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Managing Cost and Schedule Evaluation of a Construction Project via BIM Technology and Experts' Points of View

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ABSTRACT

This research examines the beneficial contributions of project management to manage the cost and schedule of construction projects providing higher accuracy and reliability levels. The study depended on two main research approaches quantitative (online survey questionnaires) and qualitative (interviews) research techniques. The questionnaires and interviews aim to predict the importance of BIM technology in managing the cost and schedule of construction projects. Also, a third research method is employed, which represents a case study of a building, to make a comparison in terms of accuracy, effort, and budget of quantity take-off between manual (hand calculations) and numerical (REVIT Software estimations) approaches. The results revealed that adopting project management principles could significantly cut considerable budget, time, and effort to execute and complete construction projects. Also, project management is vital to prevent any financial losses or resource problems resulting from cost overruns or delays. Moreover, the results indicated that using modern project management techniques (including BIM technology and REVIT Software) could support engineers and project managers calculate the cost and schedule of their projects more accurately, avoiding errors. Besides, the results confirmed that using the REVIT software could aid project managers and civil engineers in evaluating the budget and time required to accomplish the construction project with less effort, time, and cost and provide a lower number of human errors compared with hand calculations. It was found that the manual and numerical results are greatly approximate to each other. Still, the results of the REVIT software offered more significant precision because of the accuracy in the modeling and the few engineers' mistakes in calculating quantities manually.

1. INTRODUCTION

Over the last decades, the scale of construction has remarkably increased due to the rise in the rate of urbanization and population growth [1]. Notwithstanding, large-scale construction has contributed to significant levels of complexity because of the diverse activities and tasks associated with the construction process [2]. For these reasons, the management and monitoring of constriction procedures became greatly challenging for project managers and chief engineers. Hence, functional and modern project management techniques are required to adopt and implement in this context.

Modern construction techniques, including Building Information Modeling (BIM) technology, offers several advantages and critical benefits for civil engineers and project managers to monitor, control, and manage their projects efficaciously [3]. These vital advantages comprise the BIM's essential role in evaluating the cost and schedule of construction projects, providing higher degrees of precision and effectiveness compared with traditional cost estimation methods (like hand calculations). The conventional approaches of project quantity take-off may contribute to a significant magnitude of human errors, time consumed, and considerable effort required from engineers to calculate the needed materials, especially in large-scale facilities [4]. There are two critical concepts associated with the construction sector; (1) manage the cost and (2) schedule the submission date. The process of estimating, assigning, and controlling project expenditures is known as cost management. A company can lessen the likelihood of budget overruns by predicting future expenses through the project management process of cost and schedule [5]. Cost projections are greatly useful for monitoring the completion and submission of construction projects on time without delays or budget overruns. Cost can be calculated at the project planning stage and should be approved before work is started. Expenses are recorded and monitored when the project plan is carried out to ensure that every task stays within the cost control plan. When expected costs and actual costs are compared after the project is finished, benchmarks are provided for upcoming cost management plans and project budgets [5, 6]. At the same time, a schedule assessment is another vital aspect that should be considered to avoid losses in finance and resources and retardation in the completion of projects. It is a document created by the project agreement that lists the shape items of construction activities [7, 8]. The process of cooperatively

