Enablers for BIM application in architectural design: A robust exploratory factor analysis approach

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Abstract:

Professional architects with several years of experience in various projects have unique methods to design an architectural work. One of these approaches is to leverage the value of emerging information technologies such as Building Information Modeling (BIM) in architectural design. Leveraging these potentials requires promoting an appropriate context for the implementation and adoption of these new technologies. In response to the turbulent and multifaceted socio-technical nature of modern information technologies and the environmental uncertainty, architects enhance enablers to advance the architectural design process. Enablers are the preeminent factors that facilitate the implementation of new technologies and contribute to the sustainable development of projects and organizations. Given the lack of dedicated studies on the enablers affecting BIM application, this study aims to identify and classify these enablers in the architectural design phase. Following a systematic literature review approach, a comprehensive list of enablers for BIM application in the architectural design phase was identified. The prepared survey questionnaire was distributed to 205 construction experts (i.e., project managers, employers, consultants, and contractors). The collected data were analyzed with the Robust Exploratory Factor Analysis method, ended up with classifying 36 enablers into four main categories: human skills, environmental, technological, and organizational factors. The findings of this study, considering the organizational enablers, recommend that the support of government officials to implement a particular validation process for BIM adoption is crucial. The contribution of this research lies in identifying and classifying enablers for BIM application in the architectural design phase, with the potentials to be applied in real work practices to improve BIM capabilities and enhance BIM initiatives in construction projects.

Keywords: Architectural Design; BIM Enablers; Building Information Modeling (BIM); Robust Exploratory Factor Analysis (EFA); IT Value for the Construction Industry.

1. Introduction

The significance of architecture becomes more prominent when the boundaries of knowledge, insight, and teaching of architecture were considered academically, and specialization was introduced in human societies, which means that the structure was separated from the architecture and facility experts started their activities in a specialized manner. One of the necessities of architecture is that while it needs innovation and a combination of materials with technology, it should meet the requirements. However, architecture includes the fundamental aspects of buildings and structures. It means that it is responsible for planning, cost estimation, and managing the construction process (de Souza et al. 2009). The architectural design process includes a large number of decisions and their development stages, which finally creates a concept that is composed of several realities that are to be realized by the architect in the future. The construction industry with significant achievements is changing and developing in parallel with other sciences. Today, it is considered a separate engineering discipline. Undoubtedly, the horizons of the experts and specialists of this industry have gone beyond what is considered to meet the requirements and application of engineering knowledge. In this regard, the application of BIM in the construction industry with the advent of technology and new approaches has transformed this technical and engineering field (Tulubas Gokuc and Arditi 2017).

Since 2002, the BIM approach has been used as an information source for integration, a graphical design with 2D and 3D maps along with factors such as geographical location, type of building, construction materials, and weather data (Ebrahimi et al. 2019). Given the significant efficiency and welcome of architectural companies, the number of users, companies, and consultants who apply BIM to improve the accuracy and quality of their projects is increasing. In Building Information Modeling (BIM), the design method is transformed, and the designs are done on a single model. This method results in a reduced number of ambiguous and confusing models, the possibility of simultaneous design by different designers on one model, and reduced designs' interferences. This system designs, processes, and produces software documents for buildings using modern computer and information modeling methods. In this way, it develops knowledge bases for construction projects that, while creating a digital virtual space, facilitate access to databases and economization of possible changes and reforms (Ghamkhar 2012). This design method is significantly different from the previous traditional methods. Accordingly, companies, particularly architectural companies that used to design buildings by a traditional approach, need a specific executive plan to determine the position of individuals and their duties to prevent interference. Implementing these approaches requires creating an appropriate context for the acceptance and development of related technology. Managers use enablers to moderate the uncertain and complex conditions of the organizations. At the organizational level, enablers are defined as providing an innovative and agile environment using management support and participation and focus on customers to achieve the desired goals (Quinn and Spreitzer 1997).

