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Impact of the BIM system in construction management services in developing countries; Case of Turkey

Gelişmekte olan ülkelerde inşaat yönetim hizmetlerinde BIM sisteminin etkisi; Türkiye örneği

Abdulkadir BUDAK[1], *İbrahim KARATAŞ*[1*]

[1]Department of Civil Engineering, Faculty of Engineering, Osmaniye Korkut Ata University, Osmaniye, Turkey.
abudak@osmaniye.edu.tr, ibrahimkaratas@osmaniye.edu.tr

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Abstract

Today's construction industry changes and develops with the developing technology. One of the most important technological changes is the Building Information Modeling (BIM) system. Adoption of the BIM system is essential in CM services, which include consulting services in addition to engineering services. In this study, it is aimed to examine the benefits and challenges of using the BIM system in CM services and the necessity of using this system by determining the duties of the Construction Manager. In this context, a survey was conducted and analyzed for professional CM companies regarding the implementation of BIM system in CM services in construction projects in Turkey, a developing country. According to the results of the analysis, although the lack of trained staff emerged as the most important challenge, the increase in interdisciplinary coordination and the reduction of design errors with conflict analysis were determined as the most important benefits. In addition, the tasks of the Construction Manager in the use of the BIM system are listed in order of importance. This study is one of the pioneering studies on the implementation of the BIM system in CM services. In the light of the result obtained, legal regulations, standards, contracts, and execution plans can be composed for the use of the BIM system in CM services. Therefore, it is hoped that this study will contribute to the building production stakeholders in the integration of the BIM system with CM services.

Keywords Building information modeling (BIM), Construction management (CM) services, Severity index analysis, Construction manager, Construction technology.

Öz

Günümüz inşaat sektörü gelişen teknolojiyle birlikte değişim göstermekte ve gelişmektedir. En önemli teknolojik değişimlerden birisi Yapı Bilgi Modelleme (BIM) sistemidir. Mühendislik hizmetlerine ek olarak danışmanlık hizmetlerini de içeren CM hizmetlerinde de BIM sisteminin benimsenmesi elzemdir. Bu çalışmada CM hizmetlerinde BIM sisteminin kullanılmasının faydaları, zorlukları ve inşaat yöneticisinin görevleri belirlenerek bu sisteminin kullanılmasının gerekliliği incelenmesi amaçlanmıştır. Bu bağlamda gelişmekte olan bir ülke olan Türkiye'deki inşaat projelerinde BIM sisteminin CM hizmetlerinde uygulanmasına ilişkin profesyonel CM firmalarına anket düzenlenmiş ve analiz edilmiştir. Analiz sonuçlarına göre özellikle eğitimli eleman eksikliği en önemli zorluk olarak ortaya çıkmasına rağmen paydaşlar arasında iletişim ve koordinasyonun artması ve çakışma analizi ile tasarım hatalarının azaltılması en önemli faydalar olarak belirlenmiştir. Ayrıca İnşaat Yöneticisinin BIM sistemi kullanımındaki görevleri önem derecesine göre sıralanmıştır. Bu çalışma CM hizmetlerinde BIM sisteminin uygulanmasına yönelik hazırlanmış öncü çalışmalardan biridir. Elde edilen sonuçlar ışığında BIM sisteminin CM hizmetlerinde kullanımı için yasal düzenlemeler, standartlar, sözleşmeler ve yürütme planları oluşturulabilir. Dolayısıyla bu çalışmanın, BIM sisteminin CM hizmetlerine entegrasyonunda yapı üretimi paydaşlarına katkı sağlayacağı umulmaktadır.

Anahtar Kelimeler: Yapı bilgi modelleme (BIM), İnşaat yönetim hizmetleri, Şiddet indeksi analizi, İnşaat yöneticisi, İnşaat teknolojisi.

1 Introduction

Building production, which is the basis of employer expectations, should be completed in the desired axis of quality, time, and cost. Compared with developed countries, it is clear that construction projects in developing countries carry more risks in terms of quality, time, and cost. One of the most important reasons for this is the lack and difficulty of professional construction management skills [1]. Therefore, there is a need to arise for experienced and expert human resources to support usually on technical issues, especially cooperation and coordination throughout the project life cycle [2],[3].

In developed countries such as the United States and the UK, the technical specialist support received to professionalize in construction management has entered the literature under the name of construction management (CM) services [4]-[6]. CM services; it aims to control the project in general, to prepare the work schedule, to identify the changes, disagreements and delays in the project and to eliminate the problems, to provide optimum benefit in design, quality and management [5]-[7]. In this regard, CM services are quite different from traditional engineering services. Because professional CM services have a framework in the building production lifecycle, as well as engineering services and consultancy [3],[4].

It is essential to synchronize CM services in construction management in parallel with developing technology to fulfill effective, efficient and employer expectations. Because in complex construction projects, the management of the project with traditional methods is insufficient. Therefore, it is inevitable that developments in technology will be integrated into building production [8]. The building information modeling (BIM) system, which is rapidly developing and being used in the architecture, engineering, construction, and

*Corresponding author/Yazışılan Yazar

operations (AECO) sector, is the most notable proof of integrating technology into building production [9]-[11].

By creating a virtual model of the structure with the BIM system, the functions required throughout the life cycle of the building production can be demonstrated by simulation before the building is built. When the BIM system is applied in a professional way, the construction schedule and cost are reduced as well as the better quality of the construction [12]. In other words, the main purpose of the BIM system is to manage the information generated for the building. Management of information is one of the most critical components in the CM service. Construction managers must have knowledge of the BIM system with the application of the BIM system in CM services for building production [4]. CM services and BIM system are used together in many countries, especially in developed countries [13]-[17].