designing, constructing, and running a building depending on the 2D and 3D numerical modeling of the construction project is one characteristic of BIM technology. BIM principles combine the knowledge and information of engineers and numerical analysis to help cut significant levels of effort, time, and costs. Implementation of BIM methods can improve the efficiency of construction management for various small and large-scale buildings, such as skyscrapers, hospitals, office buildings, and residential structures [9]. BIM is more than just a collection of tools or a simple 3D model. It includes the model components and the considerable amount of information that goes into the project, and the method for sharing it with other engaged parties. Whereas previous workflows relied on multiple file formats and disconnected processes that quickly became out of sync when changes were made, BIM workflows allow for a much more dynamic and synchronized approach to project management [9-13]. Dao [14] executed a research analysis through which the critical role and major contributions of BIM technology and modern project management methods were investigated. And he alse considered a case study of public construction projects in Vietnam to manage the cost and schedule and prevent any financial losses. They employed BIM technology and BIM software tools to estimate the cost and schedule of the construction project. Their research analysis revealed that using BIM technology and innovative project management techniques are greatly helpful and play a beneficial role in managing the cost and schedule estimation of public construction projects in Vietnam. Skrzypczak et al. [15] published a manuscript identifying and assessing substantial contributions and relevances of different project management methods to estimate the cost and schedule of construction projects, avoiding errors and improving accuracy. They used 5D modeling and cost and schedule evaluation based on BIM software tools. Their research analysis and 5D modeling results indicated that using innovative project management approaches, like BIM software, could contribute to remarkable improvements and enhancements in the cost and schedule evaluation of construction projects. Thus, using BIM technology can help save much time for engineers to estimate the cost and schedule more accurately".

2. MATERIALS AND METHODS

This study depends on three research approaches. These research methods are (1) quantitative research approach, (2) qualitative study technique, and (3) REVIT software analysis. These three research approaches are critical and beneficial to addressing and identifying the significant contributions and main advantages of innovative and modern project management methodologies (including the importance and contributions of BIM principles and the REVIT software package) that can help achieve accurate and high-performance cost and schedule evaluation. The paragraphs below provide more information regarding the importance of each research method.

2.1 Quantitative research approach

The quantitative study method, which is also considered a descriptive cross-sectional research method, is essential to allow the researcher to collect remarkable primary data from project managers, construction professionals, and senior structural engineers who have rich experience in managing and organizing the cost and schedule estimation of different construction projects regarding the relevance and beneficial influences of BIM technology adoption in their projects. This approach can be accomplished by developing an online survey questionnaire, which can predict necessary information from those experts associated with the advantages and significance of modern project management techniques to estimate the cost and schedule of construction projects with higher degrees of accuracy and performance.

2.2 Qualitative research approach

Besides the first research method, interviews are also conducted by preparing some critical questions to help the researcher collect some pivotal data that can identify and determine various considerable aspects related to the contributions and vital values of modern project management techniques (especially BIM princicples and numerical REVIT techniques) to estimate the cost and schedule accurately of several construction projects. The points of view of different consultants, construction engineers, and project management experts can help locate some important practices that can be adopted and applied by project managers and civil engineers to improve the implementation and employment of active BIM approaches and practical REVIT techniques in their construction projects.

Table 1. Major components and floor uses of the case study

#	Floor	Area (m^2)	Parts of the floor, use
1	Basement	1108.59	Data Room, Garbage Room, Lobby, LV Room, Transformer Room, and MV Room
2	Ground floor	1127.85	Apartments Entrance, Offices, Baths, Receptions, Laundries, Kitchens, Bedrooms, Master Bedrooms, Dining Rooms, Stairs, and Elevators
3	First floor	1108.59	Apartments Entrance, Offices, Baths, Receptions, Laundries, Kitchens, Bedrooms, Master Bedrooms, Dining Rooms, Stairs, Elevators, and Balconies
4	2^{ND} -3^{RD}	1108.59	Apartments Entrance, Offices, Baths, Receptions, Laundries, Kitchens, Bedrooms, Master Bedrooms, Dining Rooms, Stairs, Elevators, and Balconies
5	24^{TH} floor	1108.59	Apartments Entrance, Offices, Baths, Receptions, Laundries, Kitchens, Bedrooms, Master Bedrooms, Dining Rooms, Stairs, Elevators, and Balconies
6	25^{TH} floor	1108.59	Apartments Entrance, Offices, Baths, Receptions, Laundries, Kitchens, Bedrooms, Master Bedrooms, Dining Rooms, Stairs, Elevators, and Balconies
7	Roof floor	97.6	Stair, Elevators Rooms

2.3 REVIT software analysis

BIM technology is employed in this work to make a comparison between manual quantity take-off and numerical

material survey depending on the REVIT software tool. REVIT software package can estimate the cost and schedule of the construction project by making accurate quantity take-off of the materials required to construct the building. The construction project considered in this study consists of a case study of a facility comprising seven floors, depending on the data available on a construction project that include a seven-floor building. Each floor contains some purposes and components, as illustrated in Table 1.