In this regard, Migilinskas et al. (2013) evaluated the influential factors regarding the challenges and benefits of BIM acceptance and application and identified 22 key factors. Morlhorn et al. (2014) also evaluated the factors affecting the success of BIM systems and concluded that various maturity levels should be considered to improve the acceptance of such a system. Hyojoo et al. (2015) studied the factors affecting the acceptance and proper application of BIM systems. They indicated that the most important factors are management support, custom creation, compatibility with needs, and the availability of applied software. Cao et al. (2015) examined the significance and necessity of using BIM systems in China and concluded that the success of such a system at first depends on the project itself, secondly on the support of the owner or applicant. In addition, they found that the availability and type of the software have also significantly influenced the success of

this system in China. Arunkumar and et al. (2018) studied the positive and negative factors influencing BIM implementation in the manufacturing industry and presented strategies for implementing BIM on a large scale. In addition, this study evaluates the benefits of using BIM and the barriers to its implementation. Another study conducted by Phuoc Luong Le et al. (2019) identified barriers and empowerments that contributed to the improvement of supply chain performance through the use of BIM, and concluded that issues such as the role of governance in adopting this approach, Issues related to education, cost and expertise are of particular importance.
Despite various studies conducted about the factors affecting BIM application (hereinafter referred to as enablers), and even though more than one decade has passed since the introduction of BIM in the construction industry, these enablers still have not been used to accelerate and facilitate BIM implementation in the construction industry. Because the identification of BIM enablers in different projects affect its alignment with changes in the project at different times and also maximum coverage of its capabilities and also providing this possibility for the project to create a more suitable context for facilitating the implementation of BIM at the early stages of design and improving its effectiveness, so the identification and qualitative and quantitative evaluation of enablers is very important for its acceptance and development. Accordingly, this study tries to identify and classify these enablers in the architectural design phase.

2. Research Literature

In this section, given the purpose of the research, we evaluate the existing studies related to BIM application in architectural design and introduce the concept of enablers.

2.1 BIM application in architectural design

Architecture has developed significantly since the introduction of computers. One of these changes is a cultural process of collaboration and information sharing using the digital capability calling BIM. Building information modeling produces outstanding results in building processes by sharing knowledge throughout its life cycle from conceptual design to management (Abd Jamil and Fathi 2018).
BIM is a method that allows architects to create digital design simulations to manage all the information related to an architectural project. In 2002, AutoDesk published a white paper entitled "Building Information Modeling" that introduced a new approach for collaboration in the construction, and its technology was focused on a database. Since then, the use of the term BIM became common. However, unlike the current popular view, where everything, from 3D models to digitalized architectural applications, is considered BIM, most of these technologies are not evolutionary (MRICS 2020).
Nowadays, architects and particularly designers are the foremost activists in BIM development and implementation in advanced construction. Almost all BIM programs have the capability of communicating and adapting with other parts of architecture or specialized versions of architecture and other modules and programs (structure, electronic and mechanical facilities, etc.) (Gamayunova and Vatin 2015). In the architectural design phase, BIM technology is something beyond a drawing tool. It allows the architect to design a parametric structural model that enables the user to observe the volume aspects, to estimate costs, to examine the quality and quantity of materials, to observe and adjust the environmental comfort and other aspects of a project, and to facilitate communication

between many experts of the process (de Souza et al. 2009). This issue significantly improves the quality of communications and consequently the quality of the end product.

The main point considering that any architect around the world is currently required to use any tool or method of BIM, in fact, depends on the country they are working in and their customers and their expectations for the project output. Usually, the selection of BIM tools to determine the project specifications is not dictated by the customer, even when BIM deliveries are constrained by the country, market, customer, and project conditions. Each architect is free to select one BIM tool that meets its customer’s information exchange needs (Laiserin 2010). According to the literature, BIM is used at the initial stage of design (55%), detailed design and tender (52%), construction stage (35%), feasibility stage (27%), and operation and maintenance stage (9%) (Eadie et al. 2013). However, the future of BIM is challenging.

Kouch et al. (2018), Examined the key factors in implementing the BIM framework in small and medium-sized organizations. They stated that the use of BIM technology. It is essential for small and medium enterprises (SMEs) that are active in the construction sector in the construction industry. Most active SME contractors are not aware of building information modeling, nor are they familiar with the BIM implementation framework and its important factors. They stated that although studies on BIM implementation show different approaches and perspectives on challenges and factors, most citations can be divided into five main areas: people, technology, process, organization, and policy.

