



Benefits of Using BIM Tools to Resolve Clashes in Iraqi Construction Projects: A Case Study

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A B S T R A C T

When the components that make up a built asset are not spatially coordinated and clashed, this is referred to as a clash in design language. These incompatibilities can be identified more quickly in a BIM process during the design phase of a project, before construction begins on site. Most construction projects in Iraqi ministries suffer from a lack of coordination between project parties, which leads to problems in later project stages, particularly during the building stage, when one of the primary issues is a confrontation between civil, architectural, and other parties. This study aims to shed light on architectural element clashes and detect them early in the design process, resulting in fewer errors during the implementation phase. The study conducted a quantitative technique that included creating a questionnaire divided into three sections and focused on time and expense overruns. The result showed that, (The financial deficit of the contractor) is the most critical factor; (the contractor's non-compliance with the technical specifications) was the second rank. The second part (Using Building Information Modeling technology that reduces and resolving clashes between project elements during the design phase) was the most critical factor. Moreover, the second factor is (BIM technology increases communication between the project team) is the second rank.

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Introduction

The Iraqi construction industry still suffers from many problems, which are represented by a lack of expertise in information technology, overruns, costs and repeated interruptions due to administrative conditions (Khaleel & Hadi, 2017). Also, ancient methods are still practiced in the construction industry, such as 2D graphics and the critical path method. With the development of designs and the trend of the building industry towards large projects and their complexity in an intertwined manner, the methods used in the construction industry mentioned above have become difficult to apply to these buildings. Therefore, the need has become urgent to use new techniques in the construction industry that make things easier and smoother and facilitate communication between the different sides of the project. One of these methods is the Building Information Modeling technique (Hamada, Haron, Zakaria, & Humada, 2016). Building Information Modeling (BIM) represents the development a use of a computer-generated model to simulate the planning, design, construction and operation of a facility. The resulting model, a Building Information Model, is a data-rich, object-oriented, intelligent and parametric digital representation of the facility, from which views and data appropriate to various users' needs can be extracted and analyzed to generate information that can be used to make decisions and to improve the process of delivering the facility (Amuda-Yusuf, 2018).

Building Information Modeling (BIM), as a popular term, is not new. The concept approaches, and methodologies that we now identify same as BIM have been studied for many years. One of the

early documented examples is a working prototype, the Building Description System presented by the "father of BIM," Chuck Eastman in 1975 (Eastman, Teicholz, Sacks, & Liston, 2008). Since then, although most researchers and organizations have focused on CAD-related studies due to the successful application of CAD in the construction industry, there have been many studies of BIM-related technologies, especially in the last decade. As a result of the variety in understandings of intelligent building and research emphases, many new terms relating to BIM have been developed. Succar (2009) identifies some of the more widely used terms in both the research and industry literature: Asset Lifecycle Information System, Building Product Models, Building SMART TM, Integrated Design Systems, Integrated Project Delivery, nD Modeling, Virtual Building TM, Virtual Design and Construction, and 4D Product Models.

Problem Statement

In Iraqi ministries, most of the construction projects have been suffering from the lack of coordination between the project parties, leading to subsequent problems in the later project phases, especially in the construction phase.

And one of the main problems is the clashes between the civil, architectural, and other parties; therefore, the problems statement of the research is as follow:

- Weakness in communication between different projects parties led to clashes among projects drawings.
- Weakness in the awareness of modern techniques such as BIM tool to represent the project insufficient method and reduce the design time,

construction error, reworking and subsequently minimize delay and over budget.

- Due to the risky environment in Iraq and too insecure conditions, there was difficulty cooperating between stockholders of different fields, which required a digital method to enhance the cooperation.

Hypothesis Test:

The hypothesis was tested based on **H₀** and **H₁** alternative, and the test was two-tailed, as follows:

H₀: BIM tools will minimize delay and over budget in Iraqi construction projects.

H₁: BIM tools will not minimize delay and over budget in Iraqi construction projects.

Research Aim and Objectives

The main aim of the research was to use BIM technology to find out the clashes and differences among various elements of the project and to achieve the main aim, the following objectives were formulated:

- Identifying the causes that led to cost and time overruns by field study.
- Identifying the effect of the BIM tools on project performance by field study.
- Motivate the use of BIM tools as a replacement of the traditional method such as CAD and others.

