ISSN: 2617-2070 (Print); 2617-2070 (Online)
Journal of Advanced Sciences and Engineering Technologies
available online at: http://www.jaset.isnra.org

Journal of Advanced Sciences and Eng. Technologies
JASET

Building Information Modelling Technology in Mitigating Cost Overruns and change orders in Construction Projects

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Keywords:

BIM, Change Order

Cost Overruns

Construction Projects

Jordan

ARTICLE INFO

Article history:
Received 01. October 2021
Accepted 15. October 2021
Available online 01 November 2021

DOI: http://dx.doi.org/10.32441/jaset.04.01.05

ABSTRACT

Variation order (VO) is one of the main issues faced by the construction industry in Jordan. Many researchers had investigated on the causes of VO and proposed procedures to minimize and control this issue; however, the VO is affecting the construction industry badly even at moment. Building Information Modeling (BIM) is a powerful management system that can make a significant difference in the project costs. However, BIM has not been examined as a tool to minimize the VO in Jordan. The main target of this study is to utilize BIM applications in reducing the effect of VO on the governmental projects in Jordan. In order to achieve this target, the researcher has designed a questionnaire to gather data related to VO causes and the BIM capability to solve this problem. The data collected from the questionnaires were analyzed statistically. The result from the analysis found that the consultant initiated the highest VO of 50% followed by the clients and the contractors of 20% and 10% unforeseen variation respectively. Moreover, it is found that BIM Design Applications, Facility Operations Simulation, Exploration Design Scenarios, BIM Design Detection and BIM Quantity Take-off and Cost Estimation were significantly capable of minimizing VO. The results show positive relationship with the application of BIM in minimizing VO in the construction industry in Jordan.

Introduction

The construction sector in Jordan, like many other countries, is an important sector that contributes to the economic growth and development. Because of the diversity and complexity of its sub-sectors, it is more crucial to economic, demographic, and social developments, since its growth is influenced by interconnected elements such as the overall political climate, a secure investment environment, and adequate infrastructure. Although, the construction industries boost the economy by creating jobs and money(Faten Albtoush, Doh, Abdul Rahman, & Albtoush, 2020), many projects are delayed, causing project time and cost estimates to be exceeded(Mohammad, Ali, & Najm, 2021) (Sweis, Sweis, Hammad, & Shboul, 2008). The project's delays has cause longer waiting time than necessary by the people and economy for the provision of public goods and services (Sharma, Rahul, & Rao, 2012).

Time, cost overruns, quality flaws, and other negative consequences of VO are common in building projects (Enshassi, Arain, & Al-Raee, 2010). Variation, according to (Oladapo, 2007), is any changes to the legally signed contract. Alsuliman et al (2012) further defined variation as modifications or conditions of work as per contract's terms and conditions, which include the change in the working environment.

Variation has been so common in construction that project completion without VO is close to impossible (Ndihokubwayo, 2009). Consequently,

(Ngwepe, Aigbavboa, & Thwala, 2014) stated that the main changes to the projects are change of scope, duration, cost and quality. Ngwepe et al. (2014) further added that VO is one of the causes of project cost and time overruns, which are permanent problems in international construction. (Al-Momani, 1996) stated that the real cost exceeds the contract cost by 30%, whereas VO result in an 8.3% cost overrun when a project is completed. This shows that in the Jordanian construction industry, there is no specific management mechanism in place to reduce VO.

Therefore, there is a serious need to improve the current practices, such as building information modelling applications since BIM has been proven of its capability to solve many construction problems globally, it is necessary to develop a sound BIM framework to mitigate cost overrun, delay, and VO in the Jordanian construction industry. This study hopes to introduce a helpful contribution through presenting BIM framework for reducing VO in Jordanian government construction projects, which gives motivation to the stakeholders in Jordan to use it, eventually, it is hoped that this framework assists stakeholders who control this industry to reduce VO, hence, enabling the local firms to participate and competence the foreign companies. Besides, it also improves the performance of construction projects, which will inevitably reflect positively on the country's economy.

