Building Information Modeling Strategy in Mitigating Variation Orders in Roads Projects

Musab Abuaddous [a], Ja'far A. Aldiabat Al-Btoosh [b*], Mohammed A. KA. Al-Btoush [c], Abdulrazzaq Jawish Alkherret [b]

[a] Department of Civil Engineering, Hijjawi Faculty for Engineering Technology, Yarmouk University, Irbid, Jordan.

[b] Department of Civil Engineering, Jerash Universtiy, Jerash, Jordan.

[c] Faculty of Engineering, Isra University, Amman, Jordan.

Abstract

Most governmental projects in Jordan have cost overrun, it rises during the on-going stage to increase the cost and prolong the time of the project. Unfortunately, until this moment, there is no particular management system in Jordan construction industry to minimize cost overrun and variation order adopted by the government. In contrast, global construction industry has witnessed a huge transformation in terms of the use of digital technologies, particularly Building Information Modeling (BIM) which is a revolutionary digital technology and operation that is reshaping the Architecture, Engineering and Construction (AEC) industry. approach and objectives causes before of this paper are firstly to review the factors contributing to variation orders in governmental road projects in Jordan, secondly, to propose a BIM design applications strategy to minimize variation orders, to achieve the objectives a quantitative approach was followed by distributing a questionnaire, then the data was analyzed statistically using relative importance index, the results were as follow. Our findings suggests that the most important factors causing change orders were as follow: Inaccurate quantity take-off (0.66); Labours or material not meeting the specifications (0.63); Logistic delays (0.60); Internal politics (0.566); and the equipment and tools are not available (0.55). The results also indicate that Contract Parties, Consultant, Contractor and Other Variations had significant positive effects on V. O, whereas the effects of BIM Design Applications, Facility Operations Simulation, Exploration Design Scenarios, BIM Design Detection, (BIM Quantity Take-off and Cost Estimation) had a passive impact on V.O. Lastly, BIM has obtained a great reputablity by enhancing the productivity in construction society, minimizing the total cost of the projects, and many other benefits.

Keywords: BIM; Cost Overrun; Adoption Strategies; Jordan.

1. Introduction

Construction projects are usually exposed to various types of challenges that could cause a delay. This delay along with the cost overrun can have severe impact on the economic status of the project especially when it has political roots. Hence, the delay of a construction project which targeting an economic development can increase the frustration among the population and postponed an economic development. [1-3].

Therefore, construction delay can be defined as the exceeding in time either after the completion date specified in a contract, or after the date that the parties have agreed upon for implementing the project. However, for a project to

exceed its planned schedule is considered a familiar problem in construction projects. For owners, delay means loss of earnings resulting from lack of production facilities and rentable space or a dependence on present firms, in some cases [4-6].

To contractors, delay means more overhead costs because of extended work period, and higher material costs due to inflation and labor cost increment [7]. Any change in basic agreement is considered as variation. Further, VO may consist conditions contributing to the project in conformity among the agreement terms, which will affect the environment of the work [8].

Typical procedures of agreements illustrate that no changes shall terminate the agreement as variations are a modification within a contract and not an alteration of the contract [9]. When the project is completed, the actual budget go beyond the original budget by 30% while variation orders effect in an 8.3% in the additional expenses. Therefore, a cooperative effort between the concerned agencies is important to mitigate construction problems which could lead to the introduction of new policies to address the obstacles ahead.

The main aim of this study was to investigate the most important factors that may cause the variation orders in road projects in Jordan. For this reason, it was important to highlight the major cause for those factors. The targeted populations were the three parties of the contract itself (client, consultant and contractor). A quantitative approach was adopted and a questionnaire was distributed and analyzed statistically to have gain a deeper understanding of the most significant causes of the variation order. The second part of the questionnaire proposed building information modeling design assessment as a management system to minimize variation order in the planning and design phase.

2. Literature Review

Several researchers considered variation orders as the main cause for delay and cost overruns. For example Pointed out that there are permanent problems in international construction However, recent evidence suggest that there are few indications of variation order contribution to project cost and time overruns [10, 11]. The present study focused on the origin causes of change orders and their impacts on time and cost through analyzing nine under construction projects. In this sense, they utilized a management system which is able to control the variation orders of a highway projects in Jordan [12].