3. RESULTS

This section represents the research findings obtained from the three research approaches. The following sections provide more details on these study findings.

3.1 Quantitative research approach results

The research results regarding the quantitative study approach are represented in this section.

3.1.1 Demographic analysis findings

Table 2 illustrates the demographic data analysis of the study population associated with gender.

Table 2 shows the frequency and gender percentage of all respondents. Males got the most significant portion, corresponding to a percentage of 77.5%. At the same time, female engineers and consultants have a percentage of 20.6%, as indicated in Figure 1.

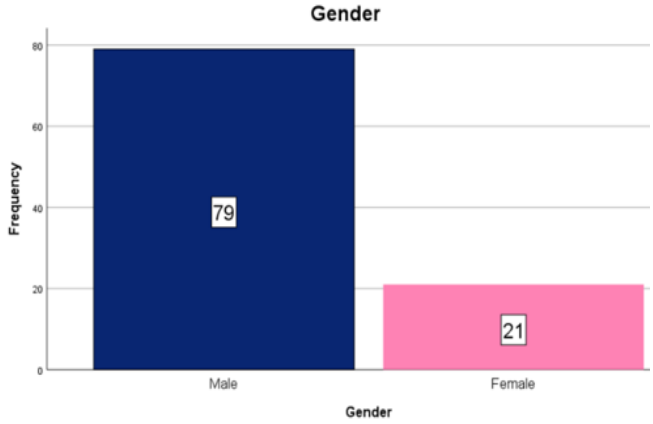

Figure 1. A graphical representation of the study sample's demographic data analysis regarding gender

Table 2. The results of the demographic information analysis of the study sample related to gender

Gender		Frequency	%	Valid %	Cumulative %
Valid	Male	79	77.5	79	79.0
	Female	21	20.6	21	100.0
	Total	100	98.0	100	
Missing	System	2	2.0		
Total		102	100		

Table 3. The results of the demographic information analysis of the study sample related to age

Age		Frequency	%	Valid %	Cumulative percent
Valid	25-30	77	75.5	77	77.0
	31-35	17	16.7	17	94.0
	36-45	4	3.9	4	98.0
	More than 45	2	2.0	2	100.0
	Total	100	98.0	100	
Missing	System	2	2.0		
Total		102	100		

Table 4. The results of the demographic information analysis of the study sample related to educational level

Educational level		Frequency	%	Valid %	Cumulative percent
Valid	BSc	24	23.5	24	24.0
	MSc	74	72.5	74	98.0
	PhD	2	2.0	2	100.0
	Total	100	98.0	100	
Missing	System	2	2.0		
Total		102	100		

Table 5. The results of the demographic information analysis of the study sample related to experience years

Experience years		Frequency	%	Valid %	Cumulative percent
Valid	Less than 5 years	9	8.8	9.0	9.0
	5-10 years	85	83.3	85.0	94.0
	11-15 years	3	2.9	3.0	97.0
	16-20 years	1	1.0	1.0	98.0
	More than 20 years	2	2.0	2.0	100.0
	Total	100	98.0	100.0	
Missing	System	2	2.0		
Total		102	100.0		

Table 6. The results of the demographic information analysis of the study sample related to qualification

	Qualification	Frequency	%	Valid %	Cumulative %
Valid	Civil engineering	76	74.5	76.0	76.0
	Electrical engineering	7	6.9	7.0	83.0
	Mechanical engineering	6	5.9	6.0	89.0
	Architectural engineering	11	10.8	11.0	100.0
	Total	100	98.0	100.0	
Missing	System	2	2.0		
	Total	102	100		

Table 3 illustrates the demographic data analysis of the study population associated with age.