The Building Information Modeling (BIM)

With the development of the science computer and the increasing demand for this knowledge, BIM technology has emerged at the beginning of the sixties of the last century. The actual step in the development of BIM was with the development of ArchiCAD programs in Hungary in 1982; the development of Revit programs in 2000 brought about a big jump in attaining BIM technologies (Smith, 2014). Since the mid-2000s, the Architecture, Engineering, and Construction (AEC) industry has been

using BIM in construction projects (Azhar, Hein, & Sketo, 2008; A Ahmad Latiffi, Mohd, Kasim, & Fathi, 2013). The use of BIM has progressed from the pre-construction to the post-construction phases (Aryani Ahmad Latiffi, Brahim, & Fathi, 2014).

There is no unified definition of BIM, as each definition represent a specific organization understanding of what BIM. BIM was defined in 2000 as a structured model that represented building elements (Ameziane, 2000). Until 2005, it was defined as the creation and application of computer software to simulate the design and operation of a facility (America, 2005). Moreover, there for a set of definition was reviewed through various studies. According to Abbasnejad, Nepal, Ahankooob, Nasirian, and Drogemuller (2021), BIM is a current invention initiative pondered to vanquish troubles like weak output within the Architecture, Engineering, and Construction (AEC) industry? In addition, BIM is an intelligent 3D model-based process for building, engineering, and construction (AEC) professionals to plan, design, build and manage buildings and infrastructure more efficiently. Provides insights and tools as stated by Autodesk (2012). Moreover, BIM is a new and powerful technology implemented by many countries (Btoush & Haron, 2017). Also, is a three-dimensional digital representation of the building containing all the physical and digital properties, which helps manage the building and share information among stakeholders (Miettinen & Paavola, 2014). A building information model can be used for the following purposes: Visualization, Fabrication/shop drawings, Code reviews, Cost estimating, Construction sequencing, Conflict, interference, and collision detection, Forensic analysis, Facilities management (Azhar, 2011). In order to

solve the problem of the demolition and rework due to insufficient drawing details, BIM provides a facility by building a 3D digital base that contains all the details of the building. This allows the project team to share it, which leads to a significant reduction in errors. It also allows the customer to see his building built in a complete digital image during the design phase. This leads to bridging the gap between the client, the stakeholder, and the project team (Demchak, Dzambazova, & Krygiel, 2009).

BIM Dimensions

As mentioned earlier, BIM is used in different stages of construction, and each stage contains a specific dimension. These dimensions as stated by Kacprzyk and Kępa (2014) are as follows:

- 3D BIM: The 3D is the dimension that considers the data representation in the design stage. The design phase is confined to three CADs and includes collecting, documenting, analyzing, and finalizing the design. It contains all the building's components and functional properties.
- 4D BIM – This dimension represents time. It includes all schedules for each item, from the start of the item through the moment it is anticipated to be demolished.
- 5D BIM – This dimension represents the cost. It is about the cost of each item in the building.
- 6D BIM– This dimension represents energy.
- 7D BIM– the last dimension represents the usage of the model in the maintenance of the building. Currently, there is no software able to provide such functionality.

BIM Benefits

The primary advantage of a building information model is its accurate geometrical representation of a building's parts in an integrated data environment

(Innovation, 2007). There are many benefits of using BIM in the construction industry, such as resolving clashes in the design phase, control and follow-up through the construction phase (Al-Ashmori et al., 2020), increasing in productivity and quality of the project, Enhancing financial management and reducing lost expenses during the construction phase (Chan, Olawumi, & Ho, 2019), solve the problem of changing orders during the construction cycle (Yang & Chou, 2019), ability to simulate building performances and energy usage (Olawumi & Chan, 2018), improves communication between team members, reducing rework (Zheng, Lu, Chen, Chau, & Niu, 2017), better information shared between project team (Mohammed & Haron, 2017), the 3-D visualization makes clients satisfied (Hong, Hammad, Akbarnezhad, & Arashpour, 2020). Other related benefits are Faster and more effective processes, Better design, Controlled whole-life costs and environmental data, Better production quality, Automated assembly, Better customer service and Lifecycle data (Azhar, 2011).