There finding suggests that variation order fluctuated from 23.9% to 5.3% of the total cost of the projects and the most vital causes were consultant related causes from the overall results of the causes. In another study from Iran, researchers examined the factors which are responsible for project variation on roadway construction projects by considering employers, consultants and contractors. The study covered the period from 2001 to 2010 in south Iran.

Their results suggest that there is a ten factors make the variation such as, a change of scope plans by client, inaccurate design, differing site conditions and contractor's financial difficulties. Moreover, they find that time and cost invades, and contentions had extreme consequences for venture execution.

In African context, Essawy et al. (2017) [13] argued that poor project governance and procurement practices are the core cause of the extreme cost overruns on Niger Delta's highway projects. While Ja`Far et al. (2018) [14] found that the main and cause of cost variation of highway projects in Sindh Province of Pakistan were financial and cash problems faced by owners, slow information between parties, change in price of material, delay of design, poor site management, payment and financial issues faced by the contractor and a delay in decision making.

focused on the most impacted factors caused the VO in Algeria, The outcomes of this study indicates that the most important factors were: slow in change orders procedure, unrealistic contract duration, VO due to extra quantities, delayed payment and poor scheduling and planning. Finally the paper approved that the client was the major responsible of the delay [15]. Another study focused on VO in road project in Kenya (particularly on rural roads). The sample consisted of 614 maintenance projects carried out by the government. They found that the cost of the selected project increased by thirteen percent. Besides and that there is a negative relationship between variation orders and the size of the project [16].

This study proposes building information modeling as a management system in mitigating variation order. Hence, it was important to highlight the BIM in general and focus on its benefits through examining previous studies. In the last twelve years since the concept of building information modeling appeared in the construction society, BIM has become a well-known word in AEC technology. The majority of the construction companies shifted from two dimensional technologies and begins to utilize 3D visualization methods in their work [17].

Therefore, building information modeling is the new way to enter the future, the AEC technology dealers who was presenting AutoCAD methods as a solutions, adopting BIM now and introducing it as a new technology [18]. In the other spectrum, few governments (e.g. USA, Denmark, Norway and Finland) have adopted the BIM for its internal projects.

The US General Services Administration (US Green Building Council (Council, 2009)) acknowledges the necessity of utilizing IFC (Industry Foundation Classes) standard by October 2006, in the USA, after ten pilot projects concluded that BIM tools are applicable. Moreover it recommends further expansion of modeling tools to meet future needs [19].

The use of BIM in UK has also received positive response. A deeper examination of the external effects which have corroborative successful BIM acceptance may specify how growth of the use of BIM in the UK might be motivated. The main construction consultant to the current incorporation in the government of UK has already approved to raise the use of BIM in UK, mostly for the future public projects that will be established using BIM.

Issues in the UK might contain the position of market constituent and subjugation with standards such as BS16001 [20]. Finally, over the past decennium, many scab, and live projects have been completed and registered in Finland, Sweden, Norway, Germany, France, Singapore and Australia. This clarifies the capacity of utilizing BIM in construction projects which were established for more durable items versus non BIM use.

The projects that adopted IFC showed server technology in an comprehensive way more than working on BIM, as well as, correlating IFC files can be accomplished by technological program developed by (value networks in construction, 2003, 2007) which focused on presenting an ideal solution to multi-story and low-rise buildings. Therefore, IFC offers instruments to simplify BIM adoption in construction and amid the program.

BIM material and procedures have been established to enhance profitability and to change the project to be more possible in dealing with the data made and saved throughout the lifecycle of the buildings in a more professional manner. Currently, the global leader in BIM performance is Finland as it has 108 projects. The specialists are dedicated to this method which present business improvements need to change to extricate the advantages from BIM [21].

The implementation of BIM is still at a premature stage [22-24]. The implementation of BIM in Jordan was explored by conducting an online survey to recognize the current level of BIM knowledge, as well as, to explain the potential benefits and difficulties that the BIM implementation faces.