Table 3 shows the frequency and percentage of the age of all respondents. It can be indicated that the most considerable portion of respondents was for ages between 25 and 30, reaching a percentage of 75.5%. This ratio is followed by the age group (31-35), corresponding to a portion of 16.7%, as described in Figure 2.

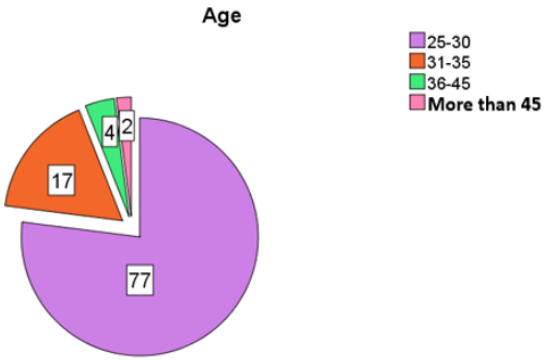

Figure 2. A graphical representation of the study sample's demographic data analysis regarding age

Table 4 illustrates the demographic data analysis of the study population associated with educational level.

Table 4 shows the frequency and percentage of educational levels for all respondents. The most significant portion of respondents holding a master's degree was 72.5%, followed by a bachelor's degree, reaching 23.5%, as illustrated in Figure 3.

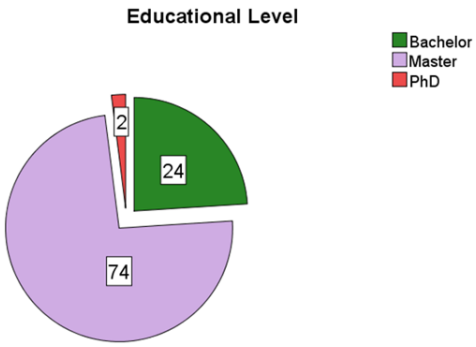

Figure 3. A graphical representation of the study sample's demographic data analysis regarding educational level

Table 5 illustrates the demographic data analysis of the study population associated with experience years.

Table 5 shows the frequency and percentage of years of experience for all respondents. The most significant portion of respondents who had experienced years ranging from (5-10) years amounted to 83.3%, followed by experience years less than five years, which amounted to 8.8%, as described in Figure 4.

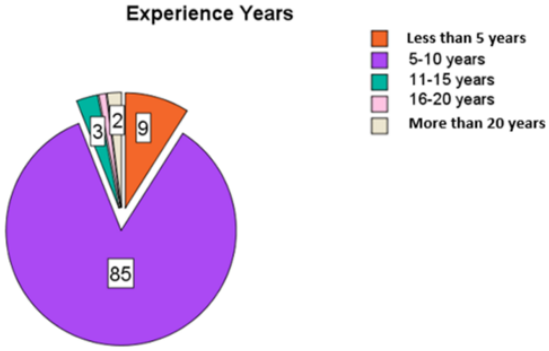

Figure 4. A graphical representation of the study sample's demographic data analysis regarding years of experience

Table 6 illustrates the demographic data analysis of the study population associated with experience years.

Table 6 shows the frequency and percentage of qualification of all respondents. The largest share of respondents working in the field of civil engineering, corresponding to 74.5%, followed by the architectural engineering field, which amounted to 10.8%. More percentages and graphical representations related to Table 6 are described in Figure 5.

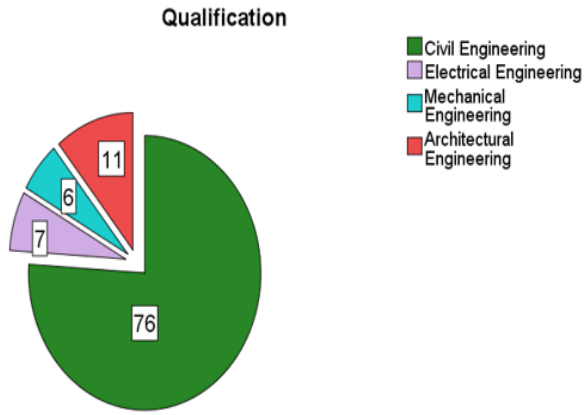

Figure 5. A graphical representation of the study sample's demographic data analysis regarding the qualification

3.1.2 Questionnaire SPSS analysis findings

Table 7 illustrates the SPSS data analysis of the questionnaire associated with the first dimension. It represents the arithmetic mean, standard deviation, Z-value, and ranking of all paragraphs related to this dimension. The dimension is "Significance of BIM Technology in Managing Construction Projects."

