DEVELOPING METHODOLOGY FOR MANAGING CHANGE ORDERS IN CONSTRUCTION PROJECTS USING BIM AND CLOUD COMPUTING

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Abstract. Change orders-CO are a fundamental feature of construction projects, as previous studies have shown that change orders rank first among the issues facing the modern construction industry, creating ongoing challenges for project managers and stakeholders, often leading to increased project duration and cost. Creating a change order usually takes a long time in the traditional methodology of project management due to the lack of effective communication in this process between the project parties and it also takes into account the expectations of those involved (project stakeholders). Consequently, the need to develop a methodology for managing change orders has become a significant matter, especially at this time to take advantage of the techniques of BIM and cloud computing, which allows us to use modern and advanced tools and software and thus complete the required change orders within a lower period and cost. In this research, a methodology has been reached that relies on the integration of Building Information Modeling (BIM) and Cloud Computing technology, enabling project parties to collaborate and make appropriate decisions in real-time (online). The research results demonstrated the possibility of creating a change order within the BIM environment and utilizing cloud computing technologies, allowing any project's party to instantly observe the resulting changes, including their impact on the project in terms of time and cost, which could improve the quality of the construction industry.

Keywords: change order management, BIM, cloud computing.

Introduction

Change orders are common and difficult to avoid in construction projects. There is hardly any local or global project that does not include them. In fact, it is rare for projects to be implemented without making changes to them, due to the long period of time required to complete them. These changes are a natural event or matter to address and correct some design errors/defects, or due to the emergence of new circumstances in the project, change the project scope by the owner, occurrence of technical developments in materials and supplies, or as a result of unexpected external factors or the emergence of some important requirements/developments during the implementation of the project, which requires adding other works and/or canceling some of them, as well as adding any idea or modification for the benefit of the project in order to complete or overcome any deficiency in the project requirements so that it is completed and fulfills the essential purpose of its implementation [1].

Change orders are an integral part of the construction project and an urgent necessity in contracting contracts, especially large and complex ones, because they allow the employer the dynamism to avoid any deficiency or error in the design. Their importance is highlighted in projects where the time difference between the design and implementation stages is large, which creates great possibilities for modification and change in some requirements. These projects also contain a large number of documents (specification, bills of quantities-BoQ, general and special conditions, plans, etc.), which are prepared by a number of engineers with various specializations, which makes the possibility of change due to the enormity of the work and the poor coordination between those specializations within the design team.

Change orders are originally intended to speed up project completion, reduce costs, and increase the project quality, but this is not always the case or can be achieved. Change orders can increase the cost of completing the work included in the contract and delay project delivery. In addition, issuing excessive change orders can result in a defect in the quality of the work performed.

Therefore, we notice that the essence of the problems that the construction industry has been suffering from since the past centuries until now has not changed, but what has changed is the increasing complexity of building projects to an unprecedented degree, which has led to the dispersion and loss of data, which requires making many changes that sometimes lead to rework, which negatively affects the project time and cost, and this in turn can affect the quality of the project, so the need to develop a methodology for managing change orders has become an urgent requirement, especially at the present time.

In the era of technological development, the construction industry needs to develop a base for managing change orders electronically in line with the expectations and ambitions of the construction

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reality, as information and communications technology (ICT) is capable of organizing and storing project data, but we need a technology that helps enhance coordination and cooperation between all parties, which can be achieved through the integration of BIM and cloud computing technologies, as this technology includes a network of web-based platforms that allow users direct access to the cloud, enabling them to collaborate, solve all problems, and manage change orders in real time.

According to the above, the basic research problem can be identified as change orders occupy the first place among the problems facing the construction industry, which suffers from weak productivity compared to the manufacturing industries that have moved to automate their activities. Analyses also show that the construction industry is weaker in productivity on-site than off-site, which makes automating activities and developing a methodology based on cloud computing to manage change orders an urgent matter.

Research objective

This research aims to develop a methodology for managing change orders-MCO in construction projects using BIM and cloud computing, as this methodology is based on effective data management in addition to improving cooperation and communication between all parties or stakeholders in construction projects.

Literature review

Researchers [2] reviewed many models of the change process through relevant research and research articles, and came up with a general model for the change process consisting of five successive stages: identification, evaluation and proposal, approval, implementation and review. They also found that one cannot find a mature software tool in the market that handles changes. The current change management tool that some software claims to have been mostly a feature that helps in recording and approving information related to the change, estimating the change, analyzing its impact, post-change analysis, and statistics, but it lacks the ability to track the change. Therefore, we note that an integrated change management system requires technical support from different technologies, including collaborative workflow, system integration with collaboration technologies and nD modeling, web-based collaborative project management tools, and online document management tools. However, a complete solution for managing change orders in construction projects has not yet been found.

The authors in [3] presented in their research the results of the analysis of changes found through the case study conducted during the implementation and operation phases, then they highlighted some of the initial patterns of changes that occur throughout the project life cycle, and discussed some of the challenges related to managing such changes, and updating building information models accordingly. They also investigated the extent to which commercially available BIM tools can meet these challenges, such as capturing changes and storing them in a BIM change log, which will help users make the appropriate decision when they need to analyze changes over time for effective maintenance.

The researcher [4] stated in his study that Building Information Modeling (BIM) can be a comprehensive answer to many of the problems facing the construction industry, as this technology uses the latest information and computer modeling methods to design and create software files for construction projects. He also concluded through his study that creating knowledge bases for projects using BIM technique helps in making any change or repair to the project in the future and during its operation, [5] presented a new model for project change management, by integrating change management with BIM, as the developed model is able to reduce the negative effects of changes, by taking change data and automatically updating changes in BIM models, and thus the developed model facilitates the collection of information and the coordination process between team members. Researchers [6] presented a report that included that working with "BIM" means working directly on the design model in the project, whether in the plans, sections or even the project schedules, all one has to do is make one change in the design model in one place and at one time and all the integrated project views will be automatically updated. The research of [7] addresses the subject of changes within the BIM environment, where it describes an advanced method for coordinating and tracking the spread of change within the multidisciplinary BIM environment. This advanced method depends on modeling change based on BIM, and on using the design structure matrix (DSM) based on the parameter to represent the various dependencies between the parameters of the facility, and employing it as a tool to track a series of successive changes within the BIM environment, and on proposing a mechanism for integrating BIM with DSM programmatically to support the process of visual representation of change paths within BIM.

