently enforced public hospitals to input all maintenance expense data to a web-based computerized maintenance management system (CMMS). It is estimated that this new system has reduced 40% of the life cycle costs of physical resources in public hospitals [52].

5- Case Study: FM processes of Hasheminejad Public Hospital

The case study of Hasheminejad public hospital, with more than 12,000 square meters area and 151 active beds in Tehran, Iran, was carried out in the research. In this case study different aspects of FM processes in public hospitals were recognized and potential points of improvement BIM can make to FM of public hospitals were identified. This hospital was selected among several available choices because of its reputation in its organized FM and effective implementation of MOHME’s new CMMS. HashemiNejad Hospital is relatively old hospital serving the society since 1957. In 1985 it became a national center for treating kidney disease. Following, different steps taken in this case study are explained.

5-1- Recognizing the FM processes

Initial interviews with FM crews, including medical-facility manager, facility maintenance supervisor and three members of facility maintenance team, were conducted to draw an overall view of the hospital’s FM process. Then, available FM documents in the hospital, including mission and policy statement, code of conduct, manual of procedures, and instructions, were reviewed. Finally, different parts of the FM processes and operations were closely observed in a two-week of shadowing. Recognitions achieved during the case study are presented into two parts including FM organizational structure and main FM processes.

• The hospital’s FM organization

The main organization of FM team in the HashemiNejad Hospital is comprised of the medical equipment section and the mechanical, electrical and plumbing (MEP) section. The FM team consists of 12 crew
including oxygen supplier, construction manager, powerhouse team, electrician team, sewage treatment plant, welder, plumber, secretary and the head of the team. The main organizational duties of the FM team is divided into five main categories, including preventive maintenance and periodic inspection, calibration and quality control of equipment, repair of ruined or damaged equipment and facilities, managing changes in hospital spaces, facility procurement and installing medical equipment and facilities.

- **Main FM processes**

Assigned duties to the FM team were done through five main complementing processes interacting with four stakeholders outside the team, including hospital manager, maintenance contractors, hospital personnel and Iran Medical University. The main five work processes identified in the FM processes were: 1) conducting periodical inspections, 2) report evaluation, 3) performing repair and maintenance works, 4) procurement, and 5) Performance report preparation. Data flow diagram (DFD) was used as the main recognition tool in this research. It is a powerful tool for capturing and structurally summarizing recognition achieved from different parts of the FM process. A holistic view of the entire FM processes and internal data interactions of the sample public hospital is presented in the FD diagrams in Figure 2. A brief explanation of each process follows.

In the first process of FM, i.e., conducting periodical the inspection, the FM team inspects and monitors MEP facilities and medical equipment on specified periods in accordance with the standard and/ or instructions set by Iran Medical University. All periodical inspections performed are reported to the University in paper forms. In the second process, report evaluation, reports prepared by FM team and external maintenance contractors as well as requests received from other hospital personnel are carefully read and evaluated. Further actions, e.g., maintenance and repair activities required, are determined based on their priorities and constraints. Subsequently, in the third process, performing maintenance and repair work, activities assigned to the related FM team crew are conducted according to the prepared schedule. During maintenance and repair activities list of items required for completing maintenance and repair
activities are prepared. In the procurement process the price of the required items are reported to the hospital manager to receive his approval. Then, items are purchased and sent to the FM team to complete the maintenance and repair activities. In the fifth process, preparing performance report, various maintenance, repair, and procurement activity reports are prepared in the form of performance reports and are sent to the Iran Medical University and the hospital manager. It should be noted that different parts of the FM processes explained here and presented in the form of the DFD in Figure 2 represent the specific condition of the sample public hospital in Iran. Not necessarily it can be adopted for hospitals in other countries. Separate recognition steps need to be undertaken in such cases.

5-2- Analyzing Capabilities of BIM

The applicability of various capabilities of BIM, identified in the literature [5] [10] [24] [39], was analyzed based on recognition obtained from different parts of the FM. The created BIM maturity matrix [53] represented a low level of BIM maturity of the hospital’s organization. Furthermore, three main constraints and requirements were considered for adopting the BIM capabilities, including:

- Forcing minimal changes to the existing organization, to receive minimal resistance from the personnel.
- Minimal money investment to be considered, as a result of limitations in the public budget.
- Minimal academic engineering background to be supposed for the FM team members, since most of them have practical experiences, rather than formal engineering training. In this perspective, FM crew should not be accounted for BIM model development and maintenance.