As to in developing countries, there are few studies in the literature related to the use of the BIM system in the CM services. Studies usually investigate impact of BIM system adoption in the construction industry. Seyis (2019) specified the benefits, challenges and risks encountered during the transition to BIM in the AECO industry and prioritized them [18]. At the same time, studies have been carried out to determine the benefits, challenges, risks and opportunities of the BIM system in the construction industry in Egypt [19], Saudi Arabian [20], Pakistan [21], Nigeria [22],[23], China [24], Brazilian [25] and the Middle East [26]. In addition to investigate the adoption of the BIM system in several countries, there are also studies on the adoption of the BIM system by different services in the construction industry. Among these studies, for example, include within the scope of sustainability in the construction sector [27],[28], occupational safety [29], collaboration of construction stakeholders [11],[30], project management knowledge areas [31], building services engineering [32], and consultant services [33]. These services can be evaluated under the CM services caption. Because CM services consist of all services throughout the project life cycle of the construction. In this context, Studies in the literature do not completely express the use of BIM in CM services. Therefore, the necessity of using the BIM system in CM services in general needs to be revealed. The absence of a general study on the topic forms a gap. In addition, it is thought that there is a shortcoming about the determination of the duties and responsibilities of Construction managers with the adoption of the BIM system. So, in this study, the necessity of using BIM system in CM services in the Turkish construction sector which one of the developing countries was addressed. For this, the survey was applied to companies providing professional CM services in Turkey. The purpose of this paper, firstly when the BIM system is used in the projects, to analyzing the benefits, difficulties, and duties of Construction Managers of the BIM system for CM companies and investigating the reasons for companies not using the BIM system. Then, it is aimed to investigate the necessity of integrating the BIM system into CM services in developing countries. For this purpose, firstly CM services in traditional projects, then BIM system and later CM services in projects using BIM system are examined. Then, analyses were carried out by conducting questionnaires to companies providing professional CM service in Turkey, one of the developing countries. According to the results of the analysis, the question of whether it is necessary to use the BIM system in CM services in the construction sector in developing countries was investigated.

2 Literature review

2.1 Construction management services

By the increasing complication of the projects in building production, the errors encountered owing to the lack of a professional expert in the technical issues that will manage the entire project throughout the project life cycle have an adversarial impact on the cost and time of the project and the increasing number of these negative factors has composed the emergence of construction management inevitable [6],[34]. Therefore, notably in developed countries such as the US and UK, the CM system has been carried out since the late 1960s [5],[35]. CM services are extensively used especially in the US beneath numerous professional organizations and have an important role in the construction sector. Among these organizations, the most broadly accepted by employers are the American Institute of Architects (AIA), the Associated General Contractors of America (AGC) and the Construction Management Association of America (CMAA) [4]-[6]. In 1975, these organizations adopted CM services as a discrete discipline and the first contract standard paper concerning CM services has been printed. So, the definition, standards, and contracts of CM services were tried to be established [5],[36].

Accordingly, CM services; is a professional application that manages resources such as labor, materials, machine, and money implemented to the planning, design, and construction of the project throughout the project life cycle to control the time, cost and quality of the project [4],[6],[37]. Nevertheless, according to the CMAA (2010) [4], the essence of well the CM services is professionalism and cooperation, and construction manager has assumed full responsibility from the creation of a management plan to the end of the project.

The standards established for CM services are split up 12 functions for a well understood of CM coverage and the well encountered of services in each function [3]-[5],[8],[36]. These; budget management, contract management, decision management, information management, material management, project management, quality management, resource management, risk management, safety management, schedule management, and value management.

Kang et al. (2018); in their study, these functions, which are divided into 12 functions, ranked by safety management, project management, quality management, and budget management according to the level of importance in developed countries. In addition to this, CM services, which has become increasingly relevant in developing countries and whose use in the construction industry has started to increase; limited knowledge of these functions has been one of the most consequential risks [1]. Another risk that comes into the use of CM services was some confusion about what CM services are and how they are implemented. Arditi & Ongkasuwan (2009) stated that these risks, which affect the quality of CM services, are due to the diverse expectancy of diverse stakeholders throughout the project life cycle. To eliminate these risks, all stakeholders have been trained and concluded that the roles of Construction Managers, who will influence their relationship with diverse stakeholders at every stage of the project life cycle, should be determined. The tasks of construction managers throughout the project lifecycle are summarized as follows [3]-[6],[38]:

- Budget planning according to the deadline of the project,
- To resolve the problems experienced throughout the project life cycle by discussing them with other stakeholders,
- Development of contracts and determination of reviews and amendments performed to the contracts,
- Budget estimation, preparation of project progress and cost monitoring reports,
- Organizing the activities related to the maintenance of the facilities after the building is constructed,
- Investigating whether the project complies with occupational health and other official regulations,
- Determination of appropriate construction methods and establishment of specifications,
- It is the conduct of project inspection throughout the project lifecycle.

2.2 Building ınformation modeling (BIM) system

The BIM system commenced emerging with surface and solid modeling programs in the 1970s and 1980s [16],[39],[40]. The BIM system was first introduced in Hungary in 1982 with the evolution of the ArchiCAD software program [40]. In the early 1990s, integrated graphical analysis and simulations were produced using parametric modeling characteristics of the BIM system as well as building geometry and material properties [39] and in 2000, the use of the BIM system enhanced with the development of the Revit software program [16],[40].