Their findings proposed that the adoption of BIM in Jordan is still in a very primal phase and the implementation of BIM is experiencing a number of serious barriers. For instance, a lack of governmental support, the lack of BIM requirements, and shortage of BIM awareness, lack of BIM standards and cost and reluctance to change are among the main causes. Similarly, the study recognized the main characteristic of potential gains of BIM such as the clash detection, minimizing conflicts and changes and reducing rework. In addition, the study specified the current knowledge of BIM in the Jordanian context. Despite the lack of knowledge in BIM, the study noted that early graduates with little experience are more aware of the BIM than those who have longer experience in the field [25].

There results showed that engineers with 2 to 5 years' experience have more knowledge of BIM than those with 5 to 10 years of experience (45 and 33% respectively). Moreover, only (3%) of engineers with 15 years of experience acquired some knowledge of BIM. Therefore, implementation of BIM in Jordan is in a premature stage, but the construction society has some knowledge in BIM [26, 27].

In June 2011, the Ministry of Public Works and Housing (MPWH) in Jordan, Jordan Engineers Association (JEA), Building SMART BIM Journal and MENA have admit to start a Building SMART discussion. The agreement established the base for implementing BIM in the Jordanian construction industry in order to control squander, enhance the construction technique and limit cost on projects. Thus, Building SMART began by a study on the pervasion of BIM in the Jordanian construction industry As a result, it was noticed that the permeation is moderate, and more than quarter of concerned people knew about the BIM system. However, only 5% of them were managing with BIM [28]. Concluded that adopting BIM can achieve strategic business benefits, the adoption of BIM should not be a separate information technology project but should be used as a business variation program that can hypothetically impact the value suggestion.

However, utilizing technology alone cannot convey business outcomes without assuring that the adopted procedure is proactively managed to guarantee that the organization gets the results it expects. Prior research methodologies were noticed in literature review, case studies surveys, interviews, individual analyses and theories. A review of the literature was made to analyze the current information offered with regards to benefits extracted from BIM usage.

The highest frequency of source type was journal article, grouping case studies and quantifiable findings, theories and general assumptions were summarized in Table 1. As we note in the table there is a considerable benefit through implementing BIM it reduced V.O by 2.68% via BIM collaboration, it is noted that this study was based on four hundred and eight projects over 6 years with total cost of $558,858,574.

Table 1. BIM implementation benefits

Source #	Data
Garrett and Garside (2003) [19]	1% of the total project cost was decreased
	Conversion of the 2D model approximately 75% of the total pilot cost
	Identified and resolved sequencing issues that avoided nearly $2 M
	Physical conflicts (clash reports) saved $0.75 M
	Schedule conflicts (scheduling interface) $1.2 M
	Data conflicts (attribute management) $0.5 M
Barlish and Sullivan (2012) [29]	Change orders representing % of base contract:
	2D projects = 18.42%
	3D only = 11.17%
	Collaborative BIM = 2.68%
	(Data is based on 408 projects over past 6 years, totaling $558,858,574)
Bryde et al. (2013) [30]	MEP systems include labor savings ranging from 20 to 30% for all the MEP subcontractors
	100% pre-fabrication for the plumbing contractor
	One recorded injury throughout the installation of MEP systems over 250,000SF
	Less than 0.2% rework for the whole project for the mechanical subcontractor
	Zero conflicts in the field installation of the systems
	A handful of requests for information for the coordination of the MEP systems between contractors and the designers
	6 months' savings on the schedule
	About $9 M savings in cost for the overall project.
Kuprenas and Mock (2009) [31]	Reduced rework — $50,000
	Shortened construction durations — $10,000
	Visualization (underground electrical)
	Sequencing — $250,000 (MEP and FP systems)
	Preassembly — $25,000
	Bundling — $10,000
	Shop fabrication — $25,000
	Conflict checking (between trades) — $4,000,000
	Bulletins — $250,000
	Other changes — $250,000

In order to propose BIM as a management system, this study firstly founded the application of BIM. Generally, clients are not representative of change in building industry. According to (Love et al., 2014), clients believed that cost overruns are regular in construction projects, quality issues, and delays. In fact, many owners believe that construction has a small capital expenses compared to project lifecycle costs and other functional costs that occur over time. However, varying marketplace conditions can change the owners views, as well as, the building transfer process can also affect their judgment. Firms that delivers assistance to owners are commonly point to hastiness their clients and the repeated modifications that made by the client, eventually impact design quality, construction cost, and schedule [28, 32]. Qualified owners can have better influence on the expertise.