Table 7 shows the mean and standard deviation of each paragraph related to the first dimension. It can be indicated from this table that these factors are arranged in descending

order. The results of the statistical analysis showed that the most important of these factors was "To what extent do you believe that BIM employment could reduce the financial losses in projects?" with an average of 4.79. At the same time, the least influential factor was "To what extent do you believe that adoption of BIM could boost the monitoring and active analysis of project activities?" corresponding to an arithmetic mean of 1.96. Table 8 illustrates the SPSS data analysis of the questionnaire associated with the second dimension. It represents the arithmetic mean, standard deviation, Z-value, and ranking of all paragraphs related to this dimension. The dimension is "Substantial Impacts of Training and Education Related to BIM Technology for Project Managers and Engineers."

Table 7. The arithmetic means, standard deviation, Z-value, and ranking of all paragraphs related to the first dimension

Paragraph	Arithmetic mean	Standard deviation	Z value	Rank
To what extent do you believe that:				
BIM employment could reduce the financial losses in projects?	4.79	0.782	22.881	1
Project managers need to apply BIM principles to mitigate delay problems in their projects?	4.52	1.010	15.052	2
BIM use could enhance the project execution performance?	4.13	1.426	7.924	3
Use of BIM modeling could promote the ability of project managers to manage their projects?	3.20	1.912	1.046	4
Adoption of BIM could boost the monitoring and active analysis of project activities?	1.96	1.294	-8.035	5

Table 8. The arithmetic means, standard deviation, Z-value, and ranking of all paragraphs related to the second dimension

Paragraph	Arithmetic mean	Standard deviation	Z value	Rank
To what level do you think that:				
Training junior engineers would improve their skills in BIM use?	4.65	1.048	15.743	1
Educating project managers on active BIM techniques could help them manage their projects?	4.27	1.406	9.033	2
Conducting educational sessions for civil chief engineers would foster their BIM experience in monitoring their projects?	3.62	1.739	3.564	3
Meeting BIM experts is vital to transfer their knowledge to proejct managers and engineers?	2.91	1.843	-0.488	4
Consulting high-experienced BIM engineers is beneficial to increase the talents of senior and junior engineers in BIM?	1.53	1.193	-12.322	5

Table 9. The arithmetic means, standard deviation, Z-value, and ranking of all paragraphs related to the third dimension

Paragraph	Arithmetic mean	Standard deviation	Z value	Rank
To what degree do you consider that:				
Using BIM technology would estimate the project's cost with higher accuracy?	3.99	1.642	6.028	1
Utilizing the REVIT software could alleviate the time required for cost evaluation?	3.53	1.817	2.917	2
Employing the REVIT software would mitigate the engineers' effort needed for cost evaluation?	3.03	1.877	0.160	3
Exploiting BIM technology would minimize the human errors of cost estimation using manual methods?	2.35	1.833	-3.545	4
Harnessing numerical quantity take-off is more effective and practical than traditional and old approaches of cost estimation?	1.42	1.112	-14.21	5

Table 8 shows the mean and standard deviation of each paragraph related to the second dimension. It can be indicated from this table that these factors are arranged in descending order. The results of the statistical analysis showed that the most important of these factors was "To what level do you agree that training junior engineers would improve their skills in BIM use?" with an average of 4.65. At the same time, the least influential factor was "To what level do you agree that consulting high-experienced BIM engineers is beneficial to increase the talents of senior and junior engineers in BIM?" corresponding to an arithmetic means of 1.53. Table 9 illustrates the SPSS data analysis of the questionnaire associated with the third dimension. It represents the arithmetic mean, standard deviation, Z-value, and ranking of all paragraphs related to this dimension. The dimension is "Relevance of BIM Technology in Evaluating the Cost of Construction Projects."