Vidalakis et al. (2020) focused on a study entitled BIM Approval and Implementation in Small and Medium Enterprises. To reach its full potential, building information modeling must be implemented throughout the supply chain. This study examines and approves BIM among small and medium-sized companies in the UK architecture, engineering, and construction sector. The results show that although SMEs have a conceptual understanding of BIM, they are particularly unfamiliar with existing BIM software support systems. Limited financial capacity is recognized as the main obstacle to BIM, while knowledge exchange initiatives are considered to be the most useful measure to facilitate the implementation of BIM.

According to the study conducted by Olatunji (2010), BIM is a combination of relatively revolutionary ideas for design technology. Although some researchers believe that BIM-related technologies were discovered in the early 80s, many others often consider BIM a new industry model. Moreover, some studies argue that the adoption of BIM is still slow, and there are some concerns about the industry’s reluctance to use BIM in the construction industry. It takes much time for design companies to adopt BIM fully. It is expected that BIM use strengthens collaboration, reduces turmoil in the industry, reduces project cost and time, and better retrieves information (Tulubas Gokuc and Arditi 2017).

The research gap in BIM implementation in the form of modeling is evident in Iranian projects and shows the power of limiting factors in the industry. However, after conducting cognitive studies on building information modeling due to the lack of acceptance of this new technology in the Iranian manufacturing industry, the focus of research has been on investigating the cause by finding obstacles to the use of this technology and existing potentials to encourage industry to use this technology (Shahhosseini et al. 2012).

Neverheless, the results of this research conducted on the levels of applying BIM in Iran show that 30% of Iranian construction companies have used this technology in some parts of their project, and

the rest of them were not very familiar with this technology (Shakeri and Asadi 2015). Meantime, although Virtual Design and Construction (VDC) is more comprehensive than BIM and performs organizational and process analyses accurately (Sen 2012), VDC has new costs and technical obstacles and more change risks than BIM (Kekana T et al. 2014). Given the economic conditions of Iran, as well as the obstacles to using BIM in projects, VDC may be more appropriate to use under better economic conditions in the future.
Since the adoption of BIM tools and processes expands slowly into the global design and construction markets, architects should be careful in selecting and supporting BIM software and methods to develop architectural values and goals. According to most architects, using BIM, whether through innovative forms, optimal performance, innovative techniques, or a combination of them, has always been considered the principal value. However, given the dynamism and rapid changes in technology, this process, in addition to the support of architects, requires the identification and application of factors improving the BIM approach. In the following, we will address the concept of enablers.

2.2 Enablers

An enabler has a heterogeneous meaning in the literature, and various people use it differently based on their existing characteristics and situations. However, the new point is the role of information technology in providing comprehensive and coherent enablers. Perhaps the most crucial support of information technology for enablers is providing correct and timely information with appropriate quality and cost. In addition, information technology can provide new tools that increase the creativity and productivity of employees and the quality of their job. In fact, enablers are one of the strategies to deal with changes and competition. It is a continuous and permanent process and is analyzed at different levels in a dynamic environment. Some of the benefits of enablers are improving the quality of products and services, increasing employees' commitment and management power, enhancing effectiveness, synergy, accountability, and increasing competitive advantage in the global market (Kahvandi et al. 2020). It is not easy to define the relationships between the main factors supporting enablers in projects. An enabler may be defined in one context but play a different role in another context or time (Gulati et al. 2012; Seddon et al. 2010).
Nowadays, the scientific and technological development of societies has become an uncontrollable process. Therefore, the world is observing the development of methods, structures, and processes that, without their application, it is not easily possible to solve the problems of organizations. It means that humans have to equip themselves with new knowledge and technologies to face and solve increasing new issues. Therefore, humans may have at some point in time the knowledge and skills necessary to deal with some phenomena. However, the tangible and hasty scientific changes and developments quickly obsolete their knowledge and skills. So, it is necessary to reconstruct their knowledge and experiences to adapt to those changes (Blanchard 2001). In order to deal with such challenges, people and technology should be enabled, i.e., they should grow in all dimensions. Indeed, the purpose of enablers is to facilitate achieving organizational goals, present the best intellectual and technological resources related to each area of organizational performance, and resolve the obstacles through interaction. Quinn (1997) believes that although enablers can bring organizations competitive advantage and many managers agree on the benefits of using them, most organizations have difficulty in their identification and implementation. The BIM approach is no