The research of [8] conducted a study on the impact of BIM on project implementation in Nairobi County. This study targeted 43 projects through which data was collected from departments and individuals working in these projects, by asking them about their perceptions and personal experiences regarding the use of BIM. After completing the data collection, it was analyzed using SPSS. The researchers concluded that the use of the BIM technique reduces design errors to a minimum, facilitates cooperation between project parties in order to improve design efficiency, and helps discover conflicts in design. Therefore, it greatly helps in the successful implementation of projects and reduces change orders due to poor coordination. It is also easier to make changes to the building model using BIM, noting how these changes affect the total costs of the project and its implementation period.

The authors [9] studied change orders in construction projects, then developed a model for analyzing change order data that is able to determine the impact of change orders on project cost and time. This model includes newly developed elements that enable: identifying the main technical reasons for change orders according to project type, determining the impact of project type and size on change order cost and duration, and automating periodic reports that can be used to mitigate the negative effects of change orders.

Summary of the reference study. After reviewing the previous studies, we find that the management of change orders in the implementation phase of a project was not addressed except within the traditional construction management environment. In BIM applications, most of these studies dealt with change orders only at the design stage. It is true that BIM technique can contribute to reducing change orders as a result of detecting clashes in the design phase and as a result of the design team's cooperation during the design process, but it cannot prevent the possibility of change occurring for other reasons such as errors or defects by the designer himself or modifications requested by the owner, for example. Other than that, there are few studies that dealt with BIM applications in the project implementation phase. Accordingly, this research is important for managing change orders in an effective manner to preserve project resources and improve its quality.

Change order management in construction projects

Change orders in construction projects are one of the most controversial issues to manage, and it is a challenge for project management to resolve any change satisfactorily to avoid claims. Although any construction contract is signed according to the principle of "good faith", which means that the parties trust each other to perform according to the contract in the future. However, once the contract needs to be modified by creating a change order, the behaviour of the parties changes with regard to the "good faith" environment that becomes forgotten as benefit and financial gain take precedence, so managing change orders requires engineering innovation to solve this problem, and so far, no complete solution has been found for managing change orders in construction projects.

- **Concept of change order**: Change orders are any changes or modifications that the owner deems necessary in the form, type, quantities or specifications of the works in the project. The change is the result of the owner's desire to modify some of the work or contract documents by adding, deleting, modifying or replacing the design of some elements of the project, which leads to an increase in quantities or a change in the nature of the work or contract documents. Therefore, change orders give owners and contractors the flexibility to address the unexpected. According to the American Institute of Architects, a change order can be defined as "a written order prepared by the architect-engineer (the owner's representative) and signed by the contractor, the architect and the owner, which obligates the contractor to make changes to the contract works, and clarifies the cost of those changes and the total value of the contract as a result of the changes, as well as the time period required to implement those changes (if any) and the total time period of the contract after implementing those changes".
- **Reasons for change orders**: The reasons for change orders can be classified into five main reasons, which include a set of sub-reasons [10].

1. **The owner**: It includes a set of sub-reasons such as the owner's desire to change the design and specifications, modify the schedule, change the functional program of the project elements, and others.
2. **The designer**, which includes a deficiency or error in the design, inaccurate planning, error in estimating quantities, conflicts in the contract documents, and others.
3. **The contractor**: Such as a lack of financial liquidity for the contractor, the unavailability of the equipment required to implement the work, the unavailability of technical and trained workers.
4. **The supervisor**: Such as the lack of experience of the supervising engineer, suspending some work and delaying the delivery of plans until consulting the studying engineer, delaying the disbursement of monthly statements to the contractor, which leads to a slowdown in work, and others.
5. **Other reasons**: Such as insufficient verification of the site and its specifications, the unavailability of project materials in the market, weather and climate conditions, failure to take safety into account, changing the rules and laws related to the contract or project work, and others.

- **Effects of change orders:** there are some effects of change orders [11]:

1. decrease in workers' productivity;
2. delay in completion period;
3. disagreement between owner and contractor;
4. decrease in project quality rates;
5. additional financial resources and profits for the contractor (in most cases);
6. increase in project cost;
7. stoppage of work;
8. increase in contractor expenses;
9. delay in payment of financial dues to the contractor;
10. demolition and reconstruction work;
11. increase in project quality;
12. increase in project duration.

- **Managing change orders using traditional methods**: Researchers [2] stated through their research that the change order management process seeks to: predict potential changes, identify changes that have already occurred, develop a plan for preventive measures, and coordinate changes throughout the entire project (Fig. 1). They also stated that small changes with minor impacts do not need to go through a formal change process, but changes with a noticeable impact (changes that increase the duration and cost of the project), whether change orders or rework, require following a formal process in managing the change order. These researchers then developed a general model for managing change orders consisting of five successive stages: **identification, evaluation and proposal, approval, implementation, and review**, where they relied on the change process models mentioned in previous research and which they used in their study. Another traditional methodology [12]: for managing change orders in construction projects is called the Six Ps, which is summarized as follows **P**rospecting/discovering, **P**reparing, **P**ricing, **P**resenting, **P**reforming and **P**ayment (getting paid for). Fig. 1 shows the general model for managing change orders traditionally.
- **Managing change orders using BIM-based methods:** Researchers [13] presented an approach to represent, coordinate, and track changes within a collaborative, multidisciplinary BIM environment through their study. This approach was adopted through a detailed case study of a large and complex BIM project, where they investigated several design changes, analyzed change management processes, and evaluated existing BIM tools.
  This approach includes three distinct aspects:

1. traceability and traceability dependencies.
2. deleting dependencies from BIM.
3. creating dependency diagrams.

First: Traceability and traceability dependencies: In this graph-based approach, component attributes are directly and indirectly linked through different types of dependencies in the graph, accordingly when a component attribute is changed, the different components affected by this change can be traced in the graph, then these graphs are represented in the form of dependency matrices, which helps in developing a computational approach for automatic propagation of design changes in BIM.

