Design Change Management using BIM and Autodesk Construction Cloud

Hiba Rai[1,*], Lama saoud[2]

[1]Student of Building Information Modeling and Management Master Programme, Syrian Virtual University, Syria

[2] Lecturer in the Maters's Programme in Building Information Modeling and Management at the Syrian Virtual University, Damascus, Syria

Emails: heba_alllah_212139@svuonline.org; t_saoud@svuonline.org

Abstract

Efficient change order management is crucial in construction, particularly as project requirements evolve over time. In Syria's traditional construction process, lengthy gaps between planning, design, and execution significantly increase the likelihood of changes. This paper introduces a methodology that leverages Building Information Modeling (BIM) and cloud computing to enhance change management. A detailed case study of the Al-Eddekhar Housing project in Tartous was conducted, where Revit was employed for 3D modeling and Primavera for scheduling and cost estimation. Changes were meticulously analyzed using Revit's Model Compare tool, tracked through Primavera, and managed using Autodesk Construction Cloud for seamless document exchange and version control. The integration of BIM and cloud computing facilitates real-time collaboration between teams, significantly reducing errors, minimizing delays, and boosting overall project efficiency. The platform also preserves a historical record of project versions, enables visual comparisons of 3D models, and streamlines the approval process for change orders.

Keywords: BIM; Information; Technology; Integration; Cloud computing; Management

1. Introduction

During the execution phase of construction projects, numerous unforeseen challenges and problems can arise, some of which may originate from the design. Typically, the consulting or supervising engineer addresses these issues by issuing change orders to the contractor[1].The conventional construction process in Syria, characterized by significant time gaps between planning, design, and execution, substantially increases the likelihood of changes and change orders[2]. (Mustafa and Hariri, 2015). Effectively managing change orders is crucial in construction projects, as changes are a regular occurrence throughout the project's execution stages.

Project changes are particularly concerning when they result in increased project duration and costs. However, changes are sometimes necessary and unavoidable to enhance project performance, correct design errors, or adapt to site conditions[3]. The construction sector has greatly benefited from technological advancements amid the rapid growth of information technology, Building Information Modelling (BIM) encompasses more than just 3D engineering; it also integrates time as the fourth dimension and cost as the fifth dimension, along with detailed information about various building elements, such as wall types, spaces, air handling units, geospatial information, and recycling areas[4]and plays a role in facility management [5] [6]. However, there is a need for technology that improves communication and collaboration among all project stakeholders, a need that can be met by cloud computing technologies. Cloud computing represents one of the most significant transformations in information and communications technology in recent years, with its services experiencing significant diversity and wide-scale applications, devices, and users[7]. This technology includes a network of web-based platforms that allow users direct access to the cloud, enabling real-time collaboration and problem-solving] 8]. This research aims to propose a methodology for change management using BIM and cloud tools.

DOI: https://doi.org/10.54216/IJBES.100105
Received: March 05, 2024 Revised: August 11, 2024 Accepted: November 12, 2024

2. Literature review

Shaban and Omran (2023) developed a system to manage change orders in the construction industry, utilizing BIM technology and cloud computing to allow real-time management of change orders from any location, whether on-site or off-site[8].BIM serves as an effective platform where all stakeholders work together to deliver more innovative project[9].This study define BIM as the modeling technology and the set of associated processes used to create and analyze building models. Additionally, it facilitates communication among the involved parties to identify necessary and feasible modifications to these model[10]. Saleh et al. (2024) highlighted BIM as a crucial component for achieving smart sustainable cities, noting that BIM, combined with AI and IoT, optimizes data integration and management, facilitating efficient urban planning and construction processes[11].. Wong et al. (2014) reviewed the use of BIM in cloud environments, focusing on building lifecycle management, though they did not address change order management[12].. Ahmed et al. (2018) developed a BIM performance improvement framework for Syrian AEC companies, addressing key performance metrics and providing guidelines tailored to the local context for effective BIM implementation[13].. Elhendawi et al. (2020) proposed strategies to encourage BIM adoption among non-users in the AEC industry, identifying key motivators and barriers and offering targeted strategies to facilitate broader acceptance. And offering targeted strategies to facilitate broader acceptance [ ]14.Many studies have focused on managing design changes within a BIM environment. (Hassan et.al. 2016).[15] proposed a method for managing Design Changes within Building Information Models by Using Design Structure Matrix. The study. [16] proposed a method for Tracking the propagation of design changes within a building information modeling environment. A research proposed. [17] integration of DSM with BIM to support the visual representation of predicting change within projects by utilizing process quality control checklists and improving quality management through the Autodesk Construction Cloud platform, which integrates BIM and cloud computing. Their findings indicated that this approach significantly improved the efficiency and effectiveness of quality management during the execution phase [18]. Moayeri (2017) introduced the BIM-Change model to visualize the effects of design changes on project duration and cost. This model was implemented in BIM-Change software, which includes features for change verification, ripple effect analysis, room aggregation, time impact assessment, cost impact analysis, and data filtering[19] . Cheng et al. (2012) explored the benefits and challenges of employing cloud computing in construction projects. They introduced a cloud-based collaborative model designed to improve project collaboration [20,21,22,23,24,25.]