exception to this rule. Some obstacles and enablers influence the degree of innovation in BIM application. Depending on which part of the world BIM is to be implemented, different BIM requirements are needed (Solihin and Eastman 2016). In contrast to the need for BIM implementation and meeting the needs and its related infrastructure, obstacles are the main factors inhibiting BIM implementation. In contrast, enables act as the factors used to resolve obstacles (Duncan Rae et al. 2019). Therefore, it is necessary to identify and apply BIM implementation enablers to resolve the existing enablers and their alignment with the project changes at different times and maximum coverage of its capabilities.

This paper investigates the enablers for BIM implementation in the architectural design phase. In the next section, while introducing the research methodology, the steps of identifying these enablers are explained using a systematic literature review, and are analyzed using the robust exploratory factor analysis method.

3. Research Methodology

In this study, using a systematic literature review, at first, a comprehensive list of enablers for BIM implementation in the architectural design phase was developed. The robust exploratory factor analysis method was used to analyze the data in the systematic review process. These methods and the way of their implementation are presented in Figure 1.

Figure 1. The research steps

3.1 Systematic Literature Review

This form of studying the research background includes a review of the evidence that specifies the research problem. In this method, pre-determined and standardized techniques are used to identify and evaluate the related studies and report, collect, and analyze the data obtained from the previous studies (Hanafizadeh and Zareravasan 2020). Usually, this method focuses on one cause and effect empirical question. Since this method is required to search the published and unpublished studies, it is more time-consuming and tedious than the traditional and non-systematic literature review method. Generally, systematic reviews help collect data and evidence; however, the mere use of systematic methods will not guarantee the validity of the review research results. Regardless of the significance and originality of the used sources, this method requires critical evaluation to determine their validity and prove the applicability of the results of the review research (Greenhalgh 2004; Greenhalgh et al. 2005). This review is focused on one question. During the review process, it is tried to answer that question by providing evidence and analyzing it. The final result is obtained from different studies. In order to perform a systematic review in this research, after selecting the desired databases, keywords, and search strategy, it was focused on selecting the research articles. Figure 2 shows seven steps of implementing systematic review based on the research subject and goal:

Figure 2. Steps and the method of systematic review based on classification (Onwuegbuzie and Houston 2016**)**

Step one: Set the question of systematic review

Problem statement and research question design play a guiding and determining role in conducting a systematic review. Considering the significance of the research question, it should be noted that the criteria for selecting and not selecting research for study are determined based on the type of questions. This research question is to find the enablers for BIM application in the architectural design phase of construction projects.

Step two: Set the review method

In order to select and summarize the previous research, specific protocols are used that determine which research is to be studied and which research with what specifications should be excluded from the process (Chang et al. 2006). In order to develop the review strategy, three sections of context, research question and research strategy, and data sources are set as follows:

- ✓ Context: according to the research topic, which identifies the enablers for BIM application in the architectural design phase of construction projects, in the previous sections, we evaluated BIM application in the architectural design phase and the generalities of the enablers.
- ✓ Research question: identifying the enablers for BIM application in the architectural design phase of construction projects
- ✓ The following keywords were considered for the search.

TITLE-ABS-KEY ("Building information management" OR "Building information modelling" OR "Building information modelling" OR BIM) AND TITLE-ABS-KEY ("Enabler" OR " Driver" OR " Facilitator") AND TITLE-ABS-KEY ("architectural design") AND (LIMIT-TO (LANGUAGE, "English")

Primary search:

In this study, the primary database for systematic review was Scopus, which was searched without time limitation. Scopus is the leading abstract and citation scientific database of peer-reviewed literature and offers the highest reliability[1] compared to other sources (Burnham 2006). Among databases such as Web of Science and Google Scholar, Scopus provides access to more than 27 million quotes and abstracts from the 1960s (Adriaanse and Rensleigh 2013). This database indexes a significant number of journals compared to PubMed, Web of Science (WOS), and Google Scholar (Falagas et al. 2008).

