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A BIM-Based Framework for Evaluating the Impact of Change Orders on Project Time and Cost in Saudi Construction Projects

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Abstract

Disputes over change orders on construction projects often arise due to varying interpretations and priorities of the key stakeholders, namely the owners, designer and contractor. This problem is particularly evident in the flourishing construction sector of the Kingdom of Saudi Arabia due to the delay of large-scale projects. A significant reason for these delays is huge claims on changes orders and traditional means of resolution such as litigation and arbitration are not able to yield timely resolutions. These challenges highlight the need to better manage and assess the impacts of change in a more proactive manner. This research proposes the BIM-based framework which offers the solution to the above-mentioned challenges through the creation of the Integrated Virtual Environment. The setup involves linking Revit for 3D modelling with Navisworks for coordination and visualization, and Primavera for scheduling and cost control into a seamless network. This link allows project information to be displayed in an orderly manner. Furthermore, any changes in design will be connected to the effect on time and cost. In this virtual environment, the framework aims to capture and visualize the effects of change orders in terms of schedule delays and cost overruns. This approach helps the stakeholders to trace how the changes are spreading in different dimensions of the project providing a clearer and common understanding of what changes those will bring. Having more light helps with better conversations, helps with discussions at the start, and helps avoid claims. The overall findings suggest that the combined use of BIM and project management tools may create a consistent virtual platform for the analysis of change orders and their impacts on time and cost. Through a real case study, the framework is developed and validated to showcase its practical capability of aiding decision-making, reducing disputes, and improving overall project performance. The effective management of change is vital in minimizing delays and facilitating better project delivery, especially in the fast-growing construction industry of Saudi Arabia.

Keywords: 4D/5D BIM simulation; change order; construction claims; time & cost impact

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Introduction

Construction claims are an inherent part of the construction process. These construction claims typically arise from change orders, design errors, contractual ambiguities, and coordination problems. Such claims are often inevitable. However, ineffective management and delays in resolution can lead to these claims becoming a major disruptor. In reality, many delayed claims lead to schedule delays, cost overruns, and deterioration of stakeholder relationships (Assaf et al., 2019; Mahamid et al., 2015; Alzara, 2022; Ramadhan and Waty, 2025). In KSA, the construction sector has significantly grown due to the Vision 2030, so this issue is of paramount importance in KSA. Even with this expansion, delay projects persisted due to claims, disputes, and other crises (Bageis, 2024; Almutairi et al., 2020; Alsulami, 2025; Alkhattabi et al., 2023). With the complexities involved in the construction contracts and the involvement of many parties, claims are growingly becoming a major

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issue affecting project performance (Alghamdi, 2022; Mattar et al., 2024). In addition, traditional dispute resolution methods like litigation and arbitration often take a long time to reach a solution and produce inefficiencies. When claims are not properly managed, they can play a vital role in causing project delays (Almutairi et al., 2020; Bageis, 2024; Assaf et al., 2019; Kundapura and Akash, 2026).

In global construction practice, claims are generally governed by a set of contractual agreements, the most famous being the FIDIC conditions of contract. Contracts set out formal procedures regulating how claims are to be initiated and evaluated, and how they are to be resolved by a series of steps which involve- notifying the claim, submitting particulars in detail, assessment by the engineer, and escalation to dispute adjudication boards (DAB), arbitration or litigation.

This structured framework mirrors the systematic character of construction claims, pursuant to which entitlements, timeframes, and documentation are clearly defined by the contractual provisions (Jung and Park, 2025; Ismaeil and Sobaih, 2024).

Claims under FIDIC-based contracts often arise due to variations, delays, and contractual disputes. This asserts that construction projects are typically complex (Abdelalim et al., 2025; Construction disputes study, 2026; Sanjaya and Isvara, 2024; Laksono and Wiyanti, 2024). The incorporation of dispute boards and alternative dispute resolution practices help in early resolution of disputes in more flexible and timely manner compared to the traditional legal resolution practices (Kundapura and Akash, 2026). Even though these procedures are there but they are not effective because of contractual observance only.

Recent studies show that the outcome of claims is largely driven by transparency, communication, and trust. Having processes that are easy to understand and well documented improves transparency and fair treatment and reduces disputes. As per the authors (Abdelalim et al., 2025), if there is effective communication and collaboration among the stakeholders, their negotiation and adversarialism can be minimized. Furthermore, under effective and mutual trust and cooperation of project participants, dispute resolution mechanisms of negotiation, mediation and adjudication are more effective than formal legal processes (Kundapura and Akash, 2026). Likewiserecent change management studies show that a collaborative management environment and active radio increase the odds of prevention in disputes. These findings contribute positively to project sustainability outcome (Ahmed et al. 2024; Mattar et al. 2024).

In general, FIDIC provides a good and practical procedure to manage construction claims, but disputes still occur in reality because just procedure is not enough. The potency of managing claims Highly influences by transparency, communication quality, and trust degree among the interested parties. This shows that a better integrated, more proactive approach would improve shared understanding and assist in managing claims and their effect on project performance.

Literature Review

Research conducted in the Kingdom of Saudi Arabia (KSA) on construction claims and their effects has revealed that construction claims are major construction issues that affect project performance. When project planning or documentation is deficient, there is a tendency for claims to be associated with change orders, design errors, inconsistencies in the drawings, and variations in the scope which increases the chances of disputes between project stakeholders (Assaf et al., 2019; Alzara, 2022; Alkhattabi et al., 2023). Delays occurring on construction projects in Saudi Arabia have been greatly associated with frequent design changes, lack of planning and a delay of payment, which proves to be connected to the occurrence of claims themselves and bolster their influence (Mahamid et al., 2015; Alsulami, 2025). In a similar vein, payment delay and contract issues have been identified to trigger disputes significantly and sometimes cause these issues to progress to the formal claims process (Bageis 2024; Wibowo et al. 2023).

The impact of claims extends beyond their occurrence to include the inefficiencies associated with their resolution. Litigation and dispute resolution measures recognised as a source of added delay thanks to their expensive and lengthy processes which disrupt the project (Almutairi et al.,

2020) A wider systems perspective indicates that claims in Saudi construction projects are prevalent and getting more sophisticated mostly due to incomplete information, contractual ambiguities, and insufficient pre-construction planning. These elements lead to lengthy claim settlement processes that take considerable time and resources. Ultimately, this delay in project completion or performance is experienced. (Alghamdi, 2022). Also, change orders have been shown to generate cascading impacts on productivity, labor efficiency, cost overrun, and schedule delay. This is particularly true in the case of large-scale and complex projects (Nila et al., 2023; Shrestha and Zeleke, 2018; Alzraiee, 2022; Ramadhan and Waty, 2025). The literature collectively confirms that the claims are primarily caused by design flaws and contract issues (Assaf et al., 2019; Alghamdi, 2022; Laksono and Wiyanti, 2024), are strongly correlated with time and cost overruns (Mahamid et al., 2015; Bageis, 2024; Alsulami, 2025), and further compounded by an inefficient resolution mechanism (Almutairi et al., 2020).