3. Research Methodology

- Surveying relevant studies.
- Proposing a framework that utilizes BIM tools and cloud computing to improve the management of changes.
- Case Study: Interview specialized engineers to monitor changes and assess the proposed framework' effectiveness.

4. Proposed Framework for Design Change Management

Figure-1 shows **Proposed Framework for Design Change Management**

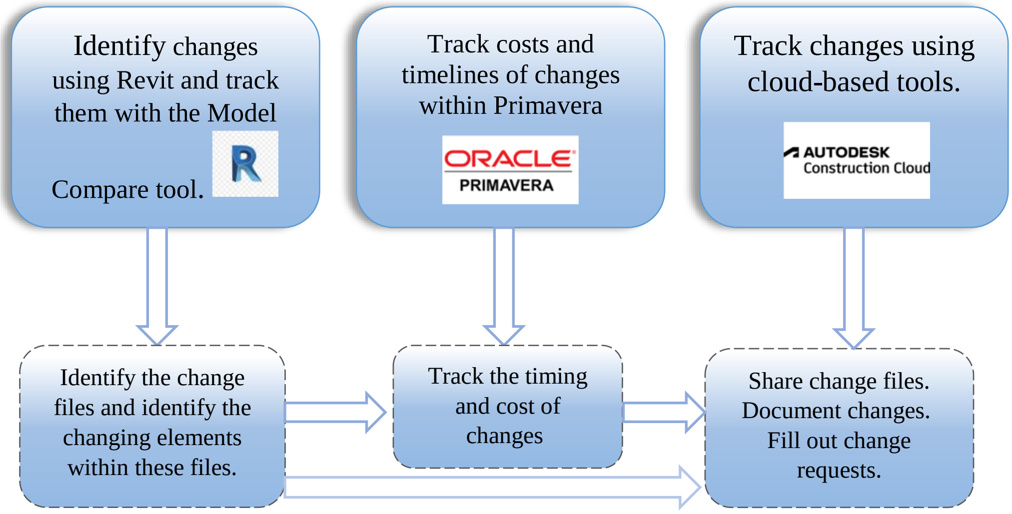


Figure 1. Proposed Framework for Design Change Management

DOI: https://doi.org/10.54216/IJBES.100105
Received: March 05, 2024 Revised: August 11, 2024 Accepted: November 12, 2024

5. Case Study

Change Monitoring and Management at Al-Eddekhar Residential Building Project in Tartous.The project implemented three stages: The first stage was monitoring Changes with Revit's Model Compare Tool.The second stage is tracking Cost and Schedule Modifications with Primavera Software The third stage is managing Change Tracking through Cloud Computing Technologies

5.1 Identify and track Design Changes

For this case study, we interviewed a group of specialized engineers to find out about project changes. While reviewing the plans created with Revit, we found that the supervising team noticed several mistakes and suggested changes that would benefit the owner.

These changes included:

- **Change 1**: Replacement of Exterior Paint with Decorative Stone As shown in Figure 2
- **Change 2:** Modification of the Architectural Layout of the First. As shown in Figure 3
- **Change 3:** :Replace stone with aluminum facades as shown in Figure 4)
- **Change 4** :Addition of Bituminous Insulation Rolls to the Final Roof Covering As shown in Figure 5
- **Change 5** :Replacement of Marble with ceramic tiles As shown in Figure 6

Design Change Tracking Using Revit (Model Compare Tool): The Model Compare tool for Revit is essential for comparing models element-by-element and parameter-by-parameter