Stakeholders must be capable to estimate the domain of design versus their own necessities for each step of the project throughout conceptual design. Thus, this process is frequently involves locative analysis which will later include an analyses for assessing whether the design has the capability to meet specifications. Nowadays, this procedure is conducted manually and the clients depend on the consultant to perform the project through drawings, or deliver animations. However, the specifications often changes even when the project has made them clear.

This could raise a problem with the client who requires a form of guarantee that all specifications have been met [33]. Hence, when looking for a project input, the clients can found it difficult to sufficiently explain and understand the schedule and drawings for the project; this may lead the owners to work with other parties in order to:

2.1. Integrate Development of Programmatic Requirements

Merge and improve the requirements needed for the projects programming throughout the on-going phase of the project, clients trying to improve the project outcomes by consulting their consultants. Clients mainly conduct the criteria with few feedbacks came from the profit and the financial side. Onuma Systems established a new virtual reality method, this method called BIM Storm. This method give chance to the clients, participants and partners in order to intellectualize the whole work, motivate data came from too many sources, those alternatives may help in on-going stage, numerous proposals from budgets, duration, and consistency perspectives [16].

A) BIM spatial analyses to improve program compliance

Through the analyses with BIM writing tools, the visual criticism is mere importance during graphical, conceptual and design. Therefore, the client can guarantee that the prerequisites of their association are achieved.

B) Visual simulation

Clients often need acceptable project feedback through partners who are usually have a busy schedules or struggle to manage the project statistics [34, 35]. The BIM along with the fast similarity of scenarios promote the review phase. The common usage of existence facility and extreme delivery through technologies are onetime actions, whereas, BIM and 4D tools go to future prediction.

C) Design scenarios exploration

Real-time arrangement is also possible based on model production instrument or a specialized arrangement tool. BIM could be utilized to rapidly assessing different scenarios and analyzing prerequisites to avoid client criticism.

Further, additional approach specifically directed to help clients to rapidly evaluate the feasibility of another building design given by the D Profiler, this technology affords the required budget, and priority needed to accomplish the project safely.

D) Simulate operations for facilities

The design may evaluate by the clients using an effective strategies to make sure that the design is fit and safe by reviewing the emulation visually. These strategies contain customer's behavior and evacuation scenarios, which can be conducted by the BIM as an initial point for producing these scenarios. Moreover, the facilities which their execution prerequisites are more serious, the initial asset in a BIM can be beneficial because it gives a precise three dimensional model [33].

E) Detection of errors and omissions

A serious work operation to any contractor must be an assortment of skill and technique. Using two-dimensional drawings, clash detection is accomplished manually by covering separate drawings on a bright object to detect potential conflicts. Correspondingly, contractors use conventional two-dimensional AutoCAD to cover CAD layers, outwardly and manually to classify potential conflicts. The traditional strategies are time consuming, costly and increase the possibilities for errors

F) Cost estimation and quantity take-off

There are several types of approximations which could be founded during the design phase. These approximations can extent from early estimated values to more accurate estimations after finishing design. Obviously, it is unfavorable to hold the cost estimate until the design stage is cleared up. Exceeding the budget after completing the design is an unexpected problem. In such case, there are two available options: the first is to stop the project and the second is to use value engineering. The former option can obtain cost reduction but it will also reduce the quality during design growths. Hence, temporary estimates can produce an early warning for potential problems in order to set and measure suitable replacements. This procedure lets the designer to implement a more reasonable decision, fulfill higher class construction that does not exceed cost constraints. Therefore, BIM significantly facilitates the progress of temporary estimates [34, 35].

1) Transfer quantities to estimation software

As discussed in previous sections, the majority of BIM tools are provided through software suppliers. These include lineaments for calculating and quantifying building information modeling elements and also contain tools that are able to transfer quantities and data to a spreadsheet.

2) BIM components linking directly to estimation software

Besides using the Excel, BIM is another tool that can be connected directly to estimating set through a plug-in tool. There are several estimating packages software which are able to provide a plug-ins to different BIM tools. It may include but not limited to Innovaya (2010), U.S. Cost (2010) and Vico Estimator.