The BIM system is described as a numerical representation of the physical and functional characteristics of the building, including all the data required for the building, associated with 3D design, collaboration, and coordination throughout the project life cycle [12],[41]-[43]. In other words, the BIM system has been suggested as a system that enables the building to be virtually constructed before the actual construction [44]. The BIM system is not only devised as software [45],[46]. But also, the BIM system emerged as a new way of thinking and a process that differ from the traditional workflow and has enabled all stakeholders to operate on a common platform throughout the project lifecycle [15],[45],[47],[48]. This feature also has made coordination and cooperation between the project stakeholders of the BIM system more productive [12],[48]-[50].

The BIM system has been adopted in many projects in many developed countries including the US and UK since the beginning of the 2000s due to its productive usage in the construction sector [16]. Kassem & Succar (2017) stated the capability stage of the BIM system among developed countries separately in Figure 1 according to modeling, collaboration, and integration, which are the 3 key elements of the BIM system. Consequently, the UK, USA, South Korea, China, Netherlands, New Zealand, and Finland are among the most principal countries in this system [51]. In the case of developing countries, it was ascertained that almost work hasn't been done on the BIM system before 2013 and the BIM system applications were limited in these countries [52]. However, with the advance and sprawl of the BIM system, the adoption of this system has commenced rising in developing countries [14],[52],[53].

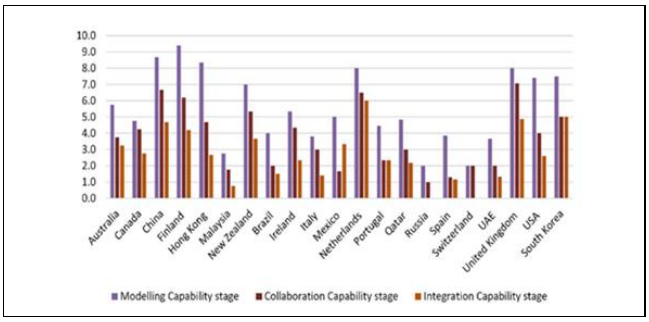

Figure 1. The capability stage of the BIM system according to modeling, collaboration and integration in developed countries [52].

2.3 CM Services for Construction Projects Using the BIM System

The use of only CM services in construction projects that are complicated in nowadays construction production has not been sufficient in controlling and coordinating construction. Hence, with the expanding use of technology, the evolution of the BIM system, which is being used in developed countries, has embraced many disciplines, especially CM services. So, it is seen in the literature that using CM services more effectively and efficiently will be possible only by integrating the BIM system into CM services [4],[8],[54]-[57]. The duties and responsibilities of the construction managers arising from the integration of the BIM system into CM services are emphasized in Table 1.

Table 1. Duties and responsibilities of the construction managers in the BIM system.

	Duties of CM Services in the BIM System	Reference from literature
D1	To prepare a BIM-related project procedure guide for all phases of the project.	
D2	Explain the BIM standards to be applied in the project, project procedure guide and construction management plan and assemble for acceptance.	
D3	Selection of design team and to ensure the preparation of the contract.	
D4	To set and develop the BIM model.	
D5	By combining data from all disciplines to ensure that the model keep up to date.	
D6	To ensure complete transition from design to construction.	[4],[6],[8],[12],[15],[26],[30],[39],[5]
D7	Identify and implement the project delivery system within the scope of BIM.	
D8	To ensure the preparation of contracts between the owner and other project stakeholders.	
D9	To ensure the correct implementation of BIM throughout the project.	
D10	Ensures proactive participation of all participants within the scope of BIM.	
D11	To provide training to all stakeholders within the BIM process.	
D12	To ensure interoperability throughout the project life cycle.	
D13	When the project is completed, ensure that the model defined under BIM passes to the owner completely.	
D14	Assisting the owner / facility manager in facility management using BIM.	

Besides, the benefits obtained in construction projects in the axis of CM services-BIM system are shown in Table 2, the challenges, deficiencies, and obstacles that should be overcome in order to maximize these benefits are shown in Table 3 and the most used BIM tools are shown in Table 4.

Table 2. Benefits of using BIM system in CM services

	Benefits of Using BIM System in CM Services	Reference from Literature
B1	Reduce Design Errors with Conflict Analysis	[20],[21],[66]-[70]
B2	Cost Savings	[20],[21],[23], [33], [46], [48], [66], [69]-[71]
B3	Saving time	[20],[21],[23],[46], [48],[66],[70],[71]
B4	Human Resources (Labor) saving	[67],[70],[72]-[74]
B5	Project management	[48],[72],[73],[75]
B6	Project Control	[48],[72],[75]-[77]
B7	Energy Efficiency and Sustainability	[20],[21],[33], [48], [66],[68],[70],[73], [78]
B8	Interdisciplinary Coordination	[20],[21],[33], [48], [66],[68],[73],[79]
B9	Parametric Modeling and 3D Visualization	[20],[21],[33],[46], [66],[67],[70],[73], [80]
B10	Occupational health and Safety	[66],[81]-[83]

Table 3. Challenges, deficiencies, and obstacles encountered in the use of BIM system in CM services.