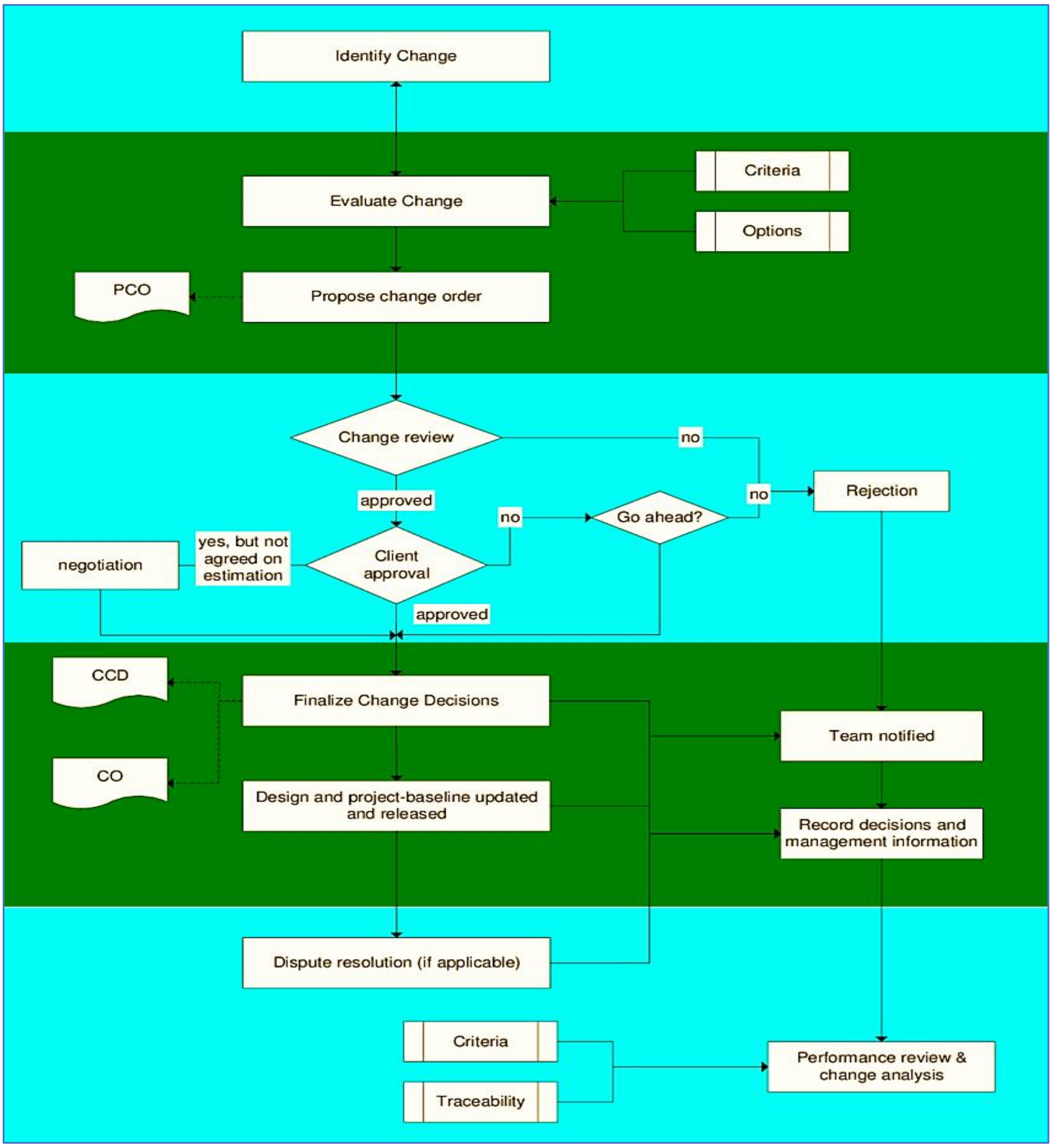

Fig. 1. **Change order management process model according to [2]**

Second: Deleting dependencies from BIM: In order to create dependency graphs, information about components and their dependencies (i.e. spatial and analytical dependencies) must be identified and stored in a common model, where information about the component and the spatial dependency between components can be extracted from BIM.

Third: Dependency graph generation: Once all dependencies are derived, a dependency graph will be formed. The graph is manipulated in the form of a matrix structure based on the concept of the affinity matrix and the theoretical data structure related to the graph. Any proposed change in the attributes of the different components will be presented as an initial "change vector". Researchers [14] conducted a study on the problems of BIM-based design change analysis, design change management and visualization of changes made to BIM models. In their study, the researchers used the *BIMestiMate* application for design change management, a Polish BIM-based application for analyzing both 4D and 5D models. This application provides the functions of selecting, viewing and comparing change options, as well as comparing an unlimited number of revisions of the same model. Using the change management functions implemented in the tool, users can view modified, deleted or added components, while the graphical representation provides filtering options to highlight the modified elements. The functions of this application allow comparing the parameters of the selected component of the model on the basis of two specific revisions, where the viewer can simply switch between the changed elements, in addition, the user can easily track the changes made to a specific component in successive revisions, by comparing the specific revisions.

Researchers [15; 16] proposed a BIM-powered change detection system to assess the impacts of change orders in construction projects. The proposed system is an analytical tool that can help project stakeholders assess the impacts of change orders on project scope, schedule, and time. The proposed system consists of three main modules: 1. Initial setup: This module defines a set of system requirements 2. Change detection: This module is the core of the proposed system because it performs all the important analysis 3. Report: Once the changed items are detected, the system will display all the filtered items and their information, including the item ID, change type, and its relationship to the cost and schedule database.

Proposed methodology for managing change orders in construction projects using cloud computing

As stated above, we find that most of change management and change order research was addressed to the design phase, and despite its importance, as it aimed to reduce change orders in the implementation phase, the management of change orders in the implementation phase within the BIM environment was not addressed in the published research. In this paragraph, we will demonstrate the steps for applying the proposed methodology through a case study, which was reached by integrating both the BIM technique and cloud computing, which has been increasingly used in the construction industry in recent years. The project-case study is a residential tower in the city of Tartous (Syria), the tower consists of ten floors in addition to the basement floor, with different floor areas (287 m^2 - 290 m^2 - 293 m^2), and each floor consists of two apartments.