3) Use a quantity take-off approach

The last alternative is using a quantity take-off tool which extracts data from several BIM, this tool enables the estimators to utilize a take-off tool precisely designed to meet estimator's requirements. To this end, it is paramount important to realize that any changes in building models will lead to a new objects settings. Moreover, these objects should be connected to exact estimating tasks in order to fit the cost estimates and to be guaranteed from building model. This in fact depends on the precision and detailed level that has been modelled.

In this sense, the Innovaya system offers a visual model of all the objects that have been extracted from the BIM model and focus in colouring those objects which have been modified since prior estimations. Further, it also focuses on those objects that were not involved in the cost estimation.

3. Methodology

In current study, a questionnaire was set to collect data from consultants, clients and contractors. Each furnished questionnaire was divided into three parts, part one captures the background information about respondents while part two focused on origin agents and causes of variation orders. Finally, part three explores the BIM applications capability to minimize variation order causes.

Argued that the Relative Importance Index method was adopted for similar studies to locate the relative importance of various factors. Hence, the RII method was adopted for the current study in order to determine the relative importance of the different causes and impacts of variation orders based on responses from the various groups [36-38].

A five-point Liker scale ranged from 1: strongly disagree; 2: disagree; 3: neutral; 4: agree; 5: strongly agree was adopted and transformed to relative importance index using the following equation:

$$RII = \frac{\sum W}{AN} \tag{1}$$

Where: W = the weight given to each factor by the respondents, ranges from 1 to 5; A = the highest weight = 5; N = the total number of respondents.

4. Results and Discussion

The main target of this research is to review and summarize the factors which contributes to variation orders. Specifically, this research focuses on building information modelling and proposes a BIM design applications strategy to minimize variation orders causes in the design and planning phase. The data was collected using 35 questionnaires achieving a 70% rate of return. Relative Importance Index (RII) was used to analyse data.

Figure 1 shows the most important factors that may cause the variation orders. The fifth factor of the variation order was lack of equipment and tools. This shortage of tools and equipment will cause delay in the ongoing stage of the project and a delay means more time and claims and will finally lead to cost overrun and VO. The fourth factor was the internal politics related to the country regulations. This factor is very important because after all, any contract implemented in any country must follow the internal regulations issued by the government of this country. Taxes and other expenses may fluctuated from time to another and it would result in the general performance of the project, and it will lead directly to the same sequence (delay, cost overrun and VO). The third factor was the logistic delay - a factor which is a general concept and happens all the time, for example, some pending required parts or equipment by customs or the necessity to acquire recourses or a simply unsuitable environment, could lead us to the VO. The second factor was labour or materials not meeting the specifications which will lead the duration of related activities to increase because of shortage in skilled labour, or inaccurate selection of the appropriate materials could happen in ongoing phase. Finally, the most important factor was the inaccurate quantity take-off. In fact, this factor is familiar in the majority of road projects because of the old and inaccurate methods used. Up until today, too many projects use programs like EXELL, and 2D ACAD. Furthermore, too many projects don't take bearing capacity of the site in their considerations. They just design the project with constant bearing and send the drawing. This factor could disappear if we use the quantity take-off procedure in BIM which was the main reason to propose BIM.
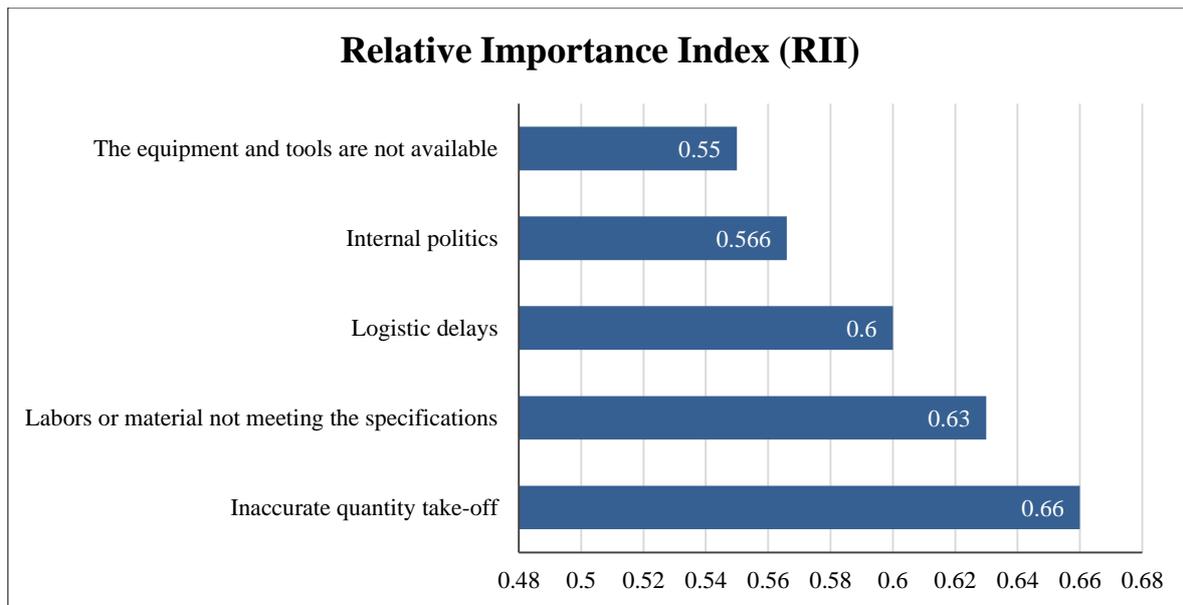
Relative Importance Index (RII)