MOHME required hospitals to maintain most updated as-built hospital drawings. In the case of HashemiNejad Hospital, since FM team member were not able to update 2D drawing’s, the hospital manager hired an engineering consulting company five years ago to update the 2D drawings. The hospital’s architectural, structural and utility systems were updated based on the old drawings and FM team input. Ever since, however, FM team has not updated modifications made to the hospital building.
So, first modification proposed to the hospital FM processes was to develop BIM-based models of the hospital building rather than 2D CAD models. The drafting or consulting company hired for preparing the BIM model needs to stay linked to the hospital for the periodical, e.g., semiannual or annual, updates based on modifications made to the hospital building over time. It is expected that, after the development of the initial BIM models, updating BIM-based models costs less compared to the 2D model updates.

Recommendations for adoption or rejection of different BIM capabilities in the public hospitals’ FM processes were made in regard to the identified constraints and requirements. Our analysis on adoption or rejection of different capabilities of BIM results in recommending six capabilities of BIM to be incorporated for improving the FM process. Recommended capabilities include: 1) locating building components, 2) new equipment layout and installation management [5], 3) coordination of FM staff (Eastman et al., 2011), 4) communication with medical and other non-technical personnel [4], 5) training contractors and personnel [5], and 6) emergency management [54]. For all recommended capabilities it was considered that minimal money investment and organizational changes are imposed on the hospital and FM crew could manage them by attending short training sessions. The rejected capabilities include: 1) storing equipment maintenance history, 2) attaching statutory compliance data and work standards [28], and 3) controlling and monitoring energy using BIM [55]. Implementation of these capabilities required either holding intensive training sessions for current FM team members or hiring new FM crew with the proper level of education. Furthermore, money investment should be made to equip the hospital with new computer hardware and software. A brief explanation of how recommended capabilities can contribute to the FM processes improvement and their implementation methods is provided in below.

- **Locating building components**

Currently, the FM team members depend on their memories for locating buried facilities. They have difficulties reading separated 2D drawings of the hospital building’s architectural, structural and utility systems which is an error-prone, time consuming and costly process. In some cases, the FM team was
forced to cut walls, floors, and ceilings to locate the facilities. For example, as per FM team member explained, mistakes made in locating the exact location of the air ducts caused the construction a new washroom unit in the ICU sector to cease. Figure 3 shows another example of the demolition performed by FM team for locating the facilities during the shadowing process of the research team in the hospital.

In the BIM model, integration of various types of drawings, 3D visualization of building components, and use of search and filter options can highly facilitate the locating process of different building components [5]. In this situation, FM crew is able to locate various components in the hospital building by navigating a prepared BIM model and searching for the identification number of different building components. No trial and error demolish experiences is required anymore.

• **New equipment layout and installation management**

Layout and installation management of new medical equipment purchased for the hospital is one responsibility of FM team. Selecting adequate moving route, finding the proper location, and installation of big size equipment gets quite challenging for FM team in the hospital. By using BIM model it is possible to visualize different spaces and their specifications in 3D views. It allows FM crew to check different possible moving routes and installation scenarios, to find the best possible choices, and to avoid trial and error approach. Furthermore, use of BIM helps the FM team more easily involve related medical personnel, who are more familiar with new equipment’s operational requirements, in this process to find the best possible layout.

• **Coordination of FM staff**

FM crew needs to access a wide range of information about target facilities to conduct their maintenance, repair, replacement, and inspection activities. Currently, for more complicated FM activities, which require coordination of several FM team members, they form coordination meetings. In the coordination team different aspects of the work is discussed by sharing past experiences and understandings about the facility and outlining each team member’s work steps on pieces of papers. Use of 3D views provided by
BIM models facilitates this coordination by demonstrating different aspects of the target facilities and assisting communication of team members [39].

• **Communication with medical and other non-technical personnel**

Frequently FM team members receive requests from different non-technical personnel, including managers, physicians, nurses, and administrative staff which are neither feasible nor applicable due to the technical limitations. Explaining these limitations to the hospital personnel is a big and time-consuming issue for the FM team and it is often seen as unacceptable excuses by the hospital personnel. Use of 2D models usually does not help since FM team members are not comfortable working with them. Furthermore, they are barely understandable for non-technical staff. In this perspective, FM crew can use 3D views provided by BIM model to explain existing limitations and embrace non-technical staff for finding alternative solutions.

• **Training contractors and personnel**

The diversity of various facilities used in hospital buildings necessitates the use of external contractors providing different types of facility management services. All these contractors require proper understandings from different parts of the hospital buildings. They need to receive orientations about different parts of the hospital and get trained by the FM team which in overall is in charge of the hospitals FM. Furthermore, in the following three situations, training becomes important for FM team members as well [5]:

1. Hiring a new FM staff: If a new member is hired in the FM team, the new member must become familiar with the work processes, MEP systems, hospital equipment, and facilities.