Faced with these challenges, researchers are proactively designing tools, frameworks, and systems that will improve construction claim management and more effectively resolve disputes. Construction claims are a universal phenomenon and recur frequently. Due to their impact on project performance, more studies are being conducted to improve their management (Kalogeraki and Antoniou, 2024). Recent studies suggest that the incorporation of advanced digital and analytical instruments. This includes building information modelling (BIM), blockchain, smart contracts, and machine learning. Which can enhance the transparency, traceability, and efficiency of the claims management process (Kalogeraki and Antoniou, 2024; Ye et al., 2024; Abdulfattah et al., 2023).

BIM-based solutions are one of the approaches getting due attention to prevent disputes and mitigate claims. BIM allows for better visualisation, coordination and integration of project data resulting in potential conflicts not escalating to a claim stage and that being resolved. These frameworks integrate scheduling, cost estimation, and visualization to detect and manage possible sources of conflict at early stages (Charehzehi et al., 2024; Handayani et al., 2019; Likhitruangsilp et al., 2018). Likewise, strategic BIM-based models are advanced to enhance collaboration among stakeholders and to early identify triggers of disputes that lower the chance of claims and improve performance (Tantawy et al., 2025; Manzoor et al., 2021; Rai and Saoud, 2025).

The recent study shows the role of BIM in preventing change orders, cost overrun and schedule delay due to increasing interoperability, integrating information and coordinating project (Muhammad et al. 2019; Ahmed et al. 2022; Alnaser et al. 2024; Alnaser et al. 2023; Al-Btoush et al. 2024). Integrated approaches using both BIM and system dynamics have also been proposed to facilitate evaluations, and consequently, mitigate the impacts of change orders and construction waste generation, achieving a more comprehensive decision-support environment (Porwal et al., 2020). Moreover, BIM-based frameworks aimed at reducing the impact of design-related change orders have been effective in minimizing the impact on projects and enhancing transparency in construction management processes (Aldiabat Al-Btoosh, 2021; Alkarawi and Jaber, 2024; Alshdiefat, 2017).

New studies underscore the increasing use of advanced computing and digital technologies in the examination of construction claims and disputes. The methods of machine learning have been used to forecast dispute outcomes, enabling stakeholders to probe potential claim outcomes ahead of time and advocate for early settlement (AlQaisi, 2022). Artificial neural network (ANN)-based frameworks have been developed to predict the time and cost impacts of claims. They act as decision-support tools, enhancing the claimers' awareness of risk and improving pre-contract planning (Hosny et al., 2015). Predictive models based on multilayer perceptron neural networks can also analyze case characteristics and predict the outcome of claims with high accuracy so that the reliance on the regular mechanism of dispute adjudication may be reduced (Chaphalkar et al., 2015). Recently, machine learning models embedded in BIM environments were introduced to predict the implication of design changes and help assess design changes effect on project performance, enabling more proactive claim and change management (Abdulfattah et al., 2023).

In BIM terms, digital models are integrated data environments that link design, schedule, and cost data to aid claim analysis, providing a more efficient and accurate method for preparation and evaluation of claims (Koc and Skaik, 2014; Handayani et al., 2019). In addition, integrated frameworks interfacing BIM with smart contracts and digital data environments are proposed to automate claim procedure, enhance traceability and improve transparency of claim execution (Ye et al., 2024). In addition to technological tools, certain process-oriented frameworks such as FIDIC-based checklists have been introduced to standardize claims procedures, enhance documentation control, and support structured decisions (Jung and Park, 2025; Ismaeil and Sobaih, 2024). In addition, according to the studies, it becomes essential to incorporate negotiation, mediation, and adjudication, as well as a structured dispute resolution mechanisms to make them more efficient and reduce litigation, stressing the importance of a combination of digital tools with communication and collaboration (Kundapura and Akash, 2026; Nusantara and Sutardi, 2023).

In addition, despite the introduction of advanced tools and frameworks in recent years, including BIM-based solutions and digital technologies, the application of these concepts has mainly been geared towards improving coordination or supporting dispute avoidance (Kalogeraki and Antoniou, 2024; Charehzehi et al., 2024; Tantawy et al., 2025). According to Qasem (2025) and Alzraiee (2022), there is still a big gap in existing approaches' ability to explicitly quantify and communicate the impact of change orders and claims on project performance, especially time and cost. Because of this obscurity, stakeholders are limited in their ability to comprehend the implications of project changes. Thus, it restricts informed decision-making and increases the risk of disputes intensifying (Assaf et al., 2019; Mahamid et al., 2015; Oh et al., 2024).

In addition, the claim management process that is in use now does not provide an integrated environment that can link design changes to schedule and cost data in a coherent and visual manner (Koc and Skaik, 2014; Ye et al., 2024; Rai and Saoud, 2025). Thus, stakeholders generally require fragmented information on different platforms which may lead to miscommunication, conflicting interpretations, and less transparency (Charehzehi et al. 2024; Assaf et al. 2019; Ahmed et al. 2022). The limitation is of critical concern in complex construction environments like those in Saudi Arabia where there are multiple stakeholders, the projects develop quickly, and there are high levels of uncertainty (Alghamdi, 2022; Mahamid et al., 2015; Alsulami, 2025).

In spite of the many tools and models developed in the literature, construction claims still remain a challenge in practice. The consistency in construction projects is mainly due to the multi-faceted and intricate nature of most construction operations involving a large cast of players with differing viewpoints and ongoing communication and transparency issues. As a result, though many technological and procedural solutions have been proposed, their implementation and efficacy remain limited. There is a need for better integrated and visualisation approaches that can enhance stakeholder understanding, improve transparency and support proactive decision making in relation to construction claims.

Research Gap and Contribution

Although there is a vast literature on construction claims, including studies which identify causes and various ways to manage and resolve such claims, the problem continues to manifest in practice. Most of the literature has focused on understanding claim sources and improving the contractual and legal aspects of dispute resolution. Nonetheless, these strategies are mostly reactive, depending on formal procedures such as claim submission, negotiation, arbitration, and litigation after the dispute occurrence (Almutairi et al., 2020; Alghamdi, 2022). The literature has shown that such mechanisms can be slow, expensive and inefficient and may lead to delay of projects rather than avoidance of the delay (Almutairi et al. 2020; Alghamdi, 2022; Abdelalim et al. 2025; Kundapura and Akash 2026; Construction Dispute Study 2026).