	Challenges, Deficiencies, and Obstacles Encountered in the Use of BIM System in CM Services	Reference from Literature
C1	Lack of standards and legislation	[20],[21],[23],[24], [79],[82]-[85]
C2	Insufficient knowledge of the BIM system and lack of BIM culture	[24],[25],[73],[83], [84],[86]
C3	Lack of adequate training services	[21],[23],[24],[87],[88]
C4	Lack of collaboration and coordination	[20],[21],[23],[24],[48],[79], [84],[88],[89]
C5	Lack of Government support for System Implementation	[21],[24],[83],[86],[87]
C6	Lack of Trained Staff	[20],[21],[23],[24],[33],[79],[87]-[89]
C7	Licensing, copyright and security issues	[24],[25],[79],[82],[88]-[90]
C8	High cost of implementing the system	[23],[24],[33],[79],[84],[88]-[90]

Table 4. BIM tools used in construction project.

	BIM Tools Used in Construction Project	Reference from Literature
F1	Parametric Modeling and 3D Visualization	[59], [80], [89], [91], [92]
F2	Conflict Analysis	[59], [91]-[94]
F3	Budget and Cost Estimating (5D BIM)	[59], [83], [89]
F4	Automatic Quantity Takeoff	[59], [95]
F5	Time Schedule (4D BIM)	[59], [71], [83], [89]
F6	Energy Analysis and Sustainability (6D BIM)	[94]
F7	Constructibility Reviews	[79], [89]
F8	Interdisciplinary Coordination and Communication	[48], [59], [79]
F9	Data Storage and Use	[45], [46], [73], [83], [89], [96]

3 Methodology

In this study, the requirement of using the BIM system in CM services has been investigated across the Turkish construction sector. The study was conducted with the survey applied to the professional CM companies in Turkey. In the determination of professional CM companies, in the construction sector and all stages of the project life cycle the companies serving were picked. According to the data obtained from the Association of Turkish Consulting Engineering and Architects, the total number of companies serving in the construction sector and in all stages of the project life cycle was determined as 40. These companies were surveyed via face-to-face, e-mail and LinkedIn, and 30 CM companies participated in this survey. The survey questions asked to the managers in these companies was composed of two sections. Firstly, professional CM companies were asked whether they apply the BIM system and what kind of projects and software the users of the BIM system usage, and their BIM experiences. In the second section of the survey, in using the BIM system in professional CM services, the challenges, the benefits, the degree of benefit in the project life cycle phases, and the frequency of using BIM tools were arranged according to the 5-point Likert scale. The Likert rating scale for assessing levels is as follows: 5 very important/very useful/always, 4 important/useful/often, 3 moderately important/moderately useful/sometimes, 2 slightly important/slightly useful/ rarely and 1 not at all important/not at all useful/never. The survey outcomes were analyzed to determine the exposures of BIM system implementation in professional CM services and levels of these exposures. Frequency and severity index (SI) analyze were used for this analysis.

3.1 Reliability test

Reliability testing was conducted to determine how reliable the results of the analysis were, and the internal consistency of the answers provided. Reliability means to consistently represent the consequences of the measurement of a survey. Reliability should also have parallels with the internal consistency that indicates how well the items that extemporize the survey form together. In this study, Cronbach's alpha reliability factor developed by Cronbach in 1951, which is one of the most widely applied reliability criteria, was practiced determining internal consistency [97],[98]. The Cronbach's alpha coefficient ranges from 0 to 1, and if the Cronbach's alpha coefficient is higher than 0.8, it is evaluated as high reliability for the reliability of the survey [98]-[101]. In light of this information, the Cronbach's alpha rate was 0.88 as a result of the reliability analysis applied to the survey study with IBM SPSS Statistics 25 software. This reveals that the survey is high in the way of reliability.

3.2 Severity index analyses

Severity index analysis is a non-parametric statistical method that enables the data obtained from the survey according to the Likert scale to be evaluated to its severity [46],[102],[103].

Severity index analysis was used to determine and compare the severity of CM services' benefits and challenges in using the BIM system as well as the severity of the use of BIM tools. When determining severity index values, firstly the frequency values of any Likert scale are achieved. Accordingly, severity index values are computed for each factor using the following formula [46],[102],[103]:

$$S.I. = \frac{\sum_{i=1}^{5}\left(w_i * \frac{fi}{n} * 100\right)}{(\alpha * 100)} \quad (1)$$

Where,

i = The point given to each criterion by the respondent, ranging from 1 to 5,

w_i = The weight for each point ranging between from 1 the very low scale to 5 very high scale,

f_i = The frequency of the point i by all respondents,

n = The total number of responses,

α = The highest weight, in this study α=5.

Computed severity index values are converted to five important levels as follows [86]:

- $0.8 \le SI \le 1$ as to High (H),
- $0.6 \le SI < 0.8$ as to High-Medium (HM),
- $0.4 \le SI < 0.6$ as to Medium (M),
- $0.2 \le SI < 0.4$ as to Medium-Low (ML),
- $0 \le SI < 0.2$ as to Low (L).

4 Results analysis and discussion

In this study, which investigated the requirement of using the BIM system in CM services throughout the Turkish construction sector, frequency and severity index analyses were used in the survey study employed to CM companies in Turkey. These analyses were performed by means of Microsoft Excel. In line with the data obtained from the Association of Turkish Consulting Engineering and Architects, surveys were distributed to 40 companies serving in the construction sector and at all phases of the project life cycle. However, 30 surveys were responded. In this survey study, the response rate to surveys is 75%.

In the first section of the survey, 30 CM companies were requested whether they used the BIM system. According to the responses received here, the companies using the BIM system and companies that do not use the BIM system were requested distinct questions. Accordingly, as shown in Figure 2, 70% of CM companies have been the move into the BIM system and practiced this system.