Clashes

In previous studies regarding BIM, clashes are defined as two or more elements that overlap in one place (Benning et al., 2010). Furthermore, a clash is the intrusion of two or more elements in the model. Based on various studies, there are many drivers that influence clashes in the BIM model, which influence the achievement of an effective design, such as Use of wrong or low level of detail (Leite, Akcamete, Akinci, Atasoy, & Kiziltas, 2011), Design uncertainty/use of Placeholders, Failing of design rules, Accuracy versus deadline, 3D model objects exceeding allowable clearance (Tommelein & Gholami, 2012), Use of

different file formats (Kensek & Noble, 2014), Designers working in isolation from each other (Craig & Zimring, 2002; Froese, 2010; Kalay, 1998), Insufficient time (Ashcraft, 2008; Benning et al., 2010), Use of 2D instead of 3D models (Leite et al., 2011; Hartmann, 2010; Shafiq, Matthews, & Lockley, 2012), and Lack of experts (Ashcraft, 2008; Kensek & Noble, 2014; Leite et al., 2011; Leon & Laing, 2012; Wang & Leite, 2014).

Clash detection is a critical requirement for trans-disciplinary projects that require complicated designs to be examined for clashes. Interference Detection examines various clashes during the tuning of 3D models, which are constructed with various new BIM programs like Revit Architectural, Revit Structural, and Revit MEPs. The technique is quite successful. Diverse 3D models, including Structural, Civil, Civil, and Architecture & MEP, are available in BIM (Mechanical, Electrical, and Plumbing). When all of these different types of models are combined to form a single BIM model, conflicts might arise (Valunjkar, 2017). When clash detection is tested during the design phase, the building's construction time and cost are reduced. Use clash detection applications in the AEC industry to increase efficiency in design and construction projects (Tommelein & Gholami, 2012).

Clashes Types

Chidambaram (2020) said that in general, clashes are often categorized as hard clashes, soft clashes, clearance clashes, duplicate clashes and animated clashes, as summarized in the following:

Hard clashes

A tricky clash involves at least two items that occupy the same physical space or two conflicted elements. These disputes are easy to spot because they usually involve only geometric concerns. Fierce conflicts

are regarded as potentially dangerous and should be resolved as soon as possible.

Soft clashes

A soft crash is a feature that can prevent the motion of multiple things and more spatial or geometrical disproportions inside the boundary that is necessary for the object to move, space, install, operate, and connect. Represents a clash that occurs at a critical moment, Conflicts between elements are highlighted, as well as buffer zones created around other elements. Conservative hard crashes are also known as soft crashes.

Clearance clashes

Clashes between elements and clearances are referred to as clearance confrontations. Construction codes, rules, or confrontations are detected, and if they occur, they are treated as intersecting if they do not maintain the specified clearance.

Clearance clashes were able to be easily prognosticated by creating specific rules. Also, note that some of these clashes are not serious design errors and can be ignored if the place can readily manage them. Clearance clashes are also recognized as imminent clashes.

Duplicate clashes

Overlapping clashes show that the kind and position of two or more intersecting objects are permitted. Modelers usually create at least two pieces in the same position because they unintentionally replicated the original item when modeling. These discrepancies in the model are easy to spot, and they only have a minor impact on the quantity of the invoice of materials or the bar bending schedule.

Animated clashed

Animated crashes depict at least two elements that collide owing to their dynamic differences, although they do not have to collide if they are in a stable

position. This type of conflict can be discovered by executing a simulated sequence, which can take a long time.

Because the project owner can run a virtual sequence to discover the rebar that cannot be built, moveable clash detection on the rebar is useful. This is similar to a soft crash, but this time we are looking for a collision between the element and another object's dynamic buffer zone (Matejka & Sabart, 2018).

Methodology

In order to formulate the objectives of the research, the subsequent methodology was applied:

Theoretical study: this part included gathering information regarding the BIM tools, software, clashes, and others regarding BIM with clash detection from the books, journals, and scientific publications.