VARIATION ORDER

Contracting projects are a massive field in Jordan as it supports the local economy and solves many problems like employment and poverty. It is an essential sector, most construction projects change their initial design, specifications and drawings, so this can be a direct result of innovative change, constitutional changes or authorization, change in conditions, topographical incongruities, non-accessibility of indicated materials, or just as a result of the continual improvement of drawings after the agreement has been granted., In vast structural designing activities, varieties can be extremely momentous, though they might be minor on small building contracts.

According to FIDIC (1999), variation's aspects can be variation in design, quantities, quality, working conditions or a sequence of work. VOs is a composed request to the contractor marked by the client and issued after execution of the agreement, permitting an adjustment in the work or any modification on the agreement ***(Arain & Pheng, 2007), any change in the contract purpose as deduced from the contract describing or defining the work to be carried out is called variation. In their study, (Hanna, Camlic, Peterson, & Nordheim, 2002) investigated that 55.4% of the VOs causing total time extension were created by owner-employees. The two standards of a flawless project and fruitful undertaking administration are the in-planned term and cost at project closing. The findings also revealed that the engineer (consultant) was the most common project party to generate variations orders, accounting for 47.1% of total cost and the owner (customer) accounting for 43.1%. On the other hand, (Bakr, 2014) looked at VOs in Jordanian construction projects, he started a survey questionnaire form and sent it to three parties (client, engineer, contractor). The study concluded that that the most frequent variation in contracts was 20% additional work.***

Causes of VOs

A viable investigation of variations and VOs requires a full comprehension of the main variations drivers, (Arain & Pheng, 2005; Hardjomuljadi & Sulistio, 2021); hence, 38 reasons of VOs were recognized, as shown in Figure 1, the researcher assembled reasons for variations under four classes:

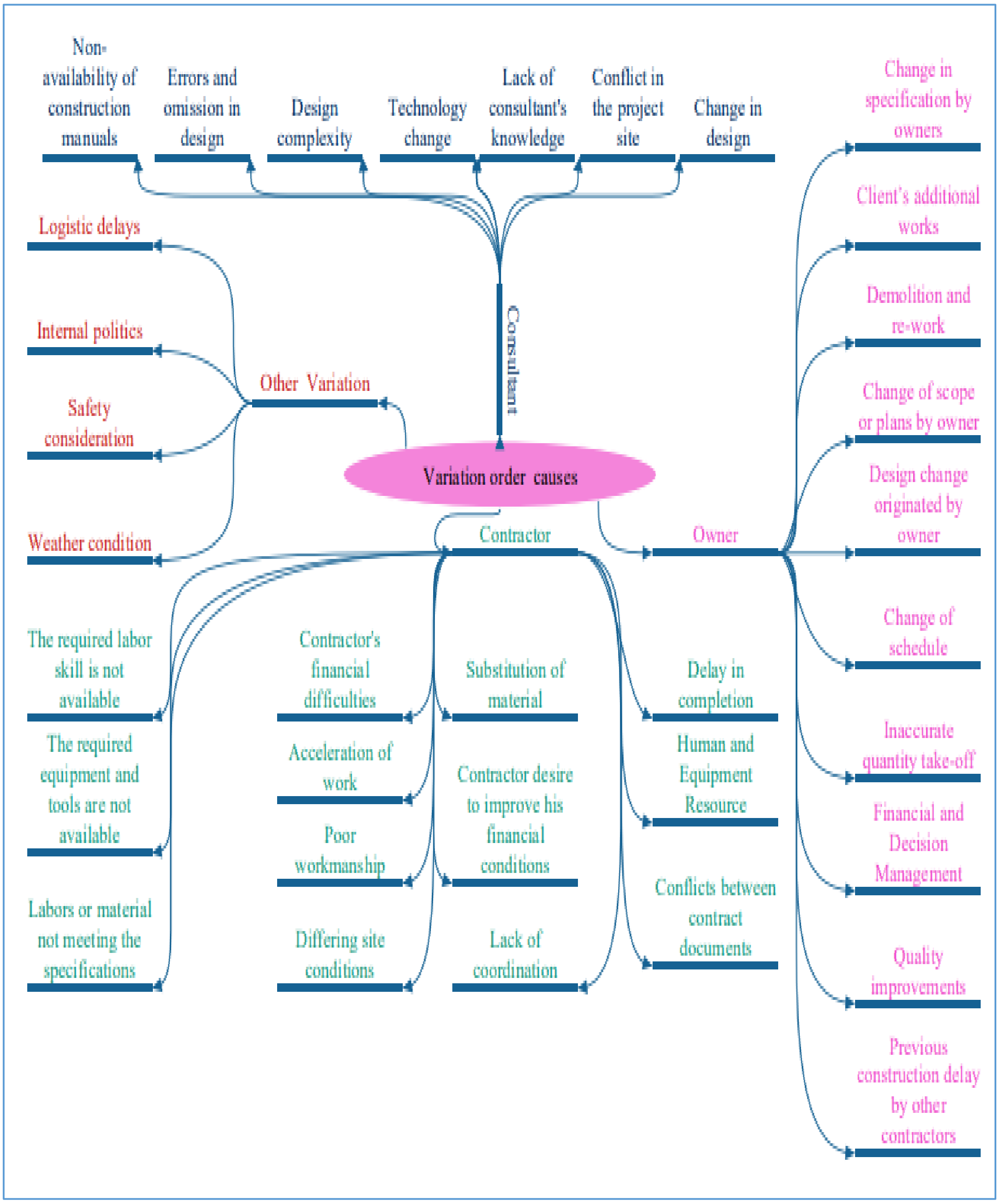

Figure 1 : Change orders causes.

variations caused by the owner, variations caused by the consultant, variations caused by the contractor and unforeseen variations due to other initiators.

Owner related VOs

An owner often initiates variations, and occasional variations are required because it could be that the owner was unsuccessful in fulfilling a certain requirement for executing the project. These causes include Inaccurate Quantity Take-off, Scope Changing or Plans by Owner, Scheduling Change and Impediment to Prompt Decision Making Process, Financial Problems for Owners, Financial and Decision Management, Design Change Originated by Owner, Demolition and Re-work, Client Related Issues, Owner Changes in Specifications, and Quality Improvements.

Consultant related VOs

The consultant specifically starts varieties variations are mandatory because the consultant missed satisfying certain necessities to execute the project. These causes include Design Changing by Engineer, Errors and Omission in Design, Technology Change, Value Engineering, Conflict in the Project Site, Complexity in Design, Design and Drawing Issues, Lack of Consultant's Knowledge in Available Materials, Non-availability of Construction Manuals and Procedures, and Insufficient Design.

Contractor related VOs

The contractor may propose some modifications to the drawings, or the project might require the modifications because the contractor failed to achieve a specific requirement to implement the project. These causes include Delay in Completion and Increase Project Cost, The Required Equipment and Tools are Not Available, Poor Workmanship, Financial Difficulties for Contractor, Contractor Desire to Improve his Financial Conditions, Site Conditions, Human and Equipment Resource, The Required Labour Skill is Not Available, Acceleration of Work, Substitution of Material or Procedures, Lack of Coordination Among Project, Labours or Material Not Meeting the Specifications, and Conflicts Between Contract Documents.

Unforeseen variations

These variations could be expected, but they could not be measured quantitatively, which included Weather Condition, Internal Politics, Safety Consideration/Emergency Field Condition, and Logistic Delays.

BUILDING INFORMATION MODELLING

Building information modeling (BIM) is a collection of information technology used by the architectural, engineering, and construction (AEC) industries to tightly integrate technology and information (Zhang, Tang, Wang, & Wang, 2020). With the BIM innovation, a correct virtual model of a building could be numerically built(Ja'far, Haron, & Albtoosh, 2016). This model, identified as the building data can be utilized for arranging, plan, development, and procedure of the venture; it helps modellers, architects and contractual workers to imagine what is to be worked in a recreated circumstance to recognize any conceivable outline, development, or agent issues (Azhar, 2011). On the other hand, the adoption of BIM has proceeded through three stages at the organizational level: an interdisciplinary object-based modelling process, a synergy based on an existing model, and a network-based synergy (Succar, 2010).