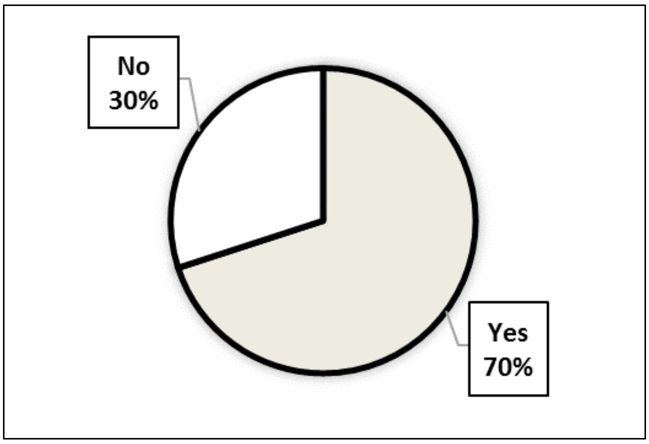

Figure 2. The rate of using the BIM system of CM companies.

Considering demographic questions about BIM, which is asked to companies adopting the BIM system, CM companies in Turkey are frequently applied in housing projects as shown in Figure 3 of the BIM system in construction projects. It is then applied in industrial facility, hospital and hotel, airport, underground and infrastructure projects, respectively.

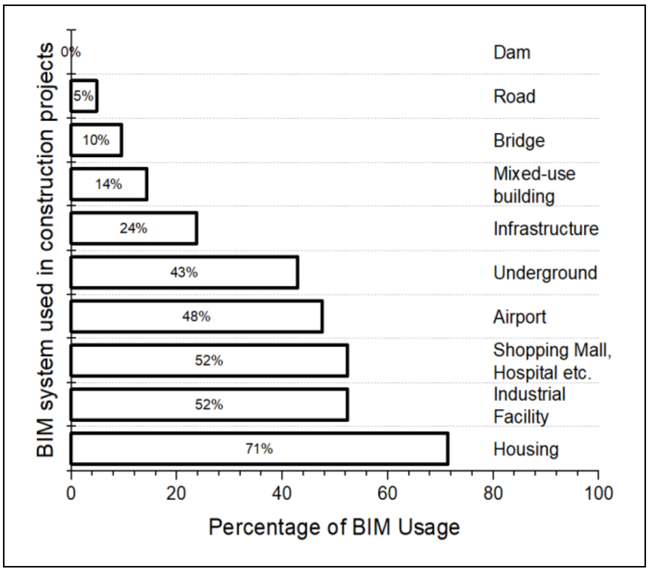

Figure 3. Percentages of the BIM system used in construction projects of CM companies in Turkey.

The CM companies use many BIM software to design and manage these projects with the BIM system. As in Figure 4, the software used by CM companies in their projects is Autodesk Revit and Autodesk Navisworks software. It was later arranged as Tekla Structure, Synchro Profession, Archicad, and Allplan.

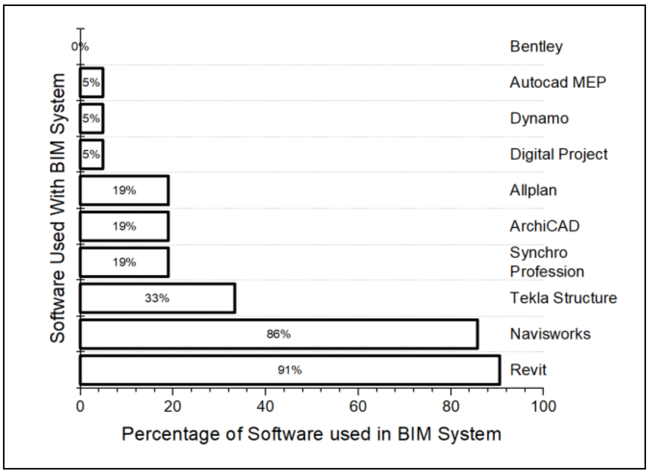

Figure 4. Percentages of software used in the BIM system of CM companies in Turkey.

Figure 5 shows the BIM experiences of CM companies applying the BIM system. Accordingly, approximately 40% of the respondents have more than 8 years of BIM experience.

On the other hand, 30% of the respondents stated that they did not apply the BIM system. According to these CM companies that do not apply the BIM system, the reasons for not using this system have been asked. Accordingly, as shown in Figure 6, the majority of respondents (44%) declared that they did not use this system because they did not know enough about the BIM system. Other important reasons are the high cost of transition to the BIM system and that the BIM system is not compatible with the existing software.

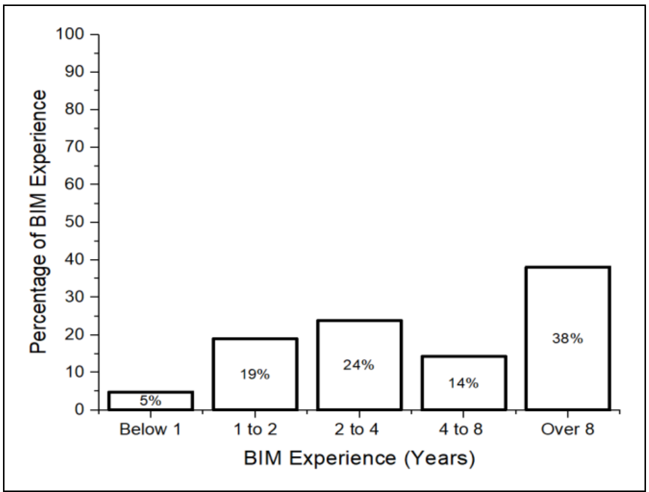

Figure 5. Percentages of The BIM Experience of CM companies in Turkey.