Field study: the fieldwork was divided into three -stages. The first one was to prepare a questionnaire to identify the main causes that led to cost and time overruns. The second stage was determining the benefits of using BIM tools in construction, and the last stage comparing the cost of tender with the cost calculated by BIM. The research methodology is summarized in Figure 1.

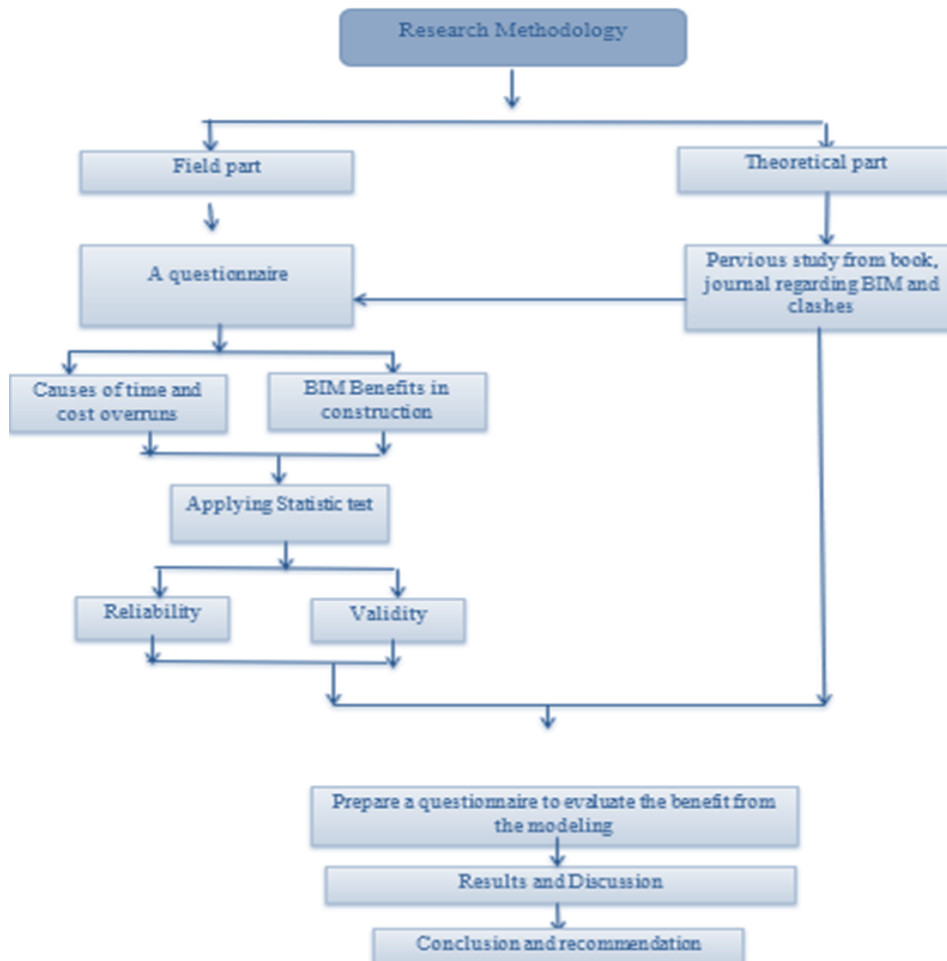


Figure 1 Research Methodology

Results and Discussion

Results of Questionnaire

The questionnaire involved three parts, the first one about the general information of the respondents, which included five questions. The second one about the factors that influenced cost and time overrun in Iraqi projects. And an additional question about respondents' interest in BIM technology to promote this technology as a solution to the problems of time and cost overrun in Iraqi projects. The third covered the impact of BIM technology in overcoming cost and schedule constrained in Iraqi projects.

Sample description

The results of the sample description analysis show that the academic achievement of most respondents was a master's degree by 48%, followed by 34% who had a bachelor's degree. About the respondent's experience, it is clear that the percentages of respondent's experience from six years and over represent 81% of the total responses. This indicates the maturity of their engineering mentality and their acquisition of more experience than newly graduated engineers, which strengthens the questionnaire.