A clear research gap exists for proactive integrated visualization-oriented decision-making frameworks that would allow stakeholders to evaluate the consequences of change orders before they develop into formal claims. In response to the current gap, this study establishes a BIM based framework to embed multiple digital tools in one virtual environment. With the linking of 3D modelling, scheduling and cost data, the proposed framework will enable simulation and

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visualization of project condition, before and after the implementation of change order with a particular focus on time and cost impacts.

The framework proposed advances the knowledge base by moving from reactive claim management to one which is proactive and provides decision-support. It increases transparency through the provision of a common representation of impacts of change which enables better communication between the parties involved while also allowing for early-stage assessment of alternatives. The fusion of these two claims integration methods may reduce disputes, delays, and traditional claims management limitations in the Saudi construction industry. For this reason, the key aim of the study is to formulate a framework that uses BIM to incorporate various digital tools for establishing a virtual environment for claims. Through the usage of 5D BIM, the framework depicts and quantifies the impact of change orders on project time and cost, allowing real-time visualization in the virtual model. By increasing the amount of transparency, implementing data-led decision making, as well as ensuring the process of assessment of construction claims is structured and properly defined.

Methodology

The methodology of the study is designed in a five-phase sequence, which basically helps to develop and validate a BIM-based framework for construction claims. This methodology starts from identifying the problem and reviewing the literature. Further, it continues on conceptual framework development and system design. This refers to the implementation of a virtual environment through BIM integration, or linking the project data in the design, time, and cost dimensions. To evaluate the impacts on the project performance, change order scenarios are simulated. In the end, a case study is used to validate the framework and its application to the situation to make a decision.

Phase 1: Problem Identification and Literature Review

This phase, shown in Figure 1, is concerned with identifying issue with the construction claims mainly due to time and cost impact. A thorough review of literature is carried out that examines what is happening at present in claim management, procedures developed on FIDIC basis as well as technology led tools that are in use. The outcomes from this stage help identify the research gap and establish the requirements for the framework being proposed.

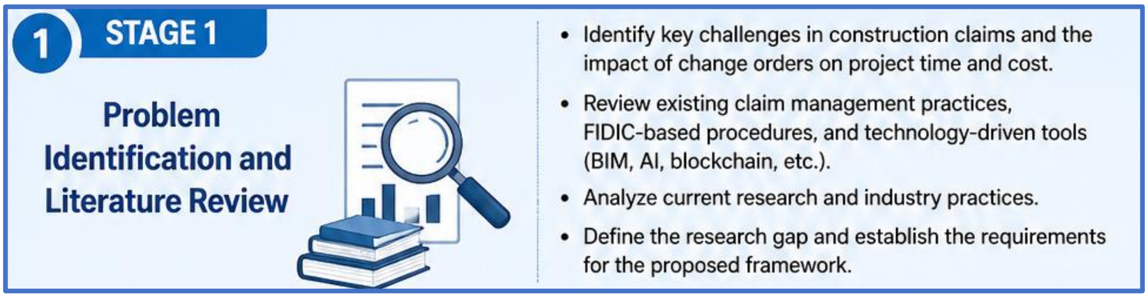

Figure 1. Literature Review and Gap Identification Phase of The Study.

Phase 2: Framework Development and System Design

During this phase, a conceptual BIM-based framework is produced for claim analysis and impact assessment, as illustrated in Figure 2. The system architecture is designed by integrating various software platforms such as Revit, Navisworks, and Primavera. In addition, the data requirements and workflows are defined to ensure the design, scheduling and costing information interlink within one system.

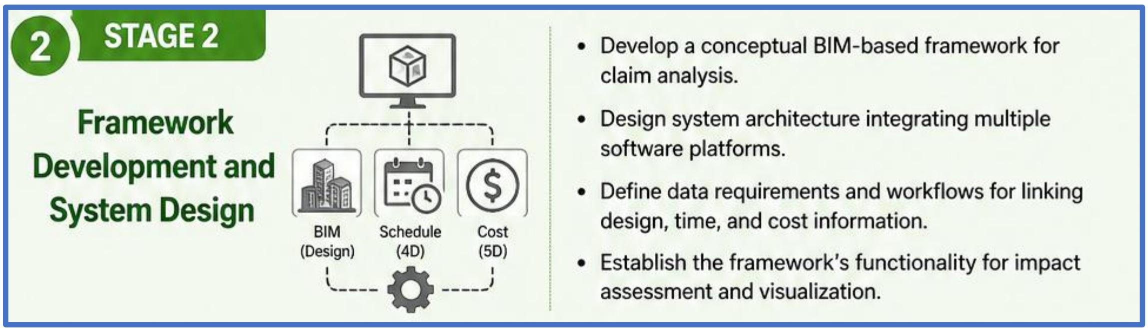

Figure 2. The Development of the framework System design Phase of The Study.

Phase 3: Virtual Environment Implementation (BIM Integration)

Figure 3 shows that in this phase, the virtual project environment is constructed to implement the proposed framework. A 3D model is produced in Revit this is integrated with scheduling data (4D) and cost data (5D). Navisworks allow coordinating and merging these data sets in one BIM-based virtual environment for simulation and visualization of the project condition.

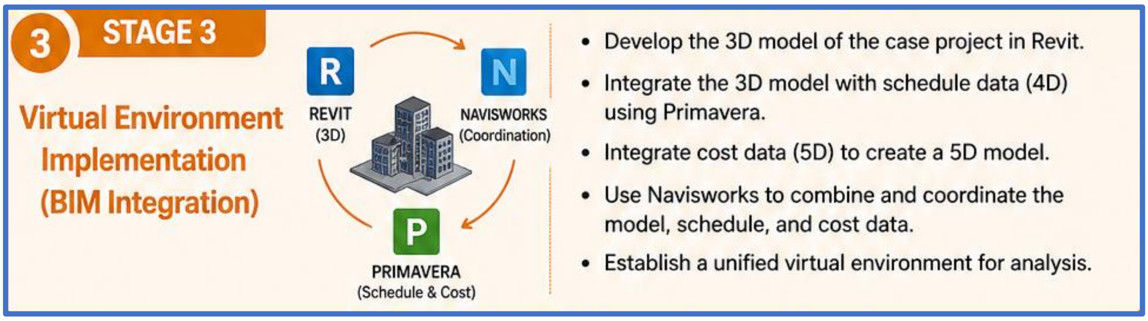

Figure 3. Development Of Virtual Environment Phase 3 of the Study.