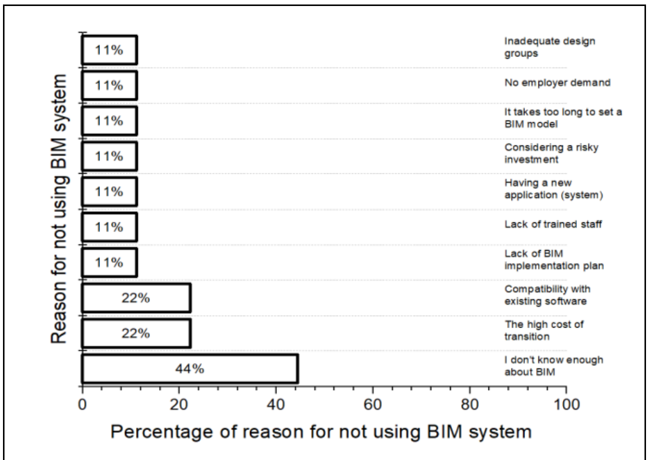

Figure 6. Percentages of the reason for not using The BIM system of CM companies in Turkey.

In the second section of the survey, in order to measure the necessity and significance of the BIM system in CM services, in accordance with the responses given to the survey developed with the Likert scale, the factors were concatenated according to severity index values and their values were established. The higher the measured severity index value, the higher the importance level for that factor, and the lower the measured severity index value, the lower the importance level for that factor.

As shown in Table 5, when the provided level of benefits by the BIM system in CM services during the project life cycle phases is evaluated, it is noticed that the SI levels are High Importance Level. In other words, according to construction managers' opinions, the BIM system benefits CM services at all phases. Besides the most useful project life cycle phases are the design phase and the procurement phase.

In CM services, according to the opinions of the Construction Manager, the benefits to be obtained in projects by applying the BIM system are shown in Table 6 to SI values. Accordingly, when applying the BIM system, the most significant benefits derived from projects are respectively reduce design errors with conflict analysis, interdisciplinary coordination, parametric modeling and 3D visualization, more efficient project management, more efficient project control, saving time, cost savings, and human resources (labor) saving.

Table 5. The degree of benefit of the BIM system in CM services during the project life cycle phases.

The degree of benefits of the BIM system in CM services during the project life cycle phases	SI	Importance Level	Rank
Pre-Design Phase	0.89	H	3
Design Phase	0.95	H	1
Procurement Phase (Bid, Contract etc.)	0.95	H	1
Construction Phase	0.90	H	2
Post Contruction Phase	0.83	H	4

Table 6. Levels of benefit of using BIM system in CM services.

Id	Benefits of Using BIM System in CM Services	SI	Importance Level	Rank
B1	Reduce Design Errors with Conflict Analysis	1	H	1
B8	Interdisciplinary Coordination	0.97	H	2
B9	Parametric Modeling and 3D Visualization	0.96	H	3
B5	More Efficient Project Management	0.92	H	4
B6	More Efficient Project Control	0.92	H	4
B3	Saving time	0.89	H	5
B2	Cost Savings	0.88	H	6
B4	Human Resources (Labor) saving	0.85	H	7
B7	Energy Efficiency and Sustainability	0.79	HM	8
B10	Occupational health and Safety	0.67	HM	9

According to construction managers' opinions, BIM tools that are most frequently used (High Important level) in projects applied BIM system in Turkey as shown in Table 7 sort by in SI values: Automatic Quantity Takeoff, Interdisciplinary Coordination and Communication, Conflict Analysis, Parametric Modeling and 3D Visualization, and Data Storage and Use. It is understood that the BIM tools that are less frequently used in BIM projects are Energy Analysis and Sustainability (6D BIM).

Table 7. Levels of frequency of use of BIM tools.

Id	Frequency of use of BIM tools	SI	Importance Level	Rank
F4	Automatic Quantity Takeoff	0.93	H	1
F8	Interdisciplinary Coordination and Communication	0.93	H	1
F2	Conflict Analysis	0.92	H	2
F1	Parametric Modeling and 3D Visualization	0.89	H	3
F9	Data Storage and Use	0.88	H	4
F5	Time Schedule (4D BIM)	0.72	HM	5
F3	Budget and Cost Estimating (5D BIM)	0.71	HM	6
F7	Constructibility Reviews	0.68	HM	7
F6	Energy Analysis and Sustainability (6D BIM)	0.54	M	8

According to construction managers' opinions, as shown in Table 8, the most encountered challenges in construction projects are respectively lack of trained staff, insufficient knowledge of the BIM system and lack of BIM culture, lack of standards and legislation, lack of collaboration and coordination, and lack of government support for system implementation.

Table 8. Levels of challenges, deficiencies, and obstacles encountered in the use of BIM system in CM services.

Id	Challenges, Deficiencies, and obstacles encountered in the use of BIM system in CM services	SI	Importance Level	Rank
C6	Lack of Trained Staff	0.87	H	1
C2	Insufficient knowledge of the BIM system and lack of BIM culture	0.87	H	1
C1	Lack of standards and legislation	0.83	H	2
C4	Lack of collaboration and coordination	0.8	H	3
C5	Lack of Government support for System Implementation	0.8	H	3
C3	Lack of adequate training services	0.74	HM	4
C8	High cost of implementing the system	0.68	HM	5
C7	Licensing, copyright and security issues	0.64	HM	6

In construction projects constructed with the BIM system, considering the construction managers' duties, according to construction managers' opinions, the duties they perform most are D9, D7, D1, and D4. On the other hand, the duties D5, D2, D3, D6, D8, D11, D12, D13, and D10 relatively less performed. The task of D14 was identified as the least-used duty by construction managers in Turkey.