As for the field of work, the results show that the percentage of respondents

who work in design and engineering consultancy field was 71%. This sector is critical because the design is the first stage and deals mainly with detecting and resolving clashes before starting the construction process to reduce time and cost. Regarding the respondent's awareness of BIM, the results show that 49% of respondents had awareness of BIM, while 51% had no awareness. This indicates a qualitative development in the direction of engineers and stakeholders in Iraqi projects, shifting from traditional methods towards using more effective ways that reduce time and cost. Finally, for the respondents engaging to learn BIM technology and its tool. The results as shown in Figure 2 revealed that many respondents had a strong desire to learn BIM technology and tools. However, only a small fraction has an absolute desire to understand the technology and tools. Compared to earlier studies by Iraqi researchers, this suggested a movement in the mindset of engineers and stakeholders toward the adoption of approaches that facilitate the building industry process in Iraqi projects (Hatem, Abd, & Abbas, 2018).

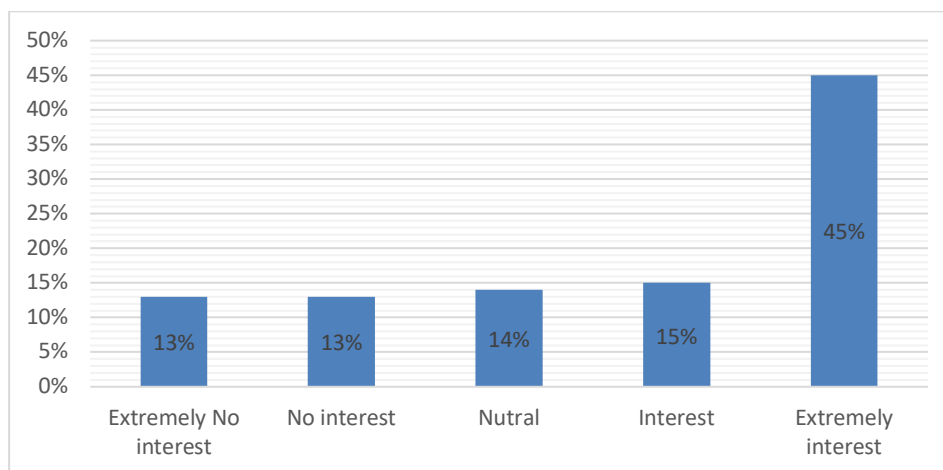


Figure 2 Respondents interesting to learn BIM technology and its tool

Analysis of factors affecting time and cost overrun and their sign test

This part contained 11 questions, and (mean, rank, standard deviation) was extracted. Every item of 11 questions was tested by using a (2-tailed) test with a confidence interval percentage of 95%, extracting the Z. score value, and examining it in the rejection area between (-1.96 – 1.96), as shown in Table 1.

Table 2 Analysis of factors affecting time and cost overrun and their sign test

No.	Item	Mean	SD	Rank	Z. value
1	The use of traditional methods in designs such as two-dimensional graphics, which require a long time to understand its details during the implementation process, what is the extent of its impact on the time and cost of the project.	3.38	1.084	11	3.096
2	The impact of not appointing a private consulting company by the beneficiary to supervise the contractor or the company executing the project on the time and cost of the project.	4.00	1.067	10	8.380
3	The impact of delay in the payment of the beneficiary entity (governmental or investment department) for the financial advances due to the contractor or the executing company according to the terms of work performed in the project on the time and cost of the project.	4.35	0.785	3	15.334
4	The financial deficit of the contractor, which in turn leads to many stops in work, what is the extent of its impact on the cost and time of the project.	4.59	0.630	1	22.527
5	The impact of the delay or difficulty of building materials reaching the project site on the time and cost of the project.	4.08	1.053	9	9.134
6	To what extent does the lack of definition and understanding of the role of each individual in the project team of their responsibilities and	4.11	0.968	8	10.282

	tasks affect the time and cost of the project.				
7	The impact of the contractor's non-compliance with the technical specifications previously agreed upon in the contract concluded with the beneficiary party on the project time and cost.	4.48	0.779	2	16.934
8	The delay in deciding to address problems that need quick solutions on the time and cost of the project.	4.25	0.819	5	13.650
9	The impact of the weak administrative and technical expertise of the project manager and his lack of knowledge of engineering project management methods on the time and cost of the project.	4.31	0.836	4	14.046
10	The impact of adopting advanced and practical engineering and administrative techniques in implementing Iraqi engineering projects on the cost and time of the project.	4.14	0.882	7	11.532
11	To what extent do the economic and financial problems of the country affect the implementation of projects.	4.21	1.015	6	10.685

The items are ranked according to the mean of each one from (high effectiveness) or (significantly effectiveness) downward. Here, the first three factors will be discussed according to their importance compared with other factors.