As illustrated in Figure 4, this phase is the main phase of the framework developed which mainly includes integration of Revit, Primavera and Navis works for multi-dimensional BIM simulation and development of an integrated virtual environment. First a detailed 3D model of the project is created in Autodesk Revit which integrates the architectural, structure, and MEP components which depict the baseline design scenario. Using this model, a Work Breakdown Structure (WBS) is drawn up that map project components to construction activities. The transfer of these activities to Primavera occurs next, with the definition of logical relationships and assignment of respective duration and cost data which produces 4D (time) and 5D (cost). Then, both the Revit model and Primavera programme are incorporated into Autodesk Naviswork, where they are merged into one platform for simulation and visualisation. This integration allows the development of a flexible virtual environment that can depict project evolution, produce S-curves, and assist in quantitative analysis of performance. The outcome of the simulation model is a base simulation which allows the evaluation pertaining to the impact of change order on the time and cost of a project using co-ordinated digital means.

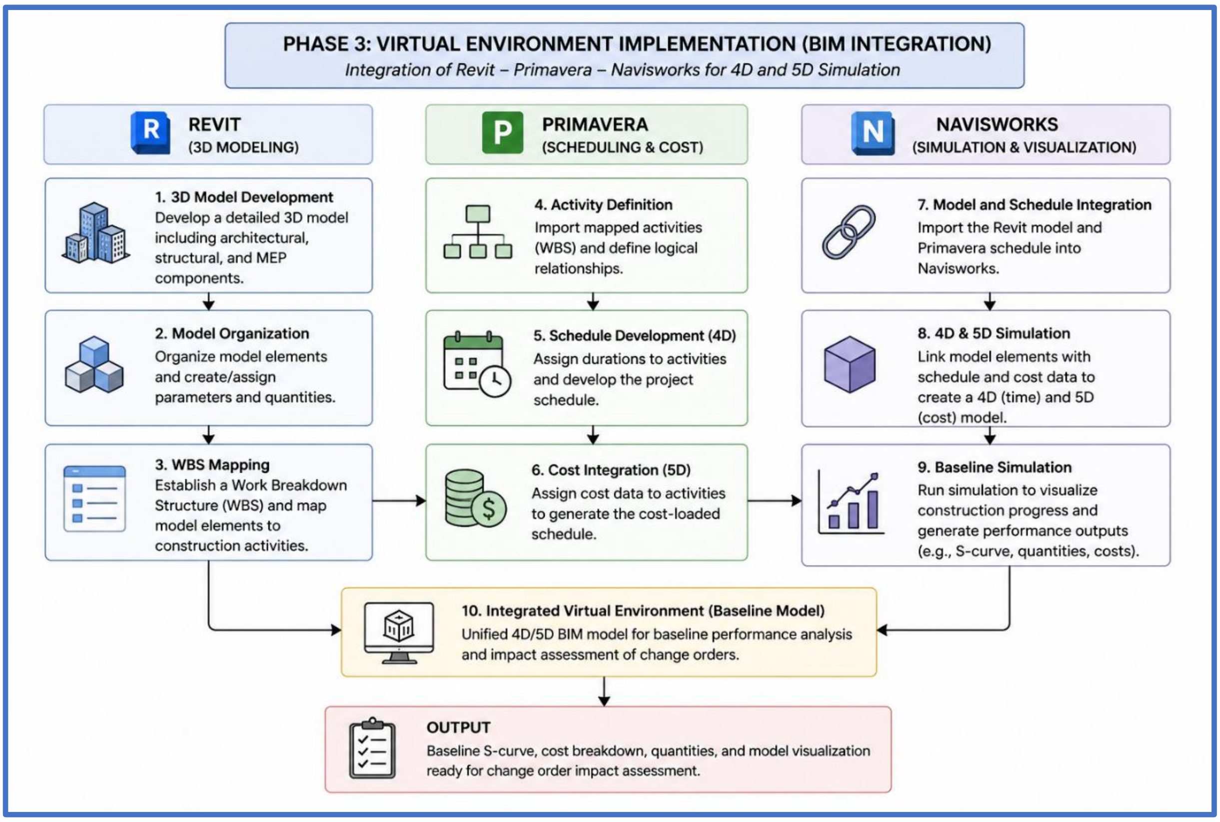

Figure 4. The Development of the Integrated Revit, Navisworks & Primavera 5D BIM model.

Phase 4: Change Order Simulation and Impact Analysis

As illustrated in Figure 5, selected change order scenarios are introduced into the virtual environment which interface of project performance assessment. The framework analysis and quantification of impact arising out of these changes on key parameters like time and cost. The visualisation of the model assists stakeholders in understanding the impacts associated with the claim.

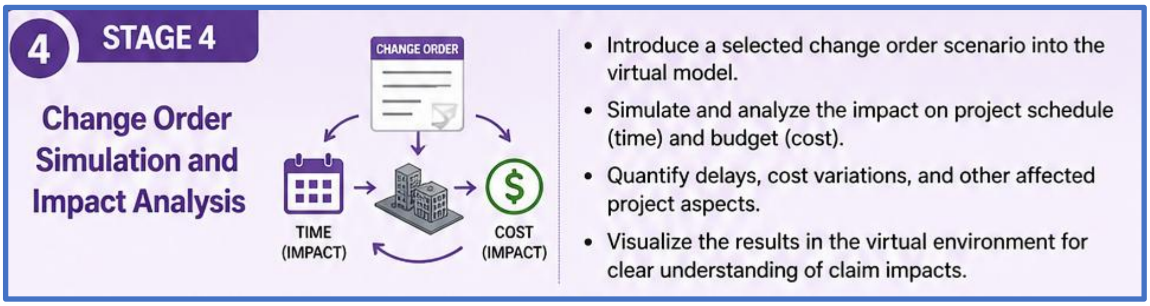

Figure 5. Change order Simulation phase of the Study.

Phase 5: Validation and Evaluation

The last phase of the framework, as shown in Figure 6, is the application of the framework to a case study validation. Comparison is done between the output of the model and the data of the actual project. So, we will also assess the effectiveness of the framework in determining transparency, making decisions as well as using construction claims.

Figure 6. Phase 5 Validation and Evaluation Phase of the Study.

Proposed BIM-Based Framework

Traditional FIDIC Claims Process (Without VR Tool)

According to Figure 7 the process of Change Order and Claims under standard FIDIC conditions generally gets initiated by the triggering event which happens during project execution. This may be a change in design, unforeseen physical condition, and instruction issued by the Engineer and so on. In this regard, the contractor shall submit a claim in accordance with the contract (e.g., Clause 20) and the Engineer shall review and determine the outcome (Clause 3.7). The purpose of this determination is to assess entitlement and quantify cost and time impacts.