According to the results of the analysis, some of the 14 different duties shown in Table 9 of CM services defined in the scope of literature are used more effectively in the projects applied the BIM system, while some tasks are not used effectively. When was examined relations among difficulties encountered, frequency of use of BIM tools, and the benefits of the BIM system in projects applied BIM system in CM services, factors affecting the effective use or inability to use of these duties are discussed below;

- It was determined that the D4 and D9 duties were used in construction projects applying the BIM system at approximately 70%. While performing these duties, it can be said that F1, F2, and F7 BIM tools are frequently used, although C6, C7, and C8 challenges are experienced, and thus factors B1, B2, B3, B5, B6, and B9 are beneficial,
- It was obtained that the D1, D2 and D7 duties were used in construction projects applying the BIM system at approximately 65%. While performing these duties, it can be said that F8 BIM tool is frequently used, although C1, C2, C4, and C6 challenges are experienced, and thus factors B3, B5, B6, and B8 are beneficial,
- It was specified that the D5, D10 and D12 duties were used in construction projects applying the BIM system at approximately 57%. While performing these duties, it can be said that F2, F8, and F9 BIM tools are frequently used, although C2, C4, C6, and C7 challenges are experienced, and thus factors B1, B5, B6, B8, and B9 are beneficial,
- It was found that the D6 and D13 duties were used in construction projects applying the BIM system at approximately 57%. While performing these duties, it can be said that F8 and F9 BIM tools are frequently used, although C1, C4, and C6 challenges are experienced, and thus factors B2, B3, B5, B6, and B8 are beneficial,
- It was found out that the D3 and D8 duties were used in construction projects applying the BIM system at approximately 57%. While performing these duties, it can be said that F7 and F8 BIM tools are frequently used, although C1, C4, and C6 challenges are experienced, and thus factors B2, B3, and B8 are beneficial,
- It was revealed that the D11 duty was used in construction projects applying the BIM system at approximately 57%. While performing this duty, it can be said that C3, C5, C6, and C8 challenges are experienced,
- It was brought out that the D14 duty was used in construction projects applying the BIM system at approximately 30%. While performing this duty, it can be said that F1, F6, and F9 BIM tools are frequently used, although C2, C3, C4, C6, and C8 challenges are experienced, and thus factors B7, B9, and B10 are beneficial.

Al-Yami et al. (2021) [20] investigated the benefits of the BIM system in the construction industry. The most important benefits were found out as reducing errors, controlling quality, detecting interdisciplinary conflicts in drawings to speed up communication, and accelerating the design process. In this study, the most important benefits of the BIM system in CM services were revealed as reducing design errors with conflict analysis, interdisciplinary coordination. However, although parametric modeling and 3D Visualization are among the most important benefits in this study, it seems to provide less benefit in the studies in the literature [18],[20]. Many challenges, deficiencies, and obstacles arise with the adoption of the BIM system in the construction industry [18],[20],[24],[25]. In the literature, the most challenges in the adoption of the BIM system are seen as lack of information and experience in BIM [18],[20], lack of comprehension and awareness of project participants regarding BIM [18], resistance to change [20], lack of standards and regulations [24], and legal issues [24]. When compared with the results in the literature, it was concluded that similar challenges were encountered in CM services. So, these challenges are usually the lack of knowledge and experience and legal regulations due to the transition to a new system. Another important result of this study is the lack of trained staff encountered in CM services with the use of the BIM system. Reducing these challenges will further facilitate the adoption and use of the BIM system in CM services.

Table 9. Duties of CM services in the BIM system used in construction projects.

Identifier	Duties of CM Services in BIM System	Frequency	Percentage	Rank
D9	To ensure the correct implementation of BIM throughout the project.	15	%71.4	1
D7	Identify and implement the project delivery system within the scope of BIM.	15	%71.4	1
D1	To prepare a BIM-related project procedure guide for all phases of the project.	14	%66.7	2
D4	To set and develop the BIM model.	14	%66.7	2
D5	By combining data from all disciplines to ensure that the model keep up to date.	13	%61.9	3
D2	Explain the BIM standards to be applied in the project, project procedure guide and construction management plan and assemble for acceptance.	12	%57.1	4
D3	Selection of design team and to ensure the preparation of the contract.	12	%57.1	4
D6	To ensure complete transition from design to construction.	12	%57.1	4
D8	To ensure the preparation of contracts between the owner and other project stakeholders.	12	%57.1	4
D11	To provide training to all stakeholders within the BIM process.	12	%57.1	4
D12	To ensure interoperability throughout the project life cycle.	12	%57.1	4
D13	When the project is completed, ensure that the model defined under BIM passes to the owner completely.	12	%57.1	4
D10	Ensures proactive participation of all participants within the scope of BIM.	11	%52.4	5
D14	Assisting the owner/facility manager in facility management using BIM.	6	%28.6	6