Table 9 shows the mean and standard deviation of each paragraph related to the third dimension. It can be indicated from this table that these factors are arranged in descending order. The results of the statistical analysis showed that the most important of these factors was "To what degree do you believe that using BIM technology would estimate the project's cost with higher accuracy?" with an average of 3.99. At the same time, the least influential factor was "To what extent do you believe that harnessing numerical quantity take-off is more effective and practical than traditional and old approaches of cost estimation?" corresponding to an arithmetic mean of 1.42. Table 10 illustrates the SPSS data analysis of the questionnaire associated with the fourth

dimension. It represents the arithmetic mean, standard deviation, Z-value, and ranking of all paragraphs related to this dimension. The dimension is "Importance of BIM Technology in Assessing the Schedule of Construction Projects."

Table 10. The arithmetic means, standard deviation, Z-value, and ranking of all paragraphs related to the fourth dimension

Paragraph	Arithmetic mean	Standard deviation	Z value	Rank
To what degree do you agree that:				
Employing BIM technology would estimate the project's schedule with higher accuracy?	3.64	1.795	3.565	1
Harnessing the REVIT software could alleviate the time required for schedule evaluation?	2.94	1.863	-0.322	2
Using the REVIT software would mitigate the engineers' effort needed for schedule evaluation?	2.33	1.729	-3.874	3
Exploiting BIM technology would minimize the human errors of schedule estimation using manual methods?	1.93	1.584	-6.754	4
Utilizing numerical schedule evaluation is more effective and practical than traditional and old approaches to schedule assessment?	1.31	0.918	-18.41	5

Table 11. A comparison between the manual method and numerical approach (REVIT software) to estimate the quantity of project's materials

Comparison	REVIT results (kg)	Manual results (kg)	
Roof / Stair - (Slabs)	42,953	43,474	
24rd / 25rd - (Slabs)	42,207	42,678	
16TH / 23rd - (Slabs)	226,198	230,691	
1st / 15TH - (Slabs)	420,621	432,545	
Basement / GF - (Slabs)	57,848	58,433	
Wall 12	105,785	108,672	
Wall 11	90,727	93,053	
Wall 10	172,175	158,765	
Wall 9	62,795	61,699	Steel (kg)
Wall 8	70,175	68,465	
Wall 7	73,986	71,782	
Wall 5	99,600	96,500	
Wall 4	40,182	38,957	
Wall 3	69,220	67,564	
Wall 2	113,713	110,189	
Wall 1	76,108	72,997	
Piles foundation	189,605	193,154	
Raft foundation	210,014	214,508	
Comparison	**REVIT results (m^3)**	**Manual results (m^3)**	Concrete (m^3)
Raft foundation	2,533.3	2,533.3	
Piles foundation	2,076.0	2,039.7	
Walls	6,252.8	6,243.1	
Slabs	5,447.0	5,458.9	
Earth Cut	6,966.6	7,025.6	Soil (m^3)

Table 10 shows the mean and standard deviation of each paragraph related to the fourth dimension. It can be indicated from this table that these factors are arranged in descending order. The results of the statistical analysis showed that the most important of these factors was "To what degree do you believe that employing BIM technology would estimate the project's schedule with higher accuracy?" with an average of 3.64. At the same time, the least influential factor was "To what extent do you agree that utilizing numerical schedule evaluation is more effective and practical than traditional and old approaches to schedule assessment?" corresponding to an arithmetic mean of 1.31. This table indicates the significance and beneficial impacts of utilizing BIM to estimate the schedule of construction projects.