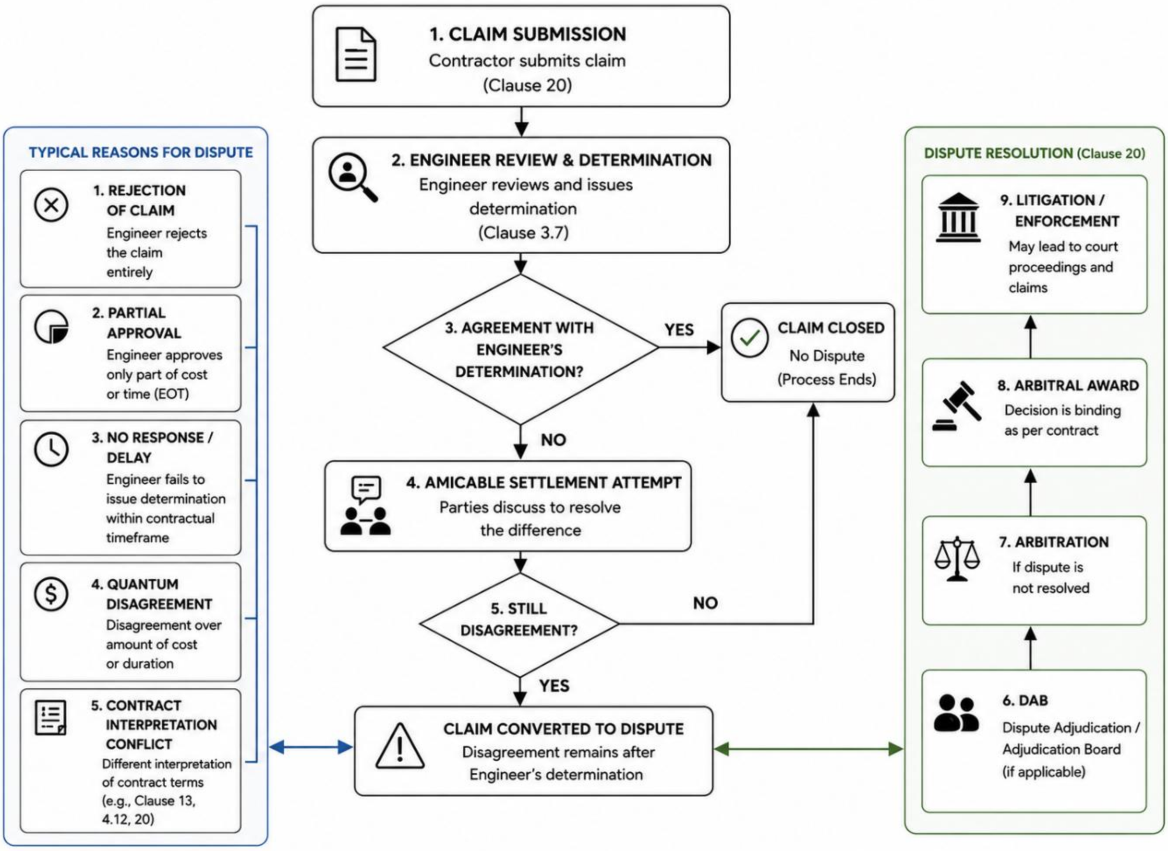

Figure 7. Traditional Fidic Claim Management Process.

On the other hand, the traditional process is still very much document driven, requiring submissions, schedules, cost reports that all vary according to the interpretations made by the stakeholders. When we do not see the change in a common picture, understanding becomes fragmented. This is particularly true when judging complex interactions between project elements, sequencing and resources.

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In the result, when entitlement is recognised, there are often disputes over the amount of compensation or the period of delay (EOT). Due to delays in communication, lack of information, and subjective interpretation of specific contract clauses, for example, Variations (Clause 13) and Unforeseen Conditions (Clause 4.12), these disagreements escalate. Consequently, numerous claims do not settle amicably but turn into disputes. Once a dispute has been identified, it goes to the mechanisms which include DAAB arbitration and sometimes litigation. Dispute Avoidance/Adjudication Board (25 words) This escalation delays project delivery while also increasing administrative and legal costs. Moreover, it also affects the collaboration and trust of the project participant. Assimilating into the above notions, the standard FIDIC approaches are largely reactive in character and, as such, addresses the dispute only after it has reached its full manifestation, which creates efficiencies and adversarial environments for projects.

Enhanced Process with VR-Based Collaborative Model

The introduction of a collaborative Virtual Reality (VR) based model augments the standard claims process through an interactive visualization-driven component at an early evaluation stage as shown in Figure 8. As seen in the standard way, the process starts with an event triggering followed by the submission of a claim and a preliminary review. But, before the final decision is made, the stakeholders are invited to take part in a structured virtual reality collaborative session, where the proposed change order is presented in 3D visualisation created from the BIM model of the project. It allows the contractor, Engineer and employer to see and measure the effect of the change on contractor's progress, cost, and quantities contemporaneously. The VR model eliminates ambiguity and mitigates the need to rely on abstract or fragmented documentation through a common, data-rich platform. Stakeholders have the option to test out other possible scenarios, see what the impacts of sequencing choices might be, and observe what happens to the project system following changes. This improvement in clarity allows for more informed conversations and objective assessment of entitlement and quantification. Thus, many possible conflicts are found, identified, and solved during early development, which increases the chances of reaching a mutual agreement without escalation. Even when differences remain, the extent of agreement reduces the depth and intensity of disagreement. As a result, there is less need to move to formal dispute resolution mechanisms such as DAAB or arbitration. The approach, which is enabled through visualization, proactively changes the focus from resolving disputes to preventing them altogether. This, in turn, helps to enhance decision-making efficiency and reduces time and cost overruns.

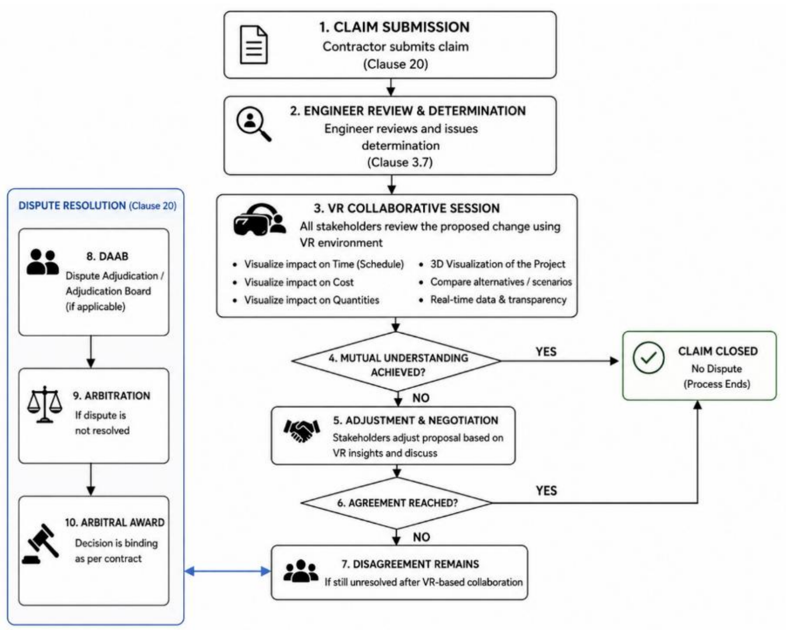

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Figure 8. BIM /VR Based Modified Fidic Claim Management Process.