2. Changing the work processes: If the work process in a sector or department undergoes a serious change, these changes can be due to the introduction of a new instruction or standard.
3. Installing new equipment and facilities: When new equipment or facilities are installed in the hospital, FM team members need to be trained in accordance with the new equipment requirements. The current training process is conducted without any auxiliary tool involved by directly taking trainees to locations various facilities are placed and explaining related information to the trainee which is very time-consuming. But with the help of 3D navigations provided by BIM models trainee can get familiar with specifications of many facilities and see the required information. In addition, they can refer to the BIM model whenever maintenance and repair activities are assigned to them.

• **Emergency Management**

In case of emergency situations, e.g., earthquake, fire, and thunderstorm, quick access to the hospital building information is vital in order to be able to promptly bring the situation under control and help the ones in need. Currently, the HashemiNejad hospital building’s drawings are stored inside the hospital and in paper formats which can easily become inaccessible in the cases of emergency situations. Use of BIM models which could also be stored in different MOHME’s computers minimizes the risk of losing access to the hospital building’s model in the case of emergency. Another potential problem in HashemiNejad hospital is lack of emergency plans and preparedness which can substantially suffer the hospital in cases of emergency situations. It is proposed that an emergency committee including different stakeholders in the hospital is formed and regular emergency coordination meeting is held. A representative from FM team should attend the meetings and walk committee members through different parts of the hospital buildings using the developed BIM model during the development of operational emergency response plans. BIM models are also used for conducting emergency training sessions, emergency tests, identifying unsafe areas, and mounting emergency signs and alerts in proper locations of the hospital building.

5-3- **Pilot implementation of the proposed improvements**
In order to test the applicability of the proposed FM improvements, they were implemented in the surgical department of HashemiNejad hospital located on the first floor with seven operating rooms and nine recovery beds. The surgical department was selected since it has the complex set of highly sensitive facilities to be operated and maintained [56]. Furthermore, fairly accurate as-built 2D drawings, to be used for BIM model developments, are available. Several modification plans were in this department for near future which could benefit from the proposed improved capabilities of BIM. The department’s ventilation system did not allow different surgical rooms to independently adjust their temperatures according to the specific needs and conditions of patients. Besides, the ventilation system was also crucial to prevent the transmission of the airborne infection to the patients [57]. Upgrading the ventilation system to an independently adjustable system was desired. Furthermore, all entries to and exits from this department were made through the only existing door in the department which did not properly support the traffic. No emergency exit was also built for the department. Building a new door for this department which could help better traffic management and be used for the emergency situations was also another planned modification.

The BIM model of the surgical department was developed in Revit 2017 software by a collaborating drafting company based on 2D architectural and MEP CAD drawings with input from the FM team (Figure 4). In order to evaluate the applicability of the proposed improvements in the FM processes, the developed BIM model and its navigation capability was presented to the FM team members on both computer screen and papers (Figure 5). Implementation of each proposed improvement in FM processes was, then, reviewed by FM team members. The team was quite welcoming and positive with the applicability and benefits the proposed improvements could bring to the FM processes of the Hospital. In an exercise, the BIM model was used in locating the best place for the second door of the surgical department by involving several other stakeholders to help them to determine the location of the door. In another practice, FM team members were encouraged to use the model to analyze the ventilation system and air channels and assess required modifications to meet the patients' needs.
6- Implementation Architecture

Since the nature of activities conducted in FM processes is quite different from those implemented in the design and construction of buildings, integration of BIM technologies in FM processes requires different implementation architectures than design and construction phases [58]. Here, we divided implementation architecture of BIM in FM processes into three following main parts; 1) defining applicable information items of BIM models for FM processes, 2) providing proper platforms to support BIM models for various staff working at different levels of the FM organization in different public hospitals, and 3) determining the methods BIM software and operational data created in FM processes are updated and maintained over the building’s lifecycle. Different parts of the implementation architecture were recommended according to the specific condition identified for the public hospitals in the country and recent achievements reported in the literature.