The research in the following paragraphs reviews the steps for preparing the 3D modeling of the residential tower project within the BIM environment, in addition to preparing its schedule and budget required to implement this project. We used three engineering software programs for this: Autodesk Revit, Autodesk Navisworks and Primavera. This section reviews the steps for using cloud computing in managing change orders, which includes using one of the open-source clouds, which is the Google Drive cloud, to store files that were implemented using the previous programs, and how to link them within the cloud and share them, and use them in managing change orders, in addition to using the Google Meet platform to enhance communication and cooperation between all project parties.

1. Project Description Using Autodesk Revit. The 2D project drawings were converted to a 3D model using Autodesk Revit, and the construction plan was developed based on the elements of the model that was created in an appropriate sequence. The Revit software is characterized by the ability of each designer to work according to his specialty on a file, then the designs are merged into one model and clashes are detected within the design. Parametric modeling is also an important feature of this software, which allows for automatic updating of the design, as automatic updating is an important aspect when calculating the schedule and budget for the design, due to its ability to automatically update the model when there is a change in the design and plan that was previously prepared. After completing the design in the 3D model, the design was coordinated through a process of detecting and fixing clashes in it, before starting to prepare the project schedule. Once the clashes were detected, we found that there are many of them, so a report is prepared for each one and sent to the designer, Fig. 2.

After the report is delivered to the designer responsible for the subject/ issues, he can directly view the clash location and address it by clicking on the Manage button and then the ID button, after entering the identification number, the clash location appears directly, then the designer corrects it. After completing the resolution of all clashes and correcting them, the tables of quantities for the project are extracted through the Schedules feature in the Revit program.

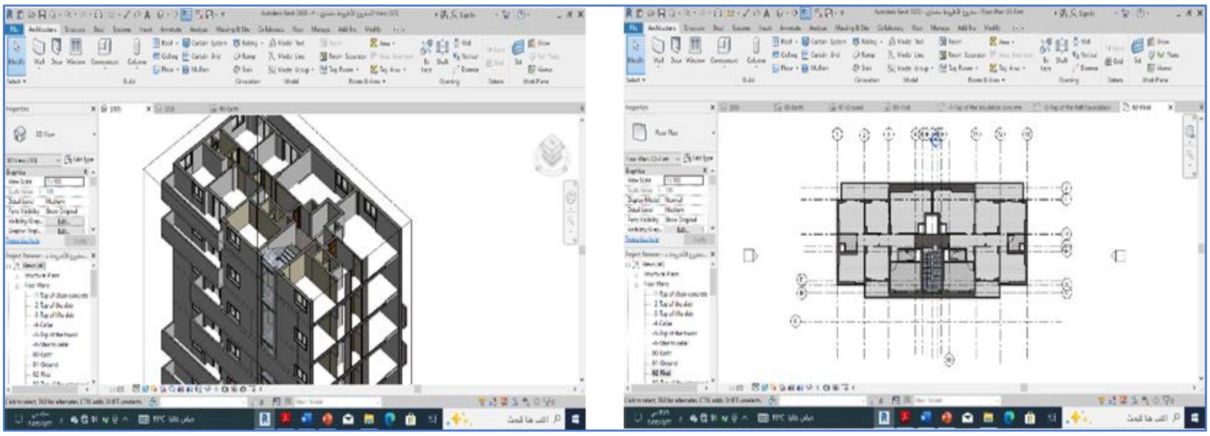

Fig. 2. **Project layout and 3 D Model**

2. Preparing the project schedule and budget using Primavera. After completing the 3D modeling process, detecting and resolving clashes, and extracting the project's bill of quantities, begins preparing both the project schedule and budget. To do this, Primavera software was used, according to the stages known to all in preparing the initial project plan (schedule + cost). Fig. 3.

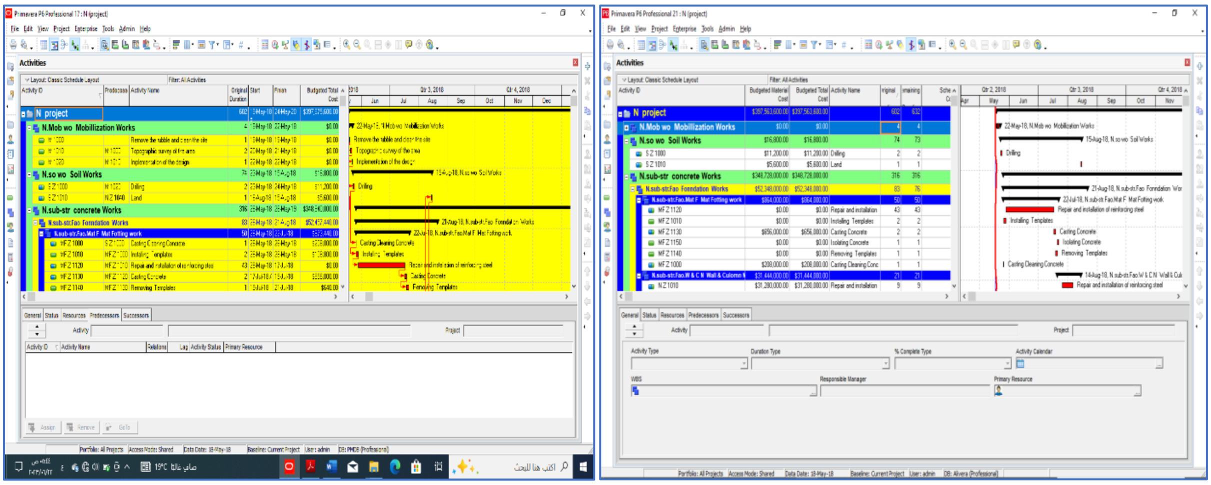

Fig. 3. **Project Gantt chart using Primavera P6**

3. Linking Autodesk Revit and Primavera using Navisworks in Google Drive/

1. First, we created four folders in Google Drive, namely Revit, Primavera, Navisworks, and Reports, as shown in Fig. 4.
2. Then a web application was programmed with four buttons, each button was linked to one of the previous folders after sharing them with the project parties/stakeholders, in order to facilitate access and work on them.
3. After that, uploaded the project files to the cloud, shared them, and synchronized them with their respective software on the computer using the Google Drive desktop application.
4. Export the Revit file, which is in (rvt) format, to (nwc) format in the cloud, so that can run the 3D model that was prepared using Autodesk Revit in Autodesk Navisworks.
5. After the export to (nwc) format is complete, open the file and perform a clash detection process between the structural and architectural models. This is done through the Clash Detective feature in Navisworks in order to resolve them before performing the linking process. It is distinguished from Revit in that it displays clashes using color coding technology and then reports are prepared on the detected clashes as shown in Fig. 5.