Building information management's advantages Pre-programming design intent is included in BIM(Cao, Shao, Huang, & Wang, 2021), allowing systems to maintain consistency across diverse building portions automatically(Abuaddous, Ja'far, Al-Btoush, & Alkherret, 2020). Additionally, it increases engineering efficiency, shorter lead times between design and manufacturing, and a continuous flow of data from sales to engineering (Ansah, Sorooshian, Mustafa, & Duvvuru, 2016). It is worth noting that the BIM framework allows for the extraction of 2D drawings and 3D models from any viewpoint, eliminating time, inaccuracies, and blunders caused by project changes (Andújar-Montoya, Gilart-Iglesias, Montoyo, & Marcos-Jorquera, 2015). According to Construction Training Fund (2014) in Australia, BIM has had a huge influence beyond project boundaries. According to Business Review Weekly's response to the CPSISC 2014-2015 Environment assessment, the adoption of BIM in construction can save enterprises between 3% and 5% in expenses, in addition to that, BIM could have a tremendous impact on the economy, not just in design and construction...might improve GDP by 0.2 basis points over the "business as usual" scenario, rising to 5 points by 2025.

Current BIM Situation in Jordan

Over the last few years, BIM has been increasingly popular in the construction industry. Many studies have been conducted worldwide to discover elements that promote BIM adoption (Gu & London, 2010; Linderoth, 2010; Xu, Feng, & Li, 2014). Although the potential benefits of BIM are tempting, the rate of adoption differs per country (Gu & London, 2010). According to previous studies, BIM implementation and usage are expanding in most developed countries (Ibrahim & Birshir, 2012). Nonetheless, in developing nations, BIM adoption is at a standstill (Zhang et al., 2020). For example, Jordan is still in the early stages of implementing BIM. The study's findings conducted by (Matarneh & Hamed, 2017) disclose that BIM adoption in Jordan is still in its early stages(Aburamadan et al., 2021). It faces a number of significant challenges, including a lack of government support, a lack of BIM mandates, a lack of BIM knowledge, a lack of BIM standards, expense, and an unwillingness to change.

Building SMART started a study to see how widespread Building Information Modelling (BIM) is in Jordan's building industry. The permeation is considerable, and more than a quarter of those surveyed were aware of the BIM system; nevertheless, only 5% of those surveyed were using it (Al Awad, 2015). In June 2011, the Jordanian Ministry of Public Works and Housing (MPWH), Jordan Engineers

Association (JEA), Building SMART BIM Journal, and MENA all agreed to start a Building SMART discussion to help BIM in the Jordanian construction industry control squander, improve construction technique, and limit project costs.

Benefits of BIM

BIM adoption will have numerous advantages, including increased production efficiency and product quality, increased sustainability, and expanded opportunities for the construction industry's growing sectors (Arayici et al., 2011; Navendren, Manu, Shelbourn, & Mahamadu, 2014; Ramilo & Embi, 2014). Furthermore, it drastically alters the traditional planning process and provides ideal solutions for the mass customization production strategy (Ern & Kasim, 2013).

(Migilinskas, Popov, Juocevicius, & Ustinovichius, 2013) presented an overview of BIM case studies for researchers; the findings of his study concluded that there are great benefits gained by using BIM, and this usage will impact the time and cost of the projects. (Migilinskas et al., 2013) also found many benefits of BIM, defined as improving the details of implementing construction by 3D visualization. (Haron, 2013) listed some of these benefits, such as recovering the transfer of project and construction over 3D visualization, integrated and computerized drawings output, intelligent documents and data recovery, consistent information and automated physical take off.