Model Development and Implementation Framework

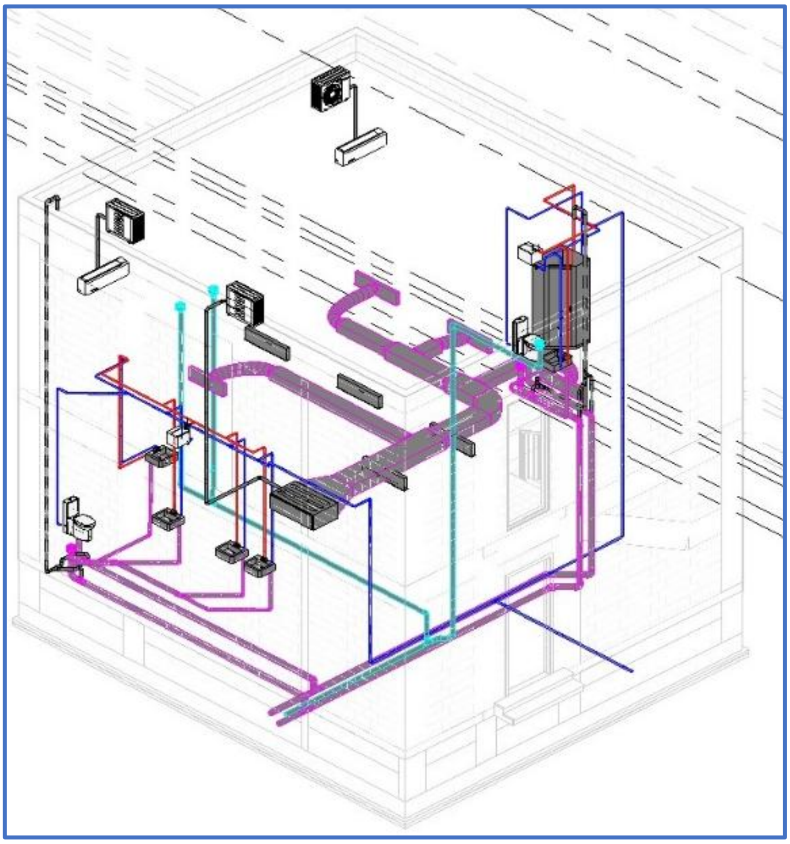
An integrated digital framework was developed using the proposed BIM-based model to assess the effect of change orders on the cost and time of construction projects before implementation. The three main platforms utilized are Autodesk Revit for 3D modelling, Primavera for scheduling and cost estimation, and Autodesk Navisworks for 4D and 5D simulation. After creating the baseline project situation, we modify the situation through a change order (CO) and check its impact through updated simulations and KPIs.

The model development stages can be divided into three consecutive steps which are a complete process from project initiation to decision-making.

Stage 1: Baseline Model Development and Simulation

The starting condition of the project will be established at this stage and used for assessing change order impacts.

The 3D Model of the building is developed in Autodesk Revit which contains Architectural, Structural & MEP components. A Work Breakdown Structure (WBS) to represent all activities of the project is defined based on this model. After that, the WBS is moved to Primavera to determine the sequence of construction through logical relationships. Next, each activity is assigned time duration and cost value that will generate the project data of 4D (time) and 5D (cost). The integration of the Revit model and Primavera schedule in Navisworks is done to perform the initial simulation and produce the S-curve and project advancement visualisation, which is presented in Figure 9.



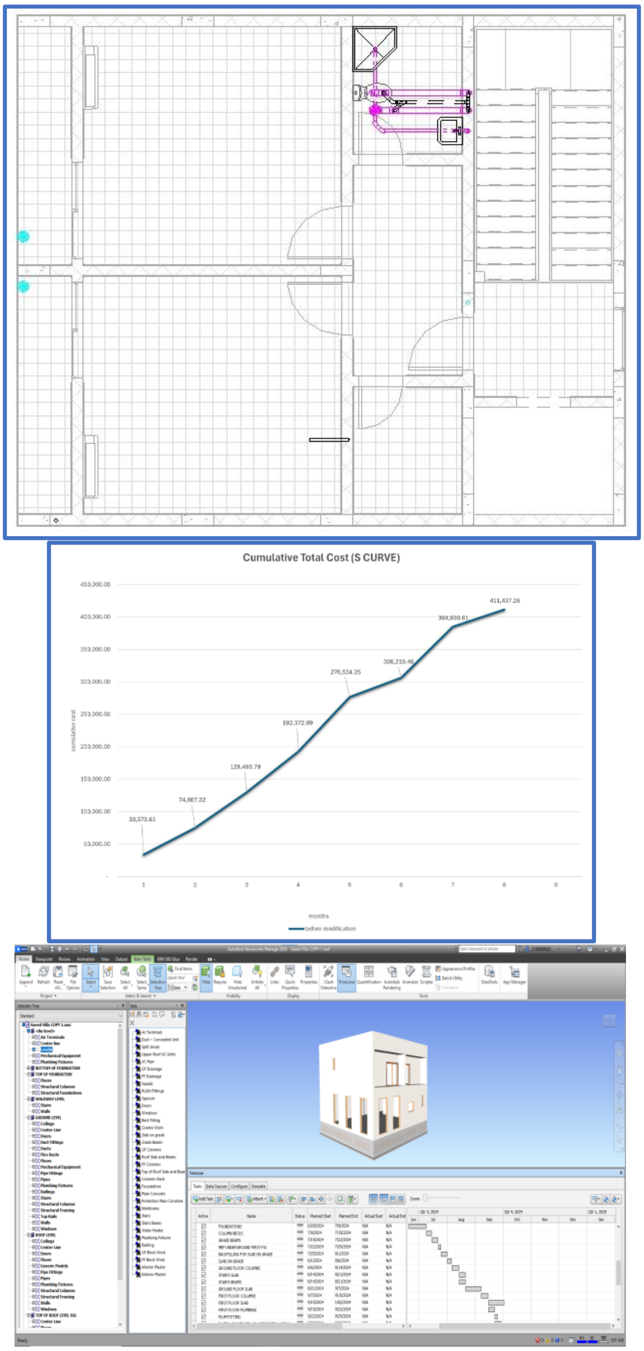


Figure 9. Initial Project Characteristics Before Change Order. Baseline 3D mode, Initial Floor Plan, S-Curve & Schedule.