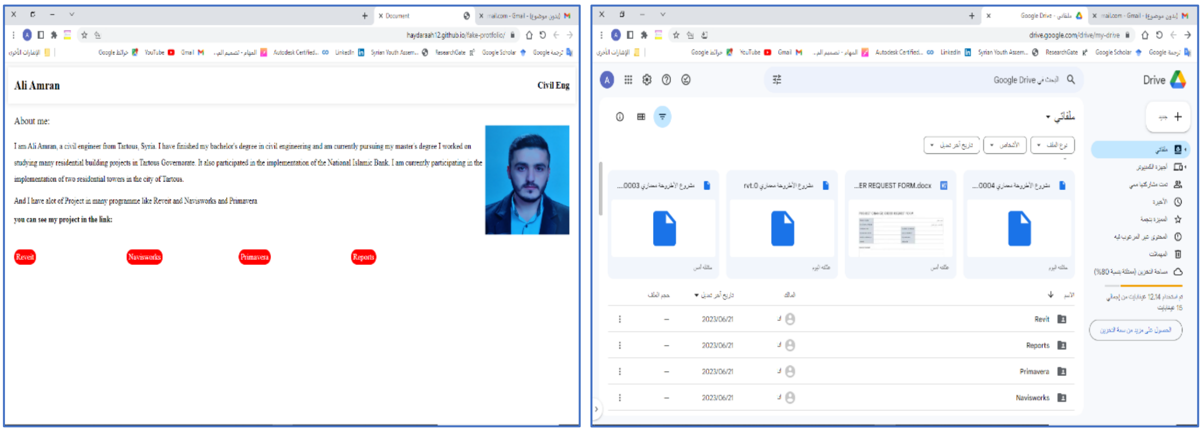

Fig. 4. **Creating project folders in Google Drive computing**

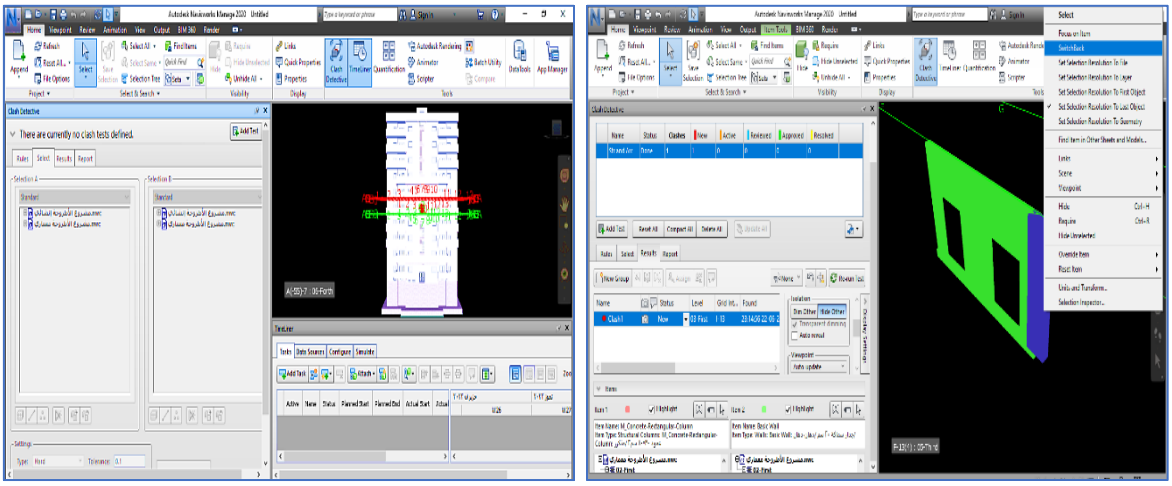

Fig. 5. **Clash Detective in Navisworks using color coding**

6. After completing the clashes detection and resolution process, the schedule and cost that were prepared in Primavera are exported to the Autodesk Navisworks file that includes the 3D model and are linked within the cloud by linking the Task ID for each activity that was prepared in Revit with the Activity ID that was prepared in Primavera within the Autodesk Navisworks file uploaded to the cloud, in order to simulate the work in the implementation phase and the possibility of making changes to the project or increasing or decreasing the time and cost, as this is done according to the following stages.

First: Export the Primavera file in MPX format from the Export command.
Second: Import the MPX file to the Navisworks file that includes the 3D model, from the Data Source tab, we choose Add, then we choose MPX from the drop-down menu, then we choose the required file.
Third: Right-click on the imported file and choose Rebuild Task Hierarchy to re-arrange the project activities within the Navisworks program as they were in the Primavera program.
Fourth: Link the schedule and cost with the 3D model and this can be done in two ways.

The first method: It is done automatically. From the Tasks tab, we choose Auto-Attach Using Rules, then we specify the parameters to be linked. In our case study, we linked between Display ID and Activity ID.

The second method: It is done manually according to the steps shown in Fig. 6.

7. A 5D BIM simulation of the project is then performed using the simulation option, which helps to see the start of the project implementation, its sequence and cost over time, as the simulation process continues for all parts of the project that have been linked to the schedule and cost, with the completion rates displayed at the time the simulation process is taking place, which gives a clear idea/imaging of the nature of the work implementation and its sequence stages, Fig. 7.