The building has been modeled

Figure 2. Replacement of exterior paint with stone

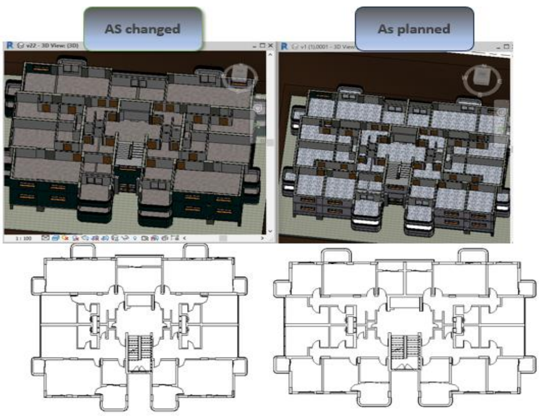
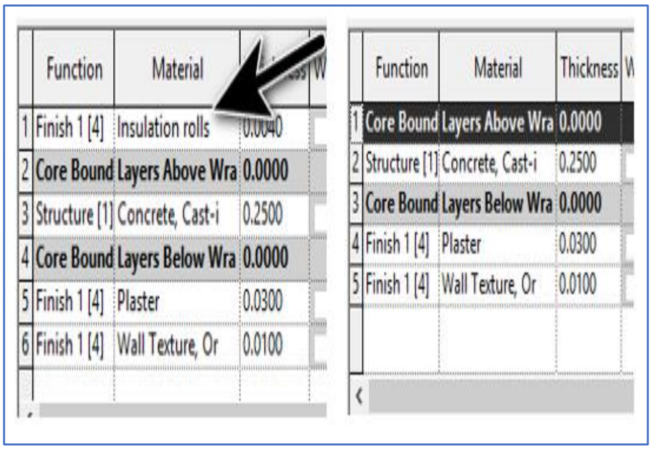


Figure 3. Modification of the Architectural Layout of the First floor

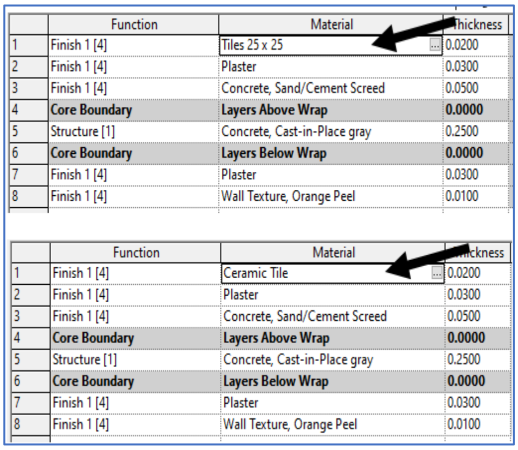
Figure 4. Replace stone with aluminum facades

DOI: https://doi.org/10.54216/IJBES.100105
Received: March 05, 2024 Revised: August 11, 2024 Accepted: November 12, 2024



	Function	Material	Thickness
1	Finish 1 [4]	Insulation rolls	0.0040
2	Core Bound	Layers Above Wra	0.0000
3	Structure [1]	Concrete, Cast-i	0.2500
4	Core Bound	Layers Below Wra	0.0000
5	Finish 1 [4]	Plaster	0.0300
6	Finish 1 [4]	Wall Texture, Or	0.0100

	Function	Material	Thickness
1	Core Bound	Layers Above Wra	0.0000
2	Structure [1]	Concrete, Cast-i	0.2500
3	Core Bound	Layers Below Wra	0.0000
4	Finish 1 [4]	Plaster	0.0300
5	Finish 1 [4]	Wall Texture, Or	0.0100



	Function	Material	Thickness
1	Finish 1 [4]	Tiles 25 x 25	0.0200
2	Finish 1 [4]	Plaster	0.0300
3	Finish 1 [4]	Concrete, Sand/Cement Screed	0.0500
4	Core Boundary	Layers Above Wrap	0.0000
5	Structure [1]	Concrete, Cast-in-Place gray	0.2500
6	Core Boundary	Layers Below Wrap	0.0000
7	Finish 1 [4]	Plaster	0.0300
8	Finish 1 [4]	Wall Texture, Orange Peel	0.0100

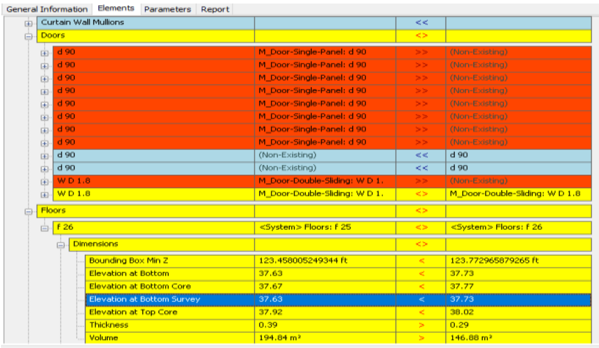
	Function	Material	Thickness
1	Finish 1 [4]	Ceramic Tile	0.0200
2	Finish 1 [4]	Plaster	0.0300
3	Finish 1 [4]	Concrete, Sand/Cement Screed	0.0500
4	Core Boundary	Layers Above Wrap	0.0000
5	Structure [1]	Concrete, Cast-in-Place gray	0.2500
6	Core Boundary	Layers Below Wrap	0.0000
7	Finish 1 [4]	Plaster	0.0300
8	Finish 1 [4]	Wall Texture, Orange Peel	0.0100