Secondary search:

To ensure comprehensive coverage of materials, a secondary search strategy (on Google Scholar) was designed to scan and review all screened study sources. All eligible citations with the inclusion/exclusion criteria described in the previous step were reviewed. In the last step, to ensure that we have not missed any important and relevant article, the review articles in the Google scholar database that were frequently cited and ranked in the top journals, were searched and selected.

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[1] https://www.elsevier.com/solutions/scopus/why-choose-scopus

1- *Abbasnejad, Behzad, et al. "Building Information Modelling (BIM) adoption and implementation enablers in AEC firms: a systematic literature review." Architectural Engineering and Design Management (2020): 1-23.*
2- *Abbasnejad, Behzad, Madhav Nepal, and Robin Drogemuller. "Key enablers for effective management of BIM implementation in construction firms." Proceedings of the CIB World Building Congress 2016: Volume I-Creating built environments of new opportunities. Vol. 1. TUT–Tampere University of Technology, 2016.*

3- *Sacks, Rafael, Ury Gurevich, and Prabhat Shrestha. "A review of building information modeling protocols, guides and standards for large construction clients." Journal of Information Technology in Construction (ITcon) 21.29 (2016): 479-503.*

Step three: Search and select the studies

Once the research question has been developed, and the scientific sources identified, the researcher should prepare a comprehensive list of criteria for selection and not the selection of studies. According to these criteria, it is decided to study which research and which one should be removed from the statistical population of the research. In order to avoid selection bias, the inclusion of a study in the research process or its exclusion should be consistent with the way of data extraction and analysis. The defined inclusion criteria of articles were as follows:

- ✓ Language of articles: English
- ✓ Research methodology: without limitation
- ✓ Nature: construction/building
- ✓ Type of studies: articles and dissertations in reliable scientific journals or conferences

After stating the research question, a comprehensive literature searches forms the basis for a systematic review. In this step, the articles found in the previous step are evaluated and screened step by step. For this aim, the obtained articles are reviewed several times, and a number of them are removed each time. After searching and reviewing the mentioned databases and evaluating their compatibility with the acceptance criteria determined in the first step, and according to the keywords, 117 articles, dissertations, etc., regarding the enablers for BIM application in the design phase were found.

1. The articles that were in the field of non-construction and buildings such as energy and sustainability, etc., were removed (28 articles were removed, and 89 remained).
2. In this step, the articles whose titles were not compatible with the research question were removed (28 articles were removed, and 61 remained).
3. The abstracts of the remaining articles were reviewed, and those not compatible with the research question were removed (23 articles were removed, and 38 remained).
4. The results of the remaining articles were studied, and the articles whose results were not compatible with the research question were removed (27 articles were removed, and 11 remained).

Based on the inclusion and exclusion criteria, 11 articles were added to the review process in the secondary search. They were indexed in Scopus. In total, 22 articles were reviewed to identify the enablers to BIM implementation in the architectural design phase. The search process for this review -the second and third steps- is presented in Figure 3.

Figure 3. Search process in the desired databases

Step four: Data extraction

After determining the eligible studies, their information was extracted. In this step, the list of extracted data should be consistent with the initial questions stated in the research design. Finally, 22 articles were remained to be studied in the fourth step of review implementation (sample size). Similarly, after evaluating the related studies, the codes of the known enablers to BIM implementation in the design phase of the construction industry were presented in Table 1.

Table 1. The identified codes through systematic literature review

Step five: Evaluating the quality and the risk of bias in studies

One of the necessary steps in systematic reviews is evaluating methodology quality or evaluating the bias risk in the primary studies. The first qualitative evaluation of articles ensures the accuracy of the search process described in the previous sections. It means that if the necessary care was considered in the previous steps of searching, screening, and selecting the appropriate articles, then in this step, the reviewer starts his/her job by extracting and evaluating information of articles with the inclusion criteria. The mentioned process has been observed in this study.

Step six: Data analysis

In this type of review, the researcher qualitatively summarizes, analyses, and combines heterogeneous and conflicting data that cannot be evaluated quantitatively. In this study, the codes obtained from the review were designed to be evaluated and analyzed in the form of a questionnaire. Then these codes were provided to the project managers, employers, consultants, and contractors active in the construction field. Finally, the obtained results were evaluated through the robust exploratory factor analysis method.