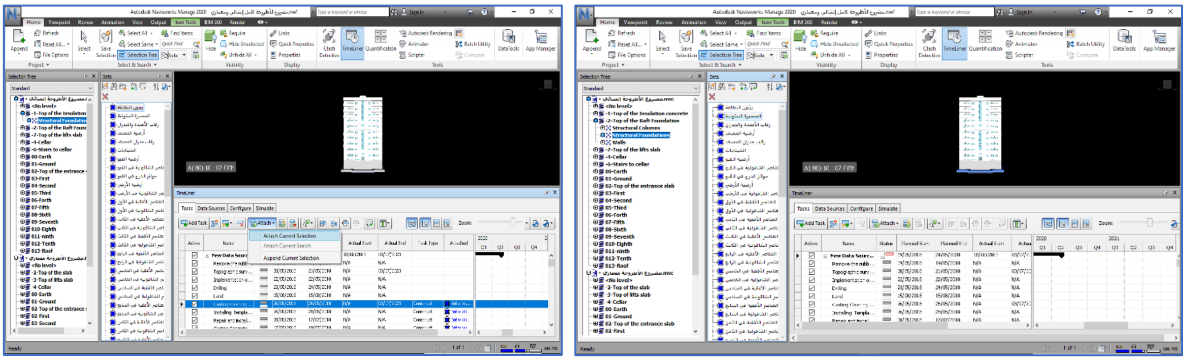

Fig. 6. **Linking project 3D (Revit) model and Primavera schedule file in Navisworks**

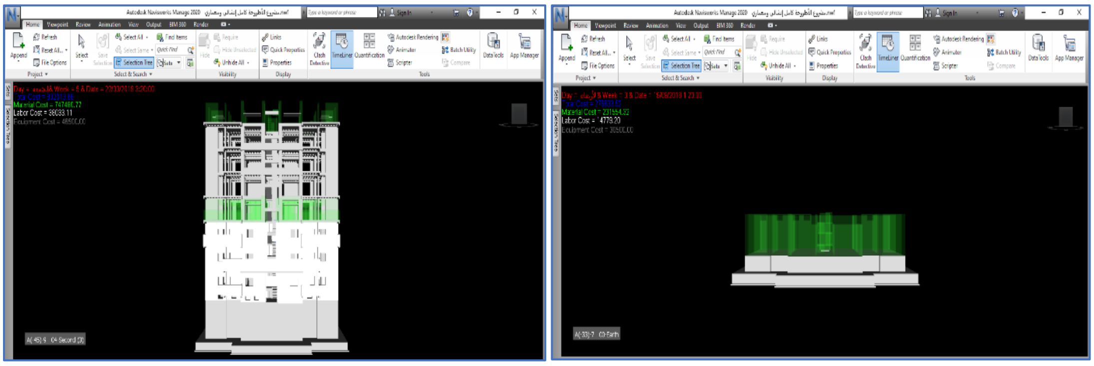

Fig. 7. **Simulation process for construction works (foundations, masonry and concrete structural elements)**

Sync Google Meeting with Google Drive to enhance communication between all project parties: Google Meeting was used to communicate between all project parties while working and discussing changes within the cloud, Fig. 8.

8. Prepare a change order template in (xlsm) format and upload it to the *Reports folder* within the *Google Drive Cloud*, Fig. 9.
9. A drop-down list has been added to the change order form to include approval or disapproval of the change order. A box for electronic signatures, a button to preview the file before printing, and a button to print have been added as well, Fig. 9.

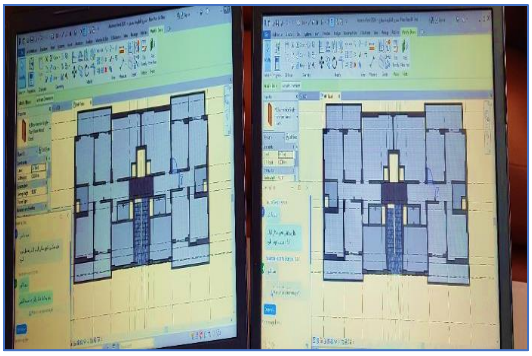

Fig. 8. **Sync Google Meeting with Google Drive**

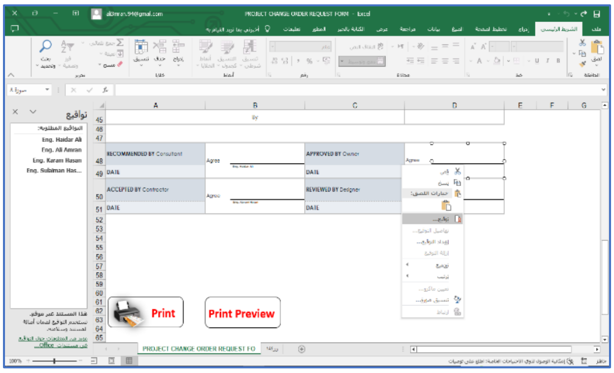

Fig. 9. **Prepare and upload a change order template (in xlsm format) to the reports folder within the Google Drive Cloud**

Case study: Testing the proposed methodology and verifying its efficiency in managing change orders

We applied the proposed framework to a residential building project in Tartus city -Syria under construction. To test the methodology, we follow the following steps:

Step1. First, inviting the project parties/stakeholders to hold a meeting, using *email*, *voice calls*, or other means of communication. After all project parties have joined the meeting, we follow the subsequent steps.

Step 2. Saving a copy of the Revit and Navisworks files in the cloud in order to use them later in the comparison process and track the project's changes.

Step 3. Open the *Revit* file in the cloud, then go to the *Add-In* tab and choose *External Tools* from it, then activate the *Navisworks Switchback* feature, Fig. 10.

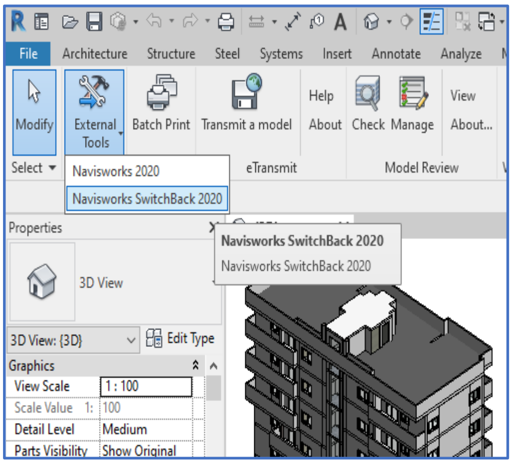

Fig. 10. **Using Navisworks Switchback feature**

Step 4. Go to the *Navisworks* file in the cloud, select the element to which we want to make changes, then click on *Switchback*, which helps the change that will be made in the Revit file to be automatically transferred to the *Navisworks* file once it is updated, as when we click on this option, it takes us to the *Revit* file that contains the selected element and shows it to us directly in the *Switchback window*, Fig. 11.