The first factor was (The financial deficit of the contractor, which in turn leads to many stops in work). Indeed, this factor is significant because there are terrible stops and stumbles in Iraqi projects due to the contractor's financial problems and financial inability to complete them due to his lack of financial liquidity or other financial problems related to his strength

in the construction industry market in Iraq.

Moreover, factor number two in terms of importance was the contractor's non-compliance with the previously agreed-upon technical specifications in the contract concluded with the beneficiary party. This was particularly critical since many contractors disregard technical standards and employ low-efficiency materials for various reasons, including contracts, sold several times between contractors until they reach the lowest bidder. As a result, it was compelled to execute them with minimal specifications since excessive

requirements would result in a financial loss.

The third most important issue was the delay in payment of cash advances owed to the contractor or executing firm under the work completed on the project by the beneficiary body (government or investment department). This is particularly essential since the administrative procedures for passing over advances to the implementing agency can be lengthy and sometimes complicated. Furthermore, the recipient may face financial difficulties due to not obtaining project funds from higher authorities, and so on.

In terms of the hypothesis test, the results of SPSS analysis for all Z-values fell

outside the rejection region, rejecting the hypothesis (H₀) that there is no influence of variables on project time and cost overrun in Iraqi projects. As a result, it would be (H₁) that all elements influence time and cost overruns in Iraqi projects.

Analysis of factors of using BIM technology that affecting on time and cost overrun and their sign test

This part contained 15 questions, and (mean, rank, standard deviation) was extracted. Every item of 15 questions was tested by using a (2-tailed) test with a confidence interval percentage of 95%, extracting the Z. score value, and examining it in the rejection area between (1.96 – 1.96), as shown in Table 2.

Table 2 Analysis of using BIM that affecting on time and cost overrun and their sign test

No.	Item	Mean	SD	Rank	Z. value
1	Using Building Information Modeling (BIM) technology that leads to reducing and resolving clashes between project elements during the design phase, what is the extent of its impact on the cost and time of the project.	4.36	0.743	1	11.423
2	What is the impact of the use of Building Information Modeling (BIM) technology on helping the financially distressed contractor to complete the project?	3.21	1.218	15	1.052
3	How does the use of BIM technology increase communication between the project team?	4.33	0.869	2	9.587
4	The multi-dimensional model of Building Information Modeling (BIM) helps to show the design in all its details to stakeholders, what is its impact on the time and cost of the project.	3.90	1.046	9	5.357
5	What is the impact of assisting Building Information Modeling	4.28	0.826	3	9.698

	(BIM) technology in resolving design clashes in reducing material waste during the implementation phase, which reflects an economic benefit?				
6	What is the impact of increasing the quality of the project by applying Building Information Modeling (BIM) technology on the completion of the project at the specified time and cost?	3.97	0.986	6	6.169
7	What are the impacts of the poor skills of engineers to use Building Information Modeling (BIM) technology tools and programs on the time and cost of the project?	3.69	1.195	12	3.617
8	What is the impact of the reliance of contracting companies and consulting offices in Iraq on Building Information Modeling (BIM) technology programs in thoroughly calculating quantities?	3.71	1.137	11	3.853
9	What is the impact of using Building Information Modeling (BIM) technology in consulting offices and contracting companies in Iraq on reducing the project implementation period?	3.76	0.883	10	5.326
10	To what extent is Building Information Modeling (BIM) used to reduce rework.	3.92	0.984	8	5.860
11	What is the impact of the use of Building Information Modeling (BIM) technology in consulting offices and contracting companies in Iraq on raising the productivity of engineering work?	4.00	1.051	5	5.940
12	What is the impact of the lack of government support for the public and private sectors on the transition from traditional methods of design to the use of Building Information Modeling (BIM) technology?	4.21	1.105	4	6.814
13	What is the impact of the lack of companies supporting Building	3.95	0.887	7	6.680