In the first part of the BIM implementation architecture applicable information items of BIM models for FM processes were determined. Many practitioners have adopted COBIE standard in their BIM-based FM processes (e.g., [35] [36] [37]. But, since the use of BIM in FM processes in many cases happens with no past records of BIM, many researchers prefer using a customized data structure for integrating BIM in FM processes [33]. Meanwhile, review of different related research efforts indicated that a wide range of tools were used for linking BIM and FM computer software (or CMMS) while the use of spreadsheets and third-party middleware (e.g., EcoDomus, Onuma Systems, and FM Interact) were two main approaches adopted [21]. IT and engineering background weakness of the current FM crews in the public hospitals and budgetary limitations of public hospitals were the main constraints considered for the recommended architecture. In this perspective, holding expensive long-term training programs for the current FM crews or hiring new high-paid qualified FM personnel being able to work with BIM models were discarded for the initial implementation. Therefore, at the initial stage of BIM implementation, it was recommended that minimum changes are made to the current organization and minimum possible
information items are added to the BIM models. Maintenance operations applied to various hospital facilities identified in the 3D models could be recorded in the existing CMMS using the same identification numbers. Nevertheless, gradually integration level of FM processes with the BIM models could be increased as BIM maturity level of the organization increases [29].

The rapid growth and publicity of high-speed internet and the distributed nature of building components has encouraged major BIM software developers and many researchers (e.g., [58] [59] [60]) to develop web-based BIM 3D navigation platforms run on portable smartphones and tablets. In addition to the facilitated use of 3D models in this approach, FM processes dependency on the expensive standalone BIM software programs installed on high-performance desktop computers is reduced and multi-purpose and widely accessible smartphones and tablets take the place. In most public hospitals currently available computers and high-speed internet connections can support the web-based approach. Use of this web-based approach was recommended in the second part of the implementation architecture.

For the public hospitals, specific instructions and mandates are set by the government to input FM operational data through currently developed CMMS which are supposed to be followed in the third part of the recommended implementation architecture. Furthermore, it was recommended that MOHME centrally maintains most updated BIM models and provides web-based access to the 3D views of the updated BIM models to the hospitals. This approach takes the advantage of the centralized management and ownership of public hospitals by MOHME and helps public hospitals overcome IT and engineering background weaknesses of FM crews. Figure 6 represents recommended implementation architecture of the BIM-based FM of public hospitals.

7- Conclusion

In this research, the applicability of various identified improvements BIM can bring to the FM processes of public hospitals in Iran was investigated. Data was collected from different aspects of Iran’s public health system and a case study of HashemiNejad public hospital in Tehran, Iran, was conducted.
Budgetary constraints and low IT and engineering background level of FM crew are two main criteria identified for the proposed BIM-based FM process. It is argued that use of capability of BIM models in conjunction with the existing CMMS improves the FM processes in six different aspects including locating building components, coordination of FM, layout planning of new facilities, communication with medical and non-technical hospital personnel, training new FM crew, and emergency management. Applicability of the proposed improvements was tested in a pilot BIM model development of the hospital’s surgical department and incorporating FM team members in the implementation of different improvements proposed. The proposed improvements were welcomed by FM crew and they acknowledged their applicability in the FM process. Finally, to implement the proposed improvements in FM processes of different public hospitals in the country an implementation architecture, which suits the current organizational structure of public health system and considers its main constraints, was recommended.

Forcing drastic changes and high investment costs were two main constraints frequently seen during the implementation process of new IT-based systems [61]. Although various BIM features could improve FM performance, it was expected that sudden changes to the processes result in high resistance from different stakeholders and slow down or even block implementation of the new processes. To avoid facing this problem, minimal changes to the current FM processes were considered.

This research is the first research conducted for incorporating BIM in the FM processes of the network of hospitals and opens a new era for future improvement of FM processes of the network of public or private hospitals. With the current extent of FM activities in the aging public hospital buildings in the country, the proposed implementation architecture can bring considerable saving to HOHME’s costs in a long run. Furthermore, it should be noted that the proposed improvements in the research only present the beginning of the long way of incorporating BIM in the FM of public hospitals. Advanced features of BIM gradually can be merged to the FM processes while BIM culture is built among FM team members and other hospitals’ personnel. Of course, before engagement of these new features in public hospitals’ FM processes further research needs to be conducted to analyze feedback from the implementation of the
currently proposed improvements and plan for implementation of new features. Results achieved in this study are presented to MOHME decision makers to encourage them for implementation of the proposed improvements in the public hospitals.

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Amin Alvanchi:

Amin Alvanchi is an assistant professor in the Department of Civil Engineering, with specialization in construction engineering and management, at the Sharif University of Technology, Tehran, Iran since February 2013. He has received his Ph.D. in construction engineering and management from the University of Alberta, Canada in 2011. His area of research focuses on building information modeling, construction project management, construction operation simulation and contract administration.

Abolfazl Seyrfar

Abolfazl Seyrfar is an MSc graduate student at Construction Engineering Management, the Sharif University of Technology since September 2015. He has recently been admitted continuing his studies at the Ph.D. level at the University of Illinois, Chicago, United States.

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