3.2 Exploratory Factor Analysis

Factor analysis is a general statistical method used to obtain a small set of latent variables, known as factors, through covariance on a broader set of observed variables called explicit variables. Exploratory factor analysis is a method that can be used to simplify the studied variables based on their dependencies. Traditionally, this method is used to discover the general structure of a set of observable variables without imposing a pre-determined structure in research studies (Glaser 2008). In the exploratory factor analysis method, the researcher does not follow specific hypotheses in advance but tries to summarize the desired data in a smaller set of factors. In fact, exploratory factor analysis is mainly hypothetical and theoretical (Skovgaard 1999).

A 36 item questionnaire was designed based on the identified enablers. The survey asked the respondents to rate every 36 enablers' importance using a nine-point scale with items ranged from 1 (strongly low) to 9 (strongly high). In this research, project managers, employers, consultants, and contractors in Iran with a high academic level and more than five years of experience participated.

At first, the companies and related experts were identified, using a database of construction firms in Tehran, Iran, to collect data from the respondents. They were contacted, and checked for their familiarity with BIM, and asked to fill the questionnaire. Then the sampling method is purposive sampling. Purposive sampling is a non-probability sampling method, and it occurs when "elements selected for the sample are chosen by the judgment of the researcher. Researchers often believe that they can obtain a representative sample by using a sound judgment, which will result in saving time and money"(Black 2011). In total, 500 qualified experts accepted to participate in our research, and questionnaires were sent out to them. 205 questionnaires were returned, and 190 usable questionnaires were obtained for data analysis (response rate: 0.38). The recommended ratio for the sample size (MacCallum *et al.*, 2001), 5:1 that is five times the questionnaire items (5 × 36 = 190), seems adequate for conducting robust EFA. Table 2 shows the demographics of the respondents:

Table 2: Demographics of the respondents

EFA is a frequently used method to discover patterns of multidimensional constructs that are subsequently used to develop measurement scales. Its main goal is to reduce the number of observed variables to fewer factors to enhance interpretability and detect hidden data structures. Here, robust EFA (Treiblmaier and Filzmoser, 2010) was applied to perform the analysis; a method has been commonly used in prior construction research (Ghalenoei et al. 2021; Jadidoleslami et al. 2018). Robust EFA has many advantages over classical factor analyses in helping the researcher choose many options, such as various types of data transformation, the choice of the factor extraction method, factor rotation, and the number of factors to be chosen. Also, it makes less restrictive assumptions about data distribution than classical factor analysis and reduces outliers' influence, which finally leads to more valid results (Amid et al. 2012).

This method aims to quantitatively classify the existing enablers for BIM application in the design phase of urban construction processes. For this aim, these enablers were identified through review studies, and 36 codes were obtained from these studies and presented in Table 2.

Before performing factor analysis, a test was conducted to verify the adequacy of data for EFA. The Kaiser-Meyer-Olkin (KMO) was calculated to ensure sampling adequacy. The KMO for the sample was 0.68, that was above the "Mediocre" threshold of 0.5 (Kaiser 1974). Furthermore, we performed a Bartlett sphericity test, which was statistically significant ($p < 0.05$ (Treiblmaier and Filzmoser 2010), indicating the eligibility of the data. Then, we used a Shapiro–Wilk test at $p < 0.05$ (Treiblmaier and Filzmoser ۲۰۱۰) to determine whether our sample had a normal distribution. None of the existing variables was normally distributed. Thus, the authors selected principal component analysis (PCA) for the factor extraction method as proposed in robust EFA.

The rotation method should also be selected for the robust EFA purpose. Oblimin rotation suggested in robust EFA (Treiblmaier and Filzmoser 2010), was used in this research. Finally, the number of factors extracted from the data was determined based on Eigenvalues greater than one and absolute factor loading values greater than 0.6 (Chin, Gopal and Salisbury, 1997). As a result, seven out of 36 factors were dropped from the initial pool. The remaining 29 factors were grouped into four categories. These results are presented in Table 3. The numbers in the table indicate loading values, which ideally should be above 0.60 (Chin, Gopal and Salisbury, 1997). A higher number is preferred for each item. The last two rows refer to the percent of variance that a set of variables assigned to each column explained. For instance, the first column explains the highest percent of the variance, with 16.34% in the model.