	Information Modeling (BIM) software to solve clashes like Autodesk Navisworks in Iraq?				
14	What is the impact of the high cost of purchasing engineering software and hiring experts in the use of Building Information Modeling (BIM) technology such as Autodesk Revit or Autodesk Navisworks on reducing the dependence of consulting offices and contracting companies in Iraq on them?	3.44	1.165	14	2.336
15	What is the impact of the fear of consulting offices and contracting companies in Iraq of not re-investing in the transition to Building Information Modeling (BIM) technology in the near term, such as training employees and purchasing software and hardware for this technology?	3.66	1.122	13	3.616

The items were graded from (high effectiveness) to (same effectiveness) to measure their mean effectiveness. The first three elements will be examined in this section to their importance compared to other factors. (Using Building Information Modeling (BIM) technology to reduce and resolve conflicts between project aspects during the design process) was the first reason. Detecting conflicts during the design phase was self-evident and necessary before beginning any BIM-enabled project. It also led to fewer mistakes during the implementation phase. Its application was critical for all phases of implementation that followed the design phase. As a result, it is no wonder that it is at the top of the list in the survey.

The second factor was how the use of BIM technology increases communication between the project team. One of the essential benefits of BIM technology is that it improves project

team communication by creating a foundation that allows everyone to exchange information from a single source, decreasing its time to communicate compared to conventional methods.

The third factor was (assisting Building Information Modeling (BIM) technology in resolving design clashes and reducing material waste during the implementation phase, reflecting an economic benefit). The detection of conflicts minimizes lost resources since numerous clashes occur in traditional techniques and during implementation, resulting in demolition, rebuilding, and transferring the elements, all of which waste materials.

The fourth factor was the lack of government support for the public and private sectors to transition from traditional design methods to the use of Building Information Modeling (BIM) technology. This was due to a change-

averse culture resistant to new technology and the fear of moving to new methods, which was a genuine concern for many engineers, managers, and stakeholders.

Conclusion

Building information modelling is a set of digital tools that help the construction industry manage projects effectively. Through the adoption of BIM, the forecasting of the performance of construction projects has been improved. Thus its operation is better, which will lead to an improvement in the ability to profit. Therefore, stakeholders in the construction industry have become more aware and aware of BIM and its benefits on the output of the construction industry. The current study results show that there is a 45% acute interest in learning BIM technology and a 15 % average interest in BIM technology, for a total of 60%. While knowledge did not reach half of the population (49%) in Iraq, it is a high proportion when contrasted to the absence or lack of Iraqi projects utilizing BIM technology. This is a good sign that engineers and professionals in Iraq are becoming more interested in understanding BIM technology.

In addition, the results revealed that the contractor's financial shortfall was the most significant issue affecting the construction sector in Iraq, resulting in time and cost overruns. The second element contributing to time and expense overruns in Iraqi projects was the contractor's non-compliance with the technical specifications. The third element contributing to time and cost overruns in Iraqi projects was the delay in payment of the beneficiary entity for financial advances owed to the contractor or executing business according to the conditions of work completed in the project.

Besides, the most significant aspect of improving and decreasing time and cost overrun in Iraqi projects was using Building Information Modeling (BIM) technology, which minimizes and resolves disputes. Building information modelling technology improves project team communication, allowing for increased information exchange and collaboration. The second factor was this. Reducing waste throughout the project implementation process was more accessible by resolving crossings between the parts.

Based on the results of the current study, the study recommended using NavisWorks During the design phase of Iraqi projects to resolve clashes. Building Information Modeling technology is also proposed to be used as a technical method at all stages of Iraqi project building. It provides an optimal design free of clashes at a reasonable time and cost. Additionally, it is essential to Hold seminars and lectures to present in-depth BIM technology to engineers and stakeholders and teach engineers how to utilize it. Finally, the study Urges the Iraqi government to support the transition from traditional construction to BIM technology.

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