Step 5. Conducting changes to the selected element in the *Switchback window* in the *Revit* file, where, for example, upon the owner's desire or needs (change scope of owner) we will delete tow walls only on the 4th floor and opening a window for each bathroom due to the design defect, as shown in the following images, then save the file, next, close the *Switchback window* in the Revit file, after that export the file in (Nwc) format with the same name as the original file and in the same location (we replace the original file with the modified file), Fig. 11.

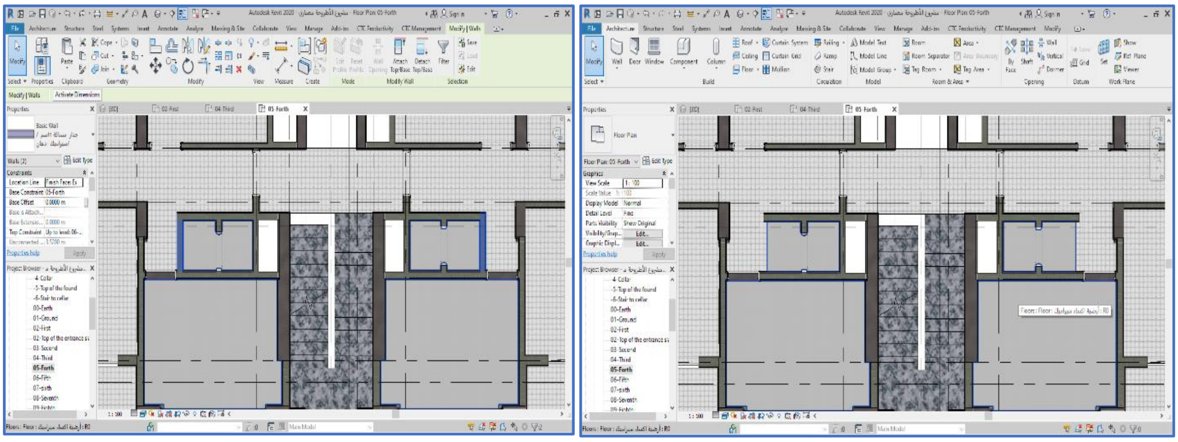

Fig. 11. **Owner's change order: deleting tow walls on 4th floor – before (lift –in blue colour) and after (right)**

Step 6. On the *Navisworks* file ONE CLICK on the *Refresh* option, hence, the changes to the model that were transferred to it appear automatically, Fig. 12.

Step 7. Now open the original file that was saved before making the modifications, using the *Append* option in the Navisworks program, then select the original and modified files that we want to compare between, then click on *Compare*, which enables us to track the changes that have been made using the *color-coding* feature. The **white color** indicates the identical items between the two files, the **red color** indicates the non-identical items that differ in parameters, the **cyan color** indicates the added items, and the **yellow color** indicates the deleted items, Fig. 12, Fig. 13.

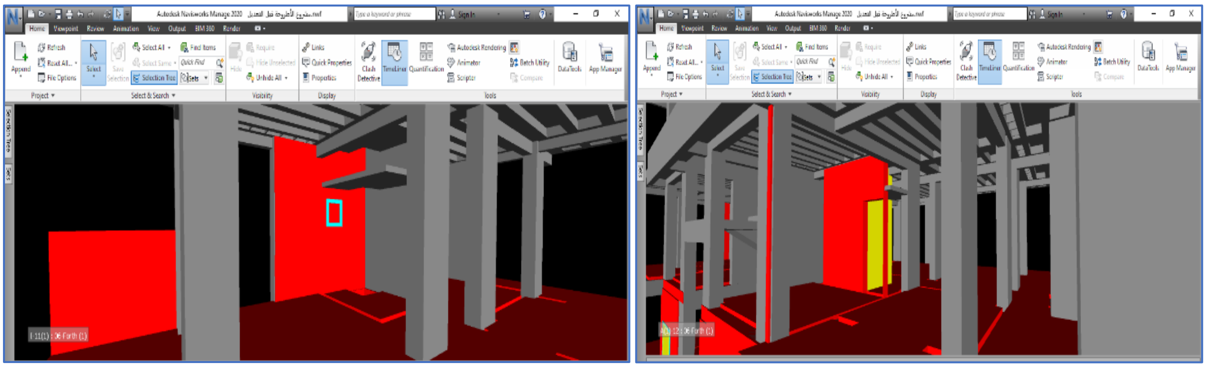

Fig. 12. **Opening bathroom window (lift –in cyan color: added items) and deleting tow walls on 4th floor (right-in yellow color: deleted items)**

Step 8. Finally, **preparing the report of the change orders-CO** that were made according to the previously prepared form and printing it in PDF format in the cloud after it is approved by all parties of the project as shown in the following images, and store it in the Reports folder in the cloud, Fig. 14, 15.

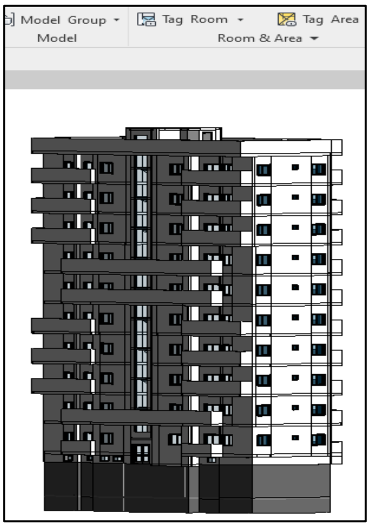

Fig. 13. **Building facade after adding bathroom window**

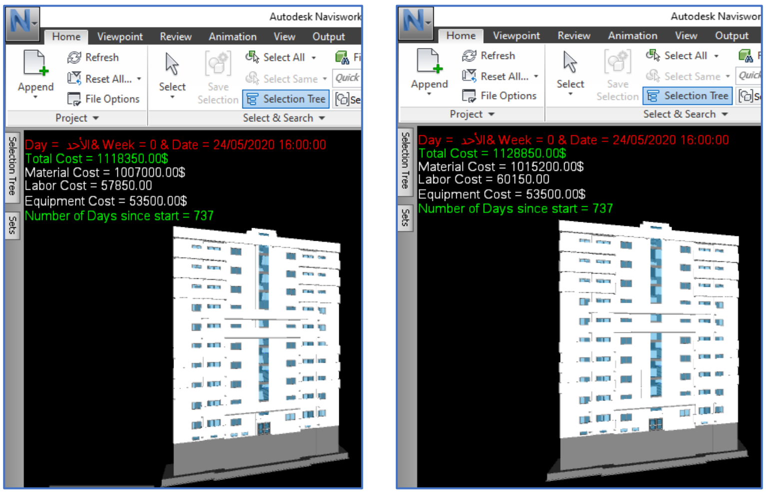

Fig. 14. **Project cost and duration before (lift) and after(right) change order**