On the other hand, (Love, Matthews, Simpson, Hill, & Olatunji, 2014) recommended to use BIM for the following reasons: (BIM) allows strategic business benefits, the adoption of BIM should not be a separated information technology project but a business variation program that can hypothetically impact their value suggestion, benefits realization recognizes that technology alone cannot deliver business outcomes and that its adoption must be handled proactively to ensure that the firm achieves its goals. Furthermore, the BIM implementation benefits from several studies are summarized, as is shown in Table 1.

Table 1 BIM Implementation Benefits

Benefits	Author
Cost less than 1% of the total project cost	

Schedule conflicts (scheduling interface) $1.2 M	(Garrett & Garside, 2003)
Data conflicts (attribute management) $0.5 M	
Conversion of the 2D model approximately 75% of the total pilot cost	
Change orders representing % of base contract: **2D projects = 18.42%** **3D only = 11.17%**	(Barlish & Sullivan, 2012)
Collaborative BIM = 2.68%	
Reduced rework — $50,000	
Shortened construction durations — $10,000	(Kuprenas & Mock, 2009)

Poor designs, inaccurate cost and time control in construction are the most prevalent reasons of delay and cost overrun(A KA Al-Btoush & Al Btoosh, 2019). BIM applications such as conflict detection, quantity take-off, design, and visualization play a vital role in the management of government construction projects ((Mohammed, Haron, Alias, Muhammad, & Baba, 2018). (Eadie, Browne, Odeyinka, McKeown, & McNiff, 2013) reviewed the phases and features of BIM concept improvement, some countries that are using BIM was mentioned by researchers, one of them talked about the UK experiment. It is found that significant impacts through BIM implementation may be realized throughout all stages of the construction process, the paper examined the use of BIM during the project lifecycle.

On the other hand, (Jung & Joo, 2011) observed that the multidimensional (nD) and talked about disseminating the CAD utilization in the construction industry that was mentioned (the overall and practical effectiveness of BIM). This paper included a BIM framework involving three dimensions and six groups; the study concluded that the framework could deliver a basis for evaluating promising areas and classifying driving factors for application.

RESEARCH METHODOLOGY

The study adopted quantitative research method using questionnaire survey that targeted engineers involved in handling construction projects in Jordan. Questionnaires were employed as the primary data collection tool in this study. A questionnaire, according to (Kumar, Luthra, & Datta, 2006) is a form that is developed and circulated in order to obtain replies. Although these questions are generally factual and aimed to secure information on particular conditions or practices that the recipient is assumed to be aware of the nature of the data to be collected led the selection of this tool. Furthermore, the researcher created a questionnaire to collect the information needed about the sources of variance orders and the potential of BIM to handle this issue. The study's main aim is to assess the reasons of VOs in Jordanian construction projects, as well as the ability of BIM tools to reduce VOs. Therefore, the respondents were asked to evaluate the causes of VOs in building construction projects and rank them according to their levels of impact on the VOs in building construction projects. Besides that, the respondents were also requested to propose and classify BIM Design applications to reduce causes of VOs.

DATA ANALYSIS

The survey questionnaires are sent to 150 engineers working on various building construction projects in Jordan. The response rate was around 70% as the returned are 105 out of 150 questionnaires. The demographic analysis shows that the majority of the respondents were architecture engineers, representing 35.2% of the total respondents. According to the designation of the respondents, the majority of respondents were working for the contractor with 50.5 %. On the other hand, all the respondents are engaged in handling building construction projects and holding managerial and executive posts.

The current study's first goal is to look at the most common sources of variance orders in Jordanian government building projects. To reach this goal, researchers looked into the origins of VOs and what kind of variants occur in Jordanian government construction projects. From the literature review, the study determined 34 causes of VOs classified into four groups based on the contract parties, such as Owner, Consultant, Contractor, and Unforeseen Variations.