When considered the project life cycle phases; according to Table 5, in CM services, it was revealed that the BIM system had the major benefits in the design and procurement phases. Nevertheless, this situation was supported by the fact that factors such as B1, B8, and B9, where the BIM system provides the major benefit, and BIM tools such as F1, F2, F4, and F8, where BIM tools are frequently used, are in the design phase. Also, the evidence for the major benefit in the procurement phase is, this phase is affected by the design phase as studies are carried out on the model obtained from the design stage. In the construction phase, be high of the level of benefit of B2, B3, B4, B5, and B6 factors and the high frequency of use of F3, F5, F8, and F9 BIM tools are evidence that it is evidence that the BIM system in CM services has a high level of benefit in the construction phase. On the other hand, in the pre-design and post-construction phases, it was determined that the B7, B10 benefit factors, and F6, F7 BIM tools were relatively low compared to the others, so the levels of benefit were determined lower than the other project life cycle phases. Eadie et al. (2013) [104], stated that the BIM system was mostly used in the design and procurement phase in their survey on the use of the BIM system in the UK construction industry. It was also determined that it was used fewer during the construction phase and pre-design phase. As to in the post-construction phase, the BIM system is rarely used. On the other hand, Olanrewaju et al. (2021) [22] listed BIM awareness in the project life cycle according to the design phase, construction phase and post-construction phase, respectively. It is thought that the reason why the BIM system is used more in some phases is that it provides more benefits in those project life cycle phases. As the frequency of use of the BIM system increases, it is inevitable that the benefit obtained by using the BIM system will increase. This confirms that the benefits of the BIM system in CM services vary depending on the frequency of use in the project lifecycle phases in this study.

When the project life cycle phases are taken into account in terms of duties; The most performed duties of CM services in the BIM system are that the D7 duty is in the procurement phase, the D9 duty is in the construction phase, the D1 duty is in the pre-design phase, and the D4 and D5 duties are in the design phase support the major of benefit in these phases. D13 and D14 duties, which are the least implemented duties, were performed in the post-construction phase, which has the least benefit.

Within the scope of the BIM system, it is understood that the duties of the construction manager at every phase of building production have a very high positive relationship with the benefit obtained from this system. Despite the frequency of BIM tools used especially when fulfilling duties and the challenges encountered, it was determined that the majority (70%) of the few CM companies in Turkey used the BIM system. Furthermore, the fact that 62% of these companies have less than 8 years of experience reveals that the adoption of the BIM system has recently launched in Turkey and that more BIM systems need to be adopted in order to build more productive buildings in the construction sector.

On the other hand, the fact that 30% of CM companies do not adopt the BIM system in construction projects in Turkey is another important argument for the implementation of the BIM system. In accordance with the data obtained in the studies on the subject and in this study, the lack of sufficient knowledge of the BIM system of the stakeholders, the high cost of transition to the BIM system, challenges such as C1, C2, C5, C6, and C8 encountered by CM companies applying the BIM system, and the BIM system is not compatible with existing software have been identified as the most important factors in not adopting the BIM system.

5 Conclusions

The adoption of BIM system in developed countries is becoming more and more important in the construction sector. This is because it provides major benefits in terms of cost, quality, and time in building production. However, in developing countries, the adoption of the BIM system is very restricted and is mostly applied in large-scale public projects. Therefore, in this study, it is examined why this system is not adopted in developing countries and why it should be applying in CM services. In this context, a survey has conducted a survey to 30 companies providing professional CM services in Turkey in the implementation of the BIM system in professional CM services, to measure the duties to be performed, the level of the challenges encountered, the level of benefits obtained, and the frequency of use of BIM tools by the construction managers. The levels of importance of the factors were determined by using the SI analysis method with the survey data obtained. In this regard, the BIM system is at which phases of building production are more beneficial, what challenges are influenced by which tasks of construction managers, what benefits can be obtained despite challenges, which BIM tools are used more frequently, and the relationships among them are examined.

As a result, although the BIM system is effectively underutilized in CM services, its benefits such as reduce design errors with conflict analysis, interdisciplinary coordination, parametric modeling, and 3D visualization are appreciable and effective, indicating that some of the BIM tools such as automatic quantity takeoff, interdisciplinary coordination and communication, and conflict analysis are used very frequently. Because of that indicates how essential the BIM system should be adopted in the construction sector. However, for construction managers to perform their duties effectively and efficiently in this system, the most common challenges in projects implemented in the BIM system are lack of trained staff, lack of BIM culture and lack of standards and legislation as well as, it is important to minimize the 8 challenges factors shown in Table 8. In addition, following the minimization of these challenges, it is thought that the number of CM companies that do not apply this system will decrease significantly when employers and companies who do not apply the BIM system are given training on the necessity and practical application of the use of the BIM system.

This study is one of the first studies to determine the benefits and challenges and Construction Manager duties obtained with the use of the BIM system in CM services. Legal regulations, standards, contracts, and execution plans can be developed for the use of BIM in CM services by considering these identified duties, benefits, and challenges. The scope of this study covers only professional CM services in Turkey. It is thought that it will direct the applications both in the use of other traditional engineering services and in CM services in other countries.

It is expected that this study will contribute to stakeholders in conducting a study on how to minimize these challenges in the future and integrating CM duties into the BIM system in practical building production applications.

6 Author contribution statements

In the scope of this study, the contributions of the authors are as follows; Abdülkadir BUDAK, in formation of the idea, design, literature review, and assessment of obtained results; İbrahim KARATAŞ, in collecting data, implementing utilized methods, assessment of obtained results, writing, supplying the materials used and examining the results.

7 Ethics committee approval and conflict of interest statement

No stage of this study required permission from the ethics committee.

There is no conflict of interest with any person / institution for this article and preparation stages thereof.

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