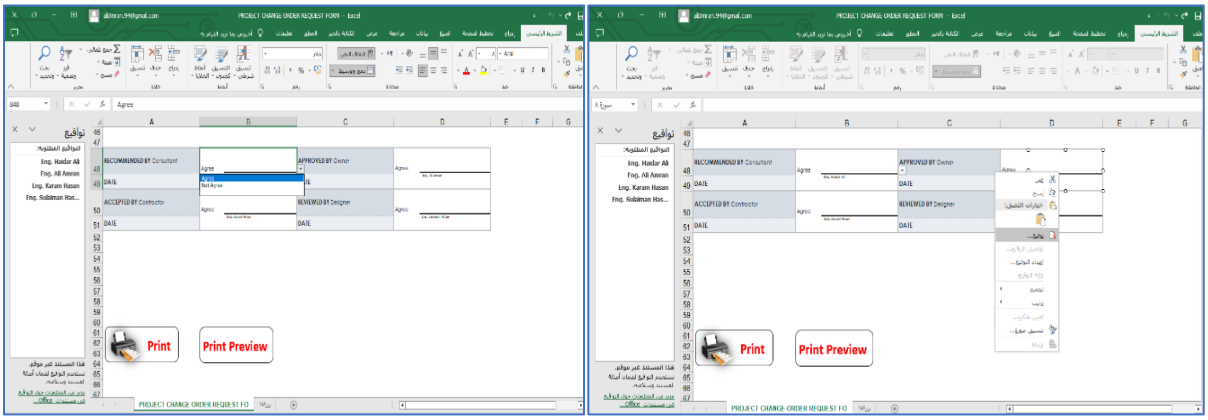

Fig. 15. **Change orders approved and validation by project parties / stakeholders**

Discussion and results

As it is well known, for construction industry professionals around the world, change orders-CO are an inevitable part of any construction project, and they rank first in terms of problems faced by the construction industry [16]. In this research, a methodology for managing change orders in construction projects has been reached - during the execution stage- within a BIM environment based on cloud computing technology. By examining practical project management practices around the world, including the change order management case study, and comparing the widely used traditional approach with the methodology proposed in this paper, the following differences can be noted.

Table 1

Comparison of characteristics of the traditional and proposed method for managing change orders

No	Traditional methodology	Proposed methodology
1	Lack of effective communication between project stakeholders	Effective and real-time communication
2	Wasting time arranging on-site meetings for project stakeholders	Meetings can be arranged remotely
3	Parties/stakeholders must meet on site	Meeting is not limited to a specific place
4	Focus on activating communication between parties	Focus on completing the change order itself
5	Change order results (time and cost) take a long time	Flexibility in obtaining deliverables instantly
6	Difficulty understanding the expected outcomes of CO for all stakeholders	Colorful visual results are attractive and easy to understand (images, videos, tables)
7	Lack the ability to offer multiple alternatives at a given time (as that requires advanced preparation)	Display multiple alternatives at once, with the cost and duration of each alternative

After testing this methodology on a real project (case study), we can list the following results:

1. The methodology for managing change orders in construction projects, which we developed in this research through the integration of BIM and cloud computing technologies, enables us to manage change orders that occur during the implementation phase in real time and from anywhere inside or outside the project site, in a completely different way from traditional management methods that used to take many days and sometimes weeks and months until the decision to change was made and managed. It also helps enhance cooperation and communication among all project team members/project parties or stakeholders.
2. Managing change orders during the implementation phase in construction projects is done more efficiently using this methodology, which leads to reduced delays in project delivery as well as reducing exceeding the budget allocated for them.
3. Using BIM technology in construction projects helps estimate the time and cost of the project more accurately during the implementation phase, by simulating the implementation process in a way that is completely similar to reality, where the three-dimensional model is linked to time and cost, thus showing the progress of the project over time. In addition, the cost of the project is also shown continuously as time progresses, which enables us to estimate the budget that must be allocated to the project during specific time periods of this phase (during each month, for example).
4. Using BIM technology in managing change orders during the implementation phase helps us greatly in tracking the change(s) through the color- coding feature, where different colors are given to each of the identical elements, non-identical elements, added elements and deleted elements, when comparing the basic and modified files. This technique/method also helps us reduce the impact of change orders by capturing the changes and storing them in separate logs.
5. Using Cloud computing in integration with BIM technology, according to the proposed methodology, in the project implementation phase helps enhance cooperation and communication

between stakeholders from anywhere and at any time, by sharing project information, which helps in taking proactive measures and procedures to avoid problems and avoid their effects.

Conclusions

By integrating BIM and cloud computing technologies, change orders that occur during the implementation phase can be managed in real time from anywhere on or off-site. This is a fundamental departure from traditional management methods, which used to take days, and sometimes weeks or months, for a change decision to be made and implemented. This reduces project delays and budget overruns. This also allows us to observe the effects of the change directly through the bills of quantities and costs that appear to all project stakeholders in real time. For example, in this project, the required change implementation took approximately six hours, divided into two sessions. First, project stakeholders discussed the rationale for the change and its importance to the project. Second, project stakeholders reviewed the results of the change and its impact on duration and cost, and approved it. Obtaining the bill of CO's quantities- BoQ and cost resulting from the CO took only a few minutes.

Recommendations

1. We recommend applying this methodology to manage change orders in construction projects, regardless of their type, as it avoids delaying the project to complete change orders.
2. Programming a chat and communication tool within design programs without the need to use an external tool- such as *Google Meet*.
3. The research strongly recommends the creation of an integrated local cloud platform specialized in managing change orders without the need to use one of the existing platforms, as was done in this research, especially in light of the inability to use global platforms - such as the Autodesk Construction Build cloud platform in Syria due to sanctions.

Author contributions

M.H.S: Conceptualization, Methodology, supervision, review, editing& validation. A.O: Data curation, resources, conceptualization, visualization, methodology, investigation, software, writing original draft.

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