Stage 2: Change Order Simulation and Management

The purpose of this stage is to evaluate the impact of change orders through model updates and simulation. This is the stage when a change order is introduced. The building model shall be updated in Revit to reflect Design Changes, and any other additional activity shall be identified and captured in WBS. The WBS that's updated is changed in Primavera along with activity relationships, duration and cost values. The updated model and schedule are reintegrated into Navisworks for a second simulation to generate updated project outputs, such as the updated S-curves and cost-time performance indicators shown in Figure 10. Stage 2 involves updating the BIM model, schedule, and cost data with respect to the change order and generating the updated simulation outputs. Although the outcomes consist of quantifiable and visual results, they are not always enough for nontechnical stakeholders to grasp the implications of the change. In order to overcome this limitation, Stage 3 of the framework takes the simulation outputs and transforms them into a VR-supported decision

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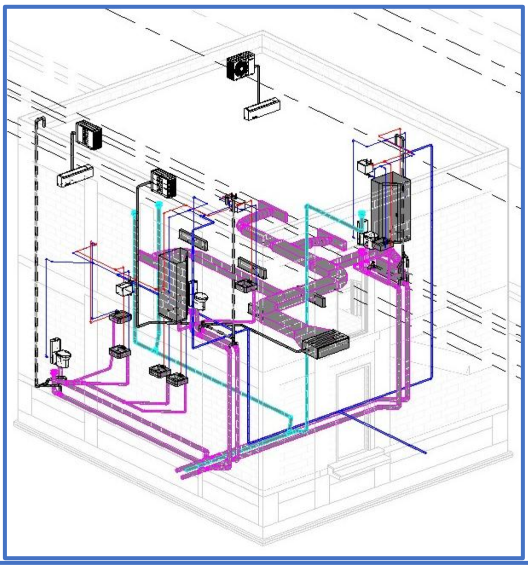
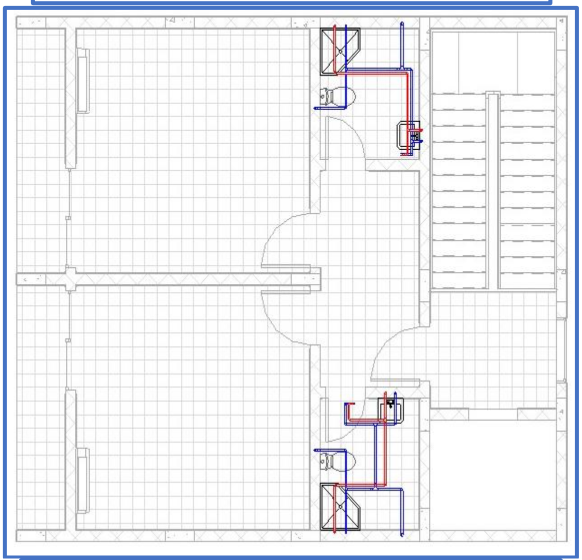
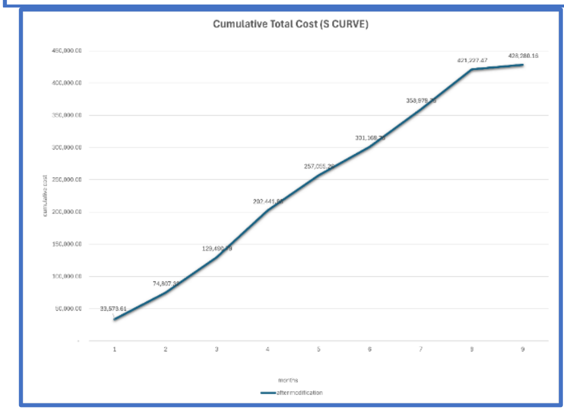
environment. This will allow for a more intuitive and immersive evaluation of the change order impacts.







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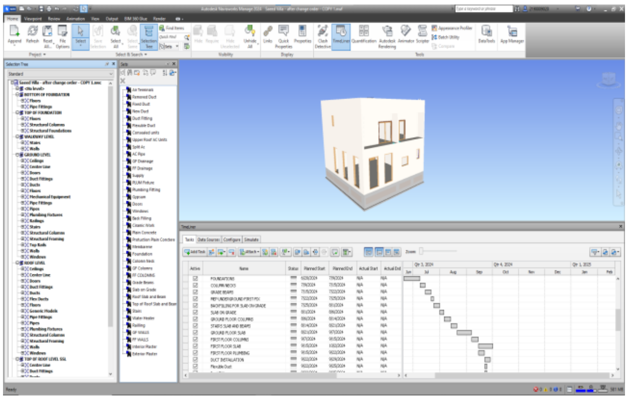

Figure 10. Project Characteristics After Applying the Change Order. Baseline 3D mode, Initial Floor Plan, S-Curve & Schedule.

Stage 3: VR-Based Change Order Evaluation and Decision-Making

At this stage, the framework becomes a VR-supported decision environment. It integrates the output of the BIM model with a view to enhancing stakeholder understanding and decision-making. The Autodesk Revit model is linked with Autodesk Navisworks, and the 3D geometry is linked with time (4D) and cost (5D) data generated in Primavera to create a VR experience. Figure 11 shows how this integration supports a live and immersive visualization of the project, allowing stakeholders to see the direct and indirect effects of change orders on-site, within a 4D modeling environment. The subject the case study is bathroom in other word the change order refers to a modification in the size and shape of the bathroom in a construction process that is at the end of its life cycle.

In the proposed framework, this stage represents the final layer where technical simulation outputs will be translated into an interactive decision support environment. This completes the process from model development (Stage 1) and change simulation (Stage 2) to stakeholder-driven decision making.