Table 3. The results of robust EFA

To indicate the meaning of the components, they have been given short labels indicating their content. Since this stage's results were open to several interpretations, we decided to use experts' opinions. Three project managers were selected with more than five years of experience in BIM projects with a high academic level. So, three project managers were invited, and based on the discussions on the factors' meanings in each component, four "organizational", "Technological", "Human", and "Environmental" labels were assigned to the extracted components. Table 3 shows the final results with specified labels.

Step seven: Results interpretation (discussion)

According to the percent of variance presented in Table 3, the factors affecting BIM application in the design phase of construction projects are organizational, technological, individual (human) skills, and environmental factors, respectively. These items are specified in 4 headings.

a. organizational

Considering that, many governments have realized the importance and significant impact of the BIM approach on improving project productivity and reducing costs in their economies; the output of this research in the group of organizational enablers confirmed that the support of government officials for implementing a specific validation process to approve BIM is the main enabler for its implementation. Collaboration and cooperation of governments to provide a strategic roadmap for Building Information Modeling (BIM) and to emphasize the need for paving the road to achieving BIM system is critical for encouraging and enhancing its application (Hamma-adama et al. 2020). The role of government in this regard should be a moderating role. In fact, governments play a key role in this field, and developing legal infrastructures and the issue of intellectual property and also resolving legal and contextual problems is the responsibility of governments and requires their support and understanding (AWAD 2017; Hamma-adama et al. 2020).

b. environmental

The factor of developing consistent subjective norms in organizations is another vital enabler identified in BIM implementation in the architectural design phase, which was classified in the group of environmental enablers. BIM is a management culture based on the digital construction of the project. By involving all project stakeholders in the design phase, BIM takes a big step to reduce duplications during the project implementation and finally provides the accurate calculation of workload and project materials, accurate cost, and time estimations for a construction project. Emerging aspects and tendencies of BIM are the main factors of change in architectural design, engineering, and construction industry (Abbasnejad et al. 2020; Doumbouya et al. 2016). This pattern development and change and subjective norms have created new expectations for architects regarding their capabilities in design and BIM. Design and construction is not a single-step process but a complex network of activity systems. Each system keeps to some extent the interests, motivations, and views toward the goal of construction activities. A significant characteristic that leads to unsatisfactory results in the construction industry is the lack of a "comprehensive view" by project members toward the product lifecycle. This issue prevents other stakeholders, particularly the operator, don't participate in the design process while performing architectural design. As a result, it causes a series of problems that the designer may not know. While these problems may be so simple that if the operator participates in the design process initially, they can be easily solved. Therefore, considering the change and development of subjective norms in the organizations will be an effective step to enable BIM implementation in the architectural design phase.

The protocol included in all contracts of the project team should create an organizational BIM-related framework. While the adaptation of BIM skills and specializations in the contracts is one of the effective environmental enablers for BIM implementation in the architectural design phase. Currently, the contractual regulations and models of many countries do not have the appropriate conditions for the cooperation of various working groups for electronic joint design, construction, procurement, and information exchange in construction projects, and the skills and capabilities of this approach are ambiguous and are not inserted clearly in contracts (Arunkumar et al. 2018; Morlhon et al. 2014). A significant part of the challenges in this regard is related to legal and contractual issues. The conventional contracts in the construction industry cannot meet the specific conditions of BIM, and various approaches have internationally been proposed to resolve this problem (Tauriainen et al. 2016). Somebody addresses this issue by developing new contracts and some others by adding special BIM attachments to the existing contracts. These approaches have been studied all over the world separately. Their analysis can provide a clear view of problem-solving methods for the decision-makers to achieve an appropriate way to develop a contractual framework for BIM. Therefore, it is necessary to develop an appropriate contractual framework compatible with the conditions and requirements of the country, and consider BIM skills and expertise in contracts to improve performance and eliminate the existing ambiguities.