3.2 Qualitative research approach results

Depending on the points of view of some critical civil engineering experts and construction professionals in the field of project management, the results indicated that the consultants who were interviewed remarked on some vital aspects, which include:

(1) Modern project management principles are necessary to implement in any construction project to help avoid any financial losses or problems in the budget and time of the project.

(2) Using innovative project management approaches in a construction project can help engineers and project managers estimate the cost and schedule of their project more accurately and flexibly.

(3) BIM technology is one example of modern project management strategies that can be implemented to enhance the performance of cost and schedule estimation related to various construction projects.

(4) Using the REVIT software package can support project managers and engineers in evaluating the budget and time required to accomplish the construction project with less effort, time, and cost and provide a lower number of errors.

3.3 The REVIT analysis results

To address the importance and accuracy of REVIT and highlight its contribution, quantity take-off was implemented using two methods. The first method is manual (hand calculations), and the second one is numerical computation using the REVIT software tool. Table 11 represents a comparison between the manual and numerical methods to estimate the materials' quantity for the case study.

It can be indicated from Table 11 that the manual and numerical results are highly close to each other, but the results of the REVIT software are more accurate due to the accuracy in the modeling and the few personal mistake in calculating quantities manually. As a result, it can be said that BIM applications and especially REVIT software are the future for controlling the modern building from design to the end of construction. Also, it is noted that through the analysis of manual quantities calculation, which is the most used method, engineers, contractors, and old experts find it difficult to calculate the quantity and make survey and take-off of the construction project with less time, effort, and cost and higher accuracy. On the other hand, the employment of BIM applications, including REVIT, contributes to the completion of the required work quickly and efficiently without human mistakes. Therefore, BIM applications are the future of modern construction.

4. DISCUSSION

The results of this work revealed that the project management principles are necessary to implement in any construction project to help avoid any financial losses or problems in the budget and time of the project. Also, the results indicated that using a project management approach in a construction project can help engineers and project managers estimate the cost and schedule of their project more accurately and flexibly. Moreover, the research results confirmed that BIM technology is one example of a modern project management strategy that can be implemented to enhance the performance of cost and schedule estimation related to various construction projects. Furthermore, depending on the analysis results of numerical calculations, the results affirmed that using the REVIT software can support project managers and engineers in evaluating the budget and time required to accomplish the construction project with less effort, time, and cost and provide a lower number of errors. Also, it was found that the manual and numerical results are greatly approximate to each other, but the results of the REVIT software are more accurate due to the accuracy in the modeling and the few personal mistake in calculating quantities manually. The results of this study are consistent with the results of references [9-15], who carried out a study analyzing the influential role of project management in estimating the cost and schedule of construction projects and found that using modern project management techniques, like BIM principles and REVIT software could significantly reduce the time, effort, and cost to estimate the construction project's cost and schedule and could achieve better accuracy and performance of the estimation process.

5. CONCLUSIONS

This research is performed to assess and explore the beneficial impacts of project management principles to estimate construction projects more accurately and reliably. The study depended on three research approaches, including quantitative and qualitative cross-sectional descriptive research, besides a third research method, which represents a case study of a building to make a quantity take-off using two methodologies. Those two methodologies include manual and numerical approaches. A comparative analysis is conducted to validate and compare the accuracy of the REVIT software with the manual method. Based on the research analysis of the three research approaches, the major study results can be summarized in the following points:

1-The project management basics are important and practical to implement in any construction project to help avoid any financial losses and issues in the budget and time of the project.

2-Utilizing a project management method in different construction projects could help engineers and project managers evaluate the cost and schedule of their projects more accurately and flexibly.

3-BIM technology is one example of modern project management strategies that can be adopted and used to promote the performance of cost and schedule estimation related to various construction projects.

4-Employing the REVIT software can support project managers and engineers in evaluating the budget and time required to accomplish the construction project with less effort, time, and cost and provide a lower number of errors.

5-The manual and numerical findings of quantity take-off were remarkably approximate to each other. Still, the results of the REVIT software are more accurate due to the accuracy of the modeling and the few personal mistake in calculating quantities manually.

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