Figure 5. Addition of Bituminous Insulation Rolls to the the final roof covering

Figure 6. Replacement of marble with ceramic tiles

- **Design Change Tracking Using Revit (Model Compare Tool):**

It alerts users to missing elements or discrepancies between models and displays results on a comparison page. The red color indicates differences between files due to deletions, the cyan color signifies differences due to additions, and the yellow color highlights variations in parameters between elements.



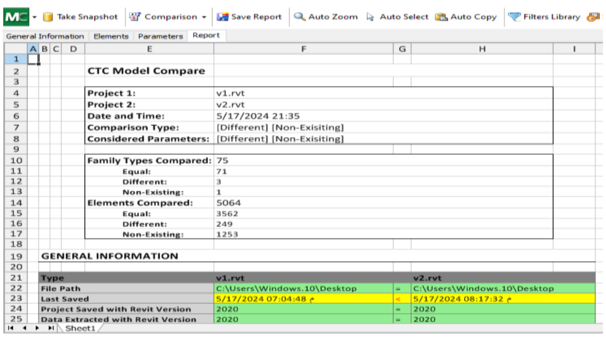


Figure 7. Comparison of Two Files in Terms of elements

Figure 8. The excel report details the comparison results

5.2 Track costs and timelines of changes within Primavera:

After making design modifications and obtaining quantity changes through the model compare tool, we calculated the impact of these changes on the project's cost and duration using Primavera.

Change 1: Replacement of Exterior Paint with Decorative Stone, **Change 3**: Replace stone with aluminum facades:

As an illustration, Figure 10 shows the changes 1&3 that have occurred and how to track the cost and time of the change in Primavera."

Activity ID	Activity Name	Original Duration	Start	Finish	Budgeted Total Cost
B0-2.3.12	Exterior cladding works	80	20-Sep-26	22-Dec-26	432,960,000 SYP
A5980	Exterior painting works	60	13-Oct-26	22-Dec-26	173,440,000 SYP
A5990	Exterior plastering works	40	30-Sep-26	25-Nov-26	99,520,000 SYP
A5970	Aluminium works	32	20-Sep-26	27-Oct-26	160,000,000 SYP

Figure 9. The cost &time before modifying the external cladding works.

DOI: https://doi.org/10.54216/IJBES.100105
Received: March 05, 2024 Revised: August 11, 2024 Accepted: November 12, 2024

Activity ID	Activity Name	Original Duration	Start	Finish	Budgeted Total Cost
B0-2.3.12	Exterior cladding works	120	13-Oct-26 A	22-Dec-26	664,000,000 SYP
A5980	Exterior stone works	120	13-Oct-26 A	22-Dec-26	264,000,000 SYP
A5970	Aluminium works	60	13-Oct-26	22-Dec-26	400,000,000 SYP

Figure 10. The cost& time after modifying the external cladding works.

5.3 Tracking Changes Using Autodesk Construction Cloud:

Autodesk Construction Cloud (ACC) allows users to effectively and easily track changes in construction projects by managing and documenting all changes that occur in the project. This includes changes in design, modifications to specifications, or any other alterations. It tracks the history of changes, identifies the responsible parties, and ensures that all stakeholders are informed of the new updates. The following figures illustrate the mechanism and results of use Autodesk Construction Cloud:

Figure (11) illustrates file sharing through the platform and selecting the versions to be compared. Figure (12) presents the results of the comparison process, including the outcomes for the deleted elements in the category of walls and the outcomes for the added elements in the category of slabs. Figure-(13)- displays the differences in information between versions, including the thermal transmittance coefficient, thermal mass, thermal resistance, and the location and dimensions of the element ,Figure- (14) – shows a sample change order after filling