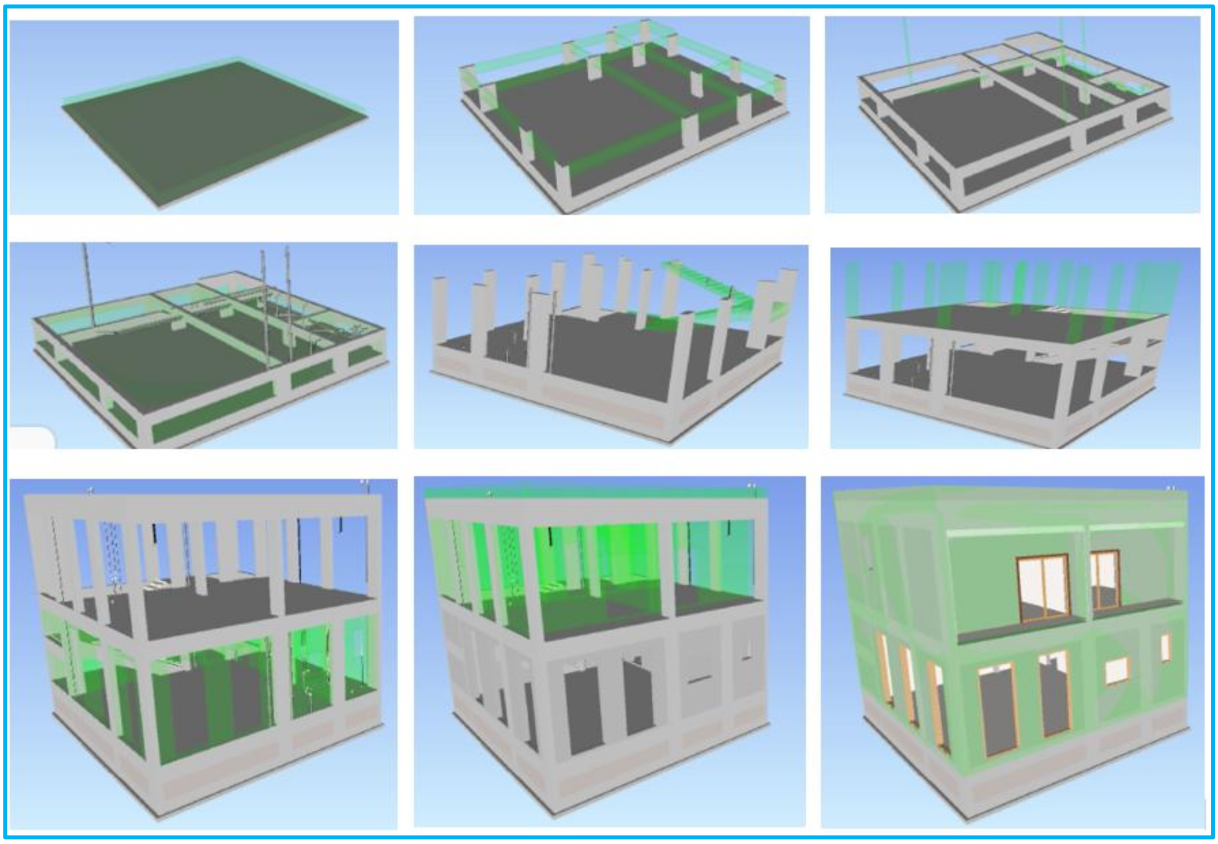

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Figure 11. Animated 3D/VR Modelling for the change Order.

While the owner may initially perceive this modification as a minor adjustment, the VR-enabled simulation reveals a significantly different reality. The model shows this change entails extensive demolition of finished works like finishes, plumbing dismantling, and modification of concealed MEP components. The activities with cascading effects on project cost, time and construction sequence, which are otherwise not visible in 2D documentation, are clearly shown in the VR environment. By visualizing these impacts interactively and immersivity, the framework closes the gap that exists between the contractor's technical assessment and the owner's perception. Stakeholders can see the entire extent of the demolition, reconstruction, and attributable delays and cost increases before any change has been implemented. It clears up communication and enables informed decisions. Consequently, it eliminates the possibility of any disputes, claims, or escalation to litigation as parties to the contract can assess the change order relying on a mutual understanding of the implications of the change order based on data.

Discussion and Implications

The study results suggest that the proposed BIM-based framework effectively and systematically evaluates the effect of the change order on the cost and time of the construction project. The integrated model leveraging Autodesk Revit, Primavera and Navisworks streamlines the quantitative and visual assessment of project changes, promoting improved decision transparency and accuracy in the project. The proposed system allows an integrated digital environment to assess changes in design compared to legacy systems where change orders are evaluated on the basis of patchy paperwork and delayed communications.

A notable aspect of the research is the addition of a decision-support layer based on VR during Stage 3 of the framework. The VR environment takes numerical and other outputs at complex stages and transforms them into an intuitive VR experience for various stakeholders. It holds particular significance in more complex construction projects, where owners and other non-technical decision-makers do not interpret 2D drawings or numerical schedules easily. A case study has shown a late-stage action, such as the transformation of a storage room into a bathroom, can have an unwelcome hidden impact. The result was not so much the dismantling of finished work, but a reconfiguration of hidden MEP and interruption of the flow of the construction process.

Through visualization using VR, these impacts became evident. Stakeholders can see how much reconstruction is needed and how it impacts cost and schedule. This goes to the heart of what is often a major source of conflict in construction: the difference between the owner's view of a change and the contractor's technical perspective. By closing this gap, the framework facilitates better and cooperative decision-making. As seen from the simulation, visualizing the order of change before execution reached consensus between parties involved without escalating to claims or disputes.

From a practical standpoint, there are valuable implications of the framework. For contractors, it is helpful for backing up claims regarding increasing costs or longer timeframe with factual and visual proof. It helps owners assess requests for changes objectively without assumptions and without insufficient information. BIM and VR integration allows a project team to proactively plan by testing out 'what if' scenarios before the decision is taken. This process of change order management shifts from reactive, often incurring delays and disputes to proactive and simulation based.

Even with all these benefits, the study has its limitations. The framework was verified through a simple low rise building model which may not be fully representative of the larger projects which consist of multiple stakeholders, negotiation of contracts and ever-changing site conditions. Moreover, the VR component could be improved upon using state-of-the-art immersive techniques such as a head-mounted display or real-time interaction through Navisworks-based simulation. There is scope for research in these aspects.

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Conclusions

This research developed a framework based on BIM to assess the effect of change orders on the cost and time of construction projects in a virtual simulation. The framework allows the integration of 3D modelling, scheduling and cost management into a single framework for simulating baseline and modified project conditions. One of the enhancements offered in this research is the inclusion of a new VR-based stage for assisting stakeholders in visualizing the impacts of change orders.

Utilizing the impact assessment framework as the guiding model in the case study demonstrated the ability to identify direct and indirect impacts for change orders. According to the results of the study, the modification scenario affected the project cost and schedule by increasing the deviation. Even a small change in scope can present itself in several activities. What is more important is the visualization based on VR skilfully captured the hidden impacts namely demolition and rework of constructed elements which are generally low-balled.

According to the study, the integration of BIM with VR-based visualization can improve the change order management process by enhancing communication, increasing transparency, and enabling data-driven decision-making. The framework enables stakeholders to see the full consequences of changes before implementation, thus reducing uncertainty and the likelihood of disputes and litigation.

The focus of future research ought to apply the framework to real projects, link the contractual and legal aspects of change management and develop the VR part through immersive technologies and real-time interaction.

Declaration

AI tools mainly Claud and ChatGPT were used for paraphrasing and word editing and modifications of some charts.

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