c. Technological

Considering solutions for not using a common platform to prevent stealing project information is important and is one of the effective Technological enablers for BIM implementation in the architectural design phase (Bosch-Sijtsema et al. 2017; Doumbouya et al. 2016; Martins and Abrantes 2010). Data centers for construction projects are very compressed. It is hard to design them; the infrastructure should be robust to avoid losing information or power or damage to other information. The use of BIM in a cloud-computing platform leads to better performance of this technology and increases security in data storage. With a standard model, there is less need for reconstruction and multiplication of maps for different requirements of the construction field. This model contains more information than a design set, which allows any field to add and link its information to the project. Unfortunately, most of the software used in the construction industry is designed for one operator. It means that one person is working on the project at a particular time and sends the file to another person to make changes. Due to the large number of such files, it is not easy to transfer them via the internet. Through cloud space, all team members can work on one file simultaneously and even in different places and share the information quickly. This approach is one of the effective Technological enablers to prevent the stealing of project information.

d. individual (Human)

Regarding individual (Human) enablers, Coordinate design performance with customer interests is one of the influential factors in implementing Beam in the architectural design phase. Considering the potential impact of stakeholders on the organisation's ability, it is essential to consider the requirements and expectations of stakeholders, including customers, to satisfy and support them in the use of BIM)Elmualim and Gilder 2014);)Abbasnejad et al. 2020);)AWAD 2017). In addition, sharing customer information with the permission of BIM can help speed up the decision-making process. On the other hand, the high speed of responding to customer demand reduces the rate of decision-making.

4. Conclusion

In this study, at first, using a systematic literature review and reviewing the opinions of experts who had used BIM, a comprehensive list of enablers for BIM implementation in the design phase was developed in the form of a questionnaire. Then, project managers, employers, consultants, and contractors active in the field of construction and mass development were surveyed.

The obtained results were analyzed using the robust exploratory factor analysis method, and 36 items were ranked. Then, they were classified into four main groups of organizational, environmental, individual (human) skills, and technological factors. This classification was performed based on the percent of variance presented in Table 3 for the impact of enablers.

Although BIM development has not been matured yet, many construction companies have considered applying this technology. Although it is believed that BIM will affect the construction industry in a way that the internet had on communications, taking the full potentials of BIM will take time. In this regard, the experience has shown that identifying enablers is a new method for the survival of leading organizations in the competitive context and the financial power of construction companies was effective in BIM implementation. This issue indicates two aspects for the companies that welcome BIM. One of its aspects is the costs of BIM-based training and implementation, and the other aspect is the scope of the project and its financial risk and BIM's ability to reduce risk and ensure contractors' expected profit. Therefore, identifying and classifying the enablers for BIM implementation in the design phase is vital for the construction industry and future studies. Given that many governments have realized the importance and significant impact of the BIM approach in improving project productivity and reducing costs in their economy. The findings of this study in the Organizational Enablers Group confirm that the support of government officials is critical to the implementation of the BIM approval process. Government support and cooperation are essential to developing a strategic plan for BIM and emphasizing the need to adopt BIM. This study also suggests that creating consistent mental norms in organizations is essential in implementing BIM in the architectural design stage. BIM is a management culture based on the digital construction of the project. It is essential to accept it.

One of the limitations of this research was that a self-reported questionnaire was used for data gathering that can be threatened by common method bias. Two remedies were followed to tackle this potential validity threat. Based on Podsakoff et al.'s (2012) procedural remedies, measures were followed to increase the instrument reliability, such as using clear, simple, and concise language, defining vague terms, and labeling all scale points. Besides, respondents were assured that their responses would remain anonymous, which could ultimately lessen the likelihood of editing their responses. Therefore, common method bias is unlikely to be a severe concern in this study.

As the second limitation, this research was conducted through a cross-sectional approach and did not consider the interrelations among enablers. Therefore, it is recommended that future research address these two shortcomings of this research. It is also suggested that BIM enablers be studied from other aspects, or different solutions be provided by experts to improve them. Moreover, considering the conditions governing the construction industry and applying experts' viewpoints, and considering the identified enablers and their significance, we should try to find solutions to improve these enablers for BIM implementation, particularly finding a practical model to implement this concept in urban construction projects.

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