The respondents were asked to evaluate every potential cause according to their experience evaluation, using the following scale, 1: strongly disagree; 2: disagree; 3: neutral; 4: agree; 5: strongly agree. Table 2 shows the rank of the causes of VOs by the relative importance index (RII). The ten most common causes of VOs in Jordanian government building projects are Inaccurate quantity take-off,

Laboure or material not meeting the specifications, Logistic delays, Internal politics, The required equipment and tools are not available, Technology change, Human and Equipment Resource, Non-availability of construction manuals and procedures, The required labour skill is not available, and change of scope or plans by owner.

Table 2 The ten most common causes of VOs in Jordanian government building projects.

VOs Causes	RII	Rank	Agent

Inaccurate quantity takeoff	0.638	1	Owner
Labors or material not meeting the specifications	0.623	2	Consultant
Logistic delays	0.608	3	Other
Internal politics	0.598	4	Other
The required equipment and tools are not available	0.594	5	Consultant
Technology change	0.590	6	Consultant
Human and Equipment Resource	0.590	7	Contractor
Non-availability of construction manuals and procedures	0.585	8	Consultant
The required labour skill is not available	0.583	9	Contractor
Change of scope or plans by owner	0.579	10	Owner

To provide a theoretical BIM framework for Jordanian government construction projects to reduce VOs. The framework items included the causes of VOs and the BIM design application to reduce VOs. The causes included four main groups, namely, Owner (OWN), Consultant (CNS), Contractor (CNT), and Unforeseen Variations (UFSV). Besides, the BIM Design Applications (BIMDA) included 27 items categorized into six groups, namely Programmatic Integration (PGI), Visual Simulation (VIS), Facility Operations Simulation (FOS), Exploration Design Scenarios (EDS), BIM Design Detection (DSD), BIM Quantity Take-off and Cost Estimation (QTCE). The mean and RII of these items are summarized in Table 3.

Table 3 The Mean, RII and rank of the constructs in the study

Framework Items	**Mean**	**RII**	**Rank**
Contract Parties (CNP)			
Owner (OWN)	2.817	0.5634	4

Consultant (CNS)	2.858	0.5716	3
Contractor (CNT)	2.867	0.5734	2
Unforeseen Variations (UFSV)	2.977	0.5954	1
BIM Design Applications (BIMDA)			
Programmatic Integration (PGI)	3.063	0.6126	6
Visual Simulation (VIS)	3.013	0.6026	7
Facility Operations Simulation (FOS)	3.162	0.6324	5
Exploration Design Scenarios (EDS)	3.248	0.6496	1
BIM Design Detection (DSD)	3.233	0.6466	4
BIM Quantity Take-off and Cost Estimation (QTCE)	3.145	0.6290	3
VO minimizing (VOM)	3.246	0.6492	2

CONCLUSION

This study highlights the present situation of the VOs in Jordanian construction buildings projects and how can solve this issue. The first path was collecting as much information as possible about VO, causes, effects, and controllers to make a clear and comprehensive view of the topic through literature. In parallel, the researcher studied the potential solutions to solve this problem. After reviewing and observing many management systems, the researcher found a promising management system to minimize VO.

The study was carried out using a survey method, with 150 questionnaires used to collect data. The data was analyzed using Partial Least Squares (PLS), percentages, Relative Importance Index (RII). The survey achieved a 70% rate of return. The study's findings revealed that the ten common causes of VOs are Inaccurate quantity take-off, Labours or material not meeting the specifications, Logistics delays, Internal politics, and the equipment and tools are not available. Besides, the results indicated that Contract Parties, Consultant, Contractor and Unforeseen Variations had significant positive effects on V. O. BIM Design Applications, Facility Operations Simulation, Exploration Design Scenarios, BIM Design Detection, BIM Quantity Take-off, and Cost Estimation, on the other hand, had a negative impact on VO.

After the study outcome has been analyzed and discussed, it was clear that building information modeling applications in the design phase are essential to mitigate the causes of the VO. The outcome is based on the construction industry players, so, as a conclusion, if the construction industry in Jordan follows results, VO , cost and time overrun will be minimized.

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