Factor	RII
The equipment and tools are not available	0.55
Internal politics	0.566
Logistic delays	0.6
Labors or material not meeting the specifications	0.63
Inaccurate quantity take-off	0.66

Figure 1. The most important factors that may cause the variation orders

The third part of the questionnaire was to explore the BIM applications capability to minimize variation order causes, namely: BIM Design Applications, Facility Operations Simulation, Exploration Design Scenarios, BIM Design Detection, (BIM Quantity Take-off and Cost Estimation), Table 2 shows the weight for each one those applications .

Table 2. The weight of BIM applications

BIM application	Number of agreed respondent	%
BIM Design Applications	33	94.3
Facility Operations Simulation	32	91.43
Exploration Design Scenarios	31	88.57
BIM Design Detection	31	88.57
BIM Quantity Take-off and Cost Estimation	30	85.71

Table 2 the weight of BIM applications.Based on previous results it is obvious that BIM applications have a passive impact on V.O, the majority of the respondent agreed that BIM Applications was appropriate in mitigating VO, as its obvious in Table 2, and this results was expected, for example, the most important cause of the variation order was the inaccurate quantity take-off , the problem would be avoided if we simply use *a quantity take-off tool* which extracts data from several BIM, this tool enables the estimators to utilize a take-off tool precisely designed to meet estimator's requirements.

5. Conclusion

This research is mainly concerned with The Building Information Modelling Strategy in Mitigating Variation Orders in Roads Project. Its contribution to this topic lies in providing BIM Design: an applied strategy that is able to reduce the order of change in road projects. The study recommends that this strategy can be used to address the problems associated with the construction industry in Jordan, given the fact that BIM has endorsed its ability to solve construction problems around the world, as BIM- related functions. Through visual communication, information database management and compatibility with analysis and workflows, BIM finds its way to being useful strategy throughout the lifecycle of a project, from design to construction and operation. This is also with the increasingly important role of advising organizations and project teams on how best to use project management principles in the deployment of BIM and related new technologies and paradigms. As BIM becomes a vehicle for exploring the introduction of other technologies and paradigms, project managers will need to assist organizations and project teams along the way. The results indicate that the Contract Parties, Consultant, Contractor and Other Variations have significant positive effects on V. O, whereas the effects of BIM Design Applications, Facility Operations Simulation, Exploration Design Scenarios, BIM Design Detection, (BIM Quantity Take-off and Cost Estimation) have a passive impact on V.O. The Orders in Roads Projects must take on the increasingly important role of advising organizations

and projects teams on how best to use project management principles in deploying BIM and associated emerging technologies and paradigms

6. Acknowledgement

7. Conflicts of Interest

The authors declare no conflict of interest.

8. References

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