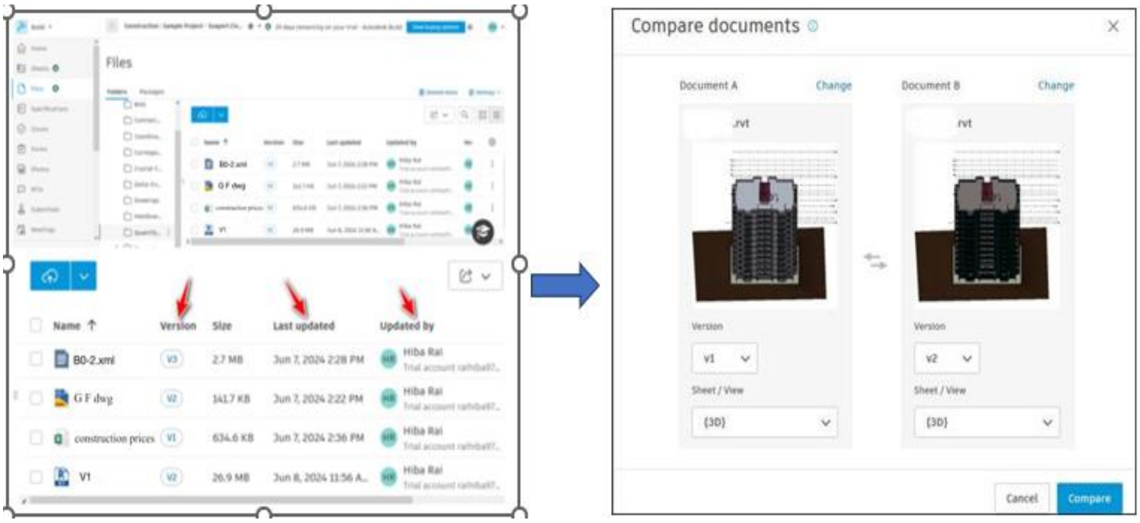


Figure 11. File sharing through the platform and selecting the versions to be compared.

Figure 12. The results of the comparison process

DOI: https://doi.org/10.54216/IJBES.100105
Received: March 05, 2024 Revised: August 11, 2024 Accepted: November 12, 2024

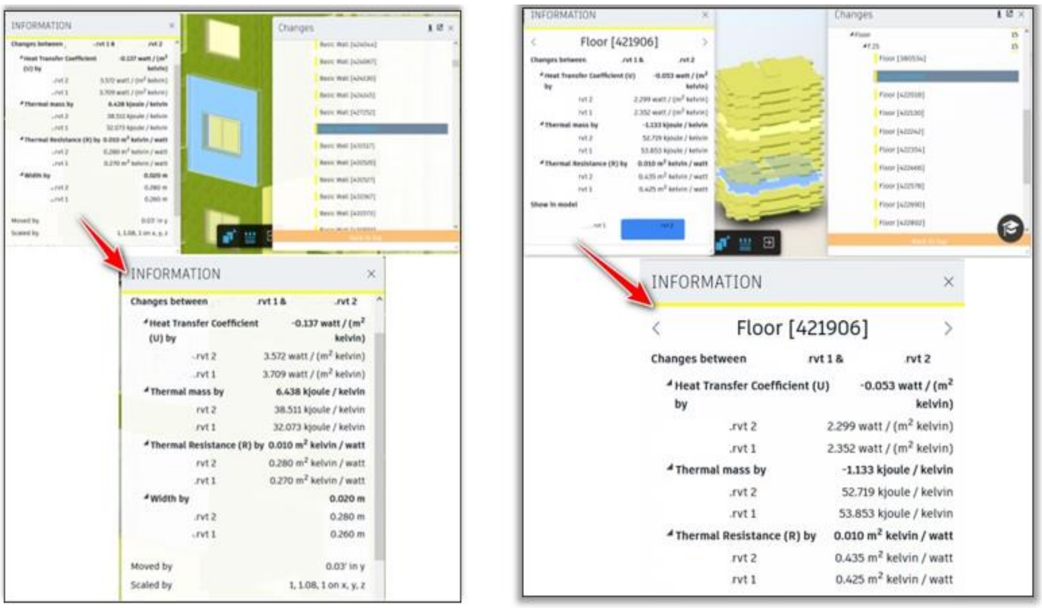


Figure 13. The differences in information between versions

#	Description of change	Modifiy Date	before change		after change		Difference	Difference in	owner	consultant
			duration	cost(s.p)	duration	cost(s.p)	in duration	cost	ALI AMIN	Hiba Rai
1	Replacement of Exterior Paint with Decorative Stone	01/04/2024	80	432,960,000	120	664,000,000	40	231,040,000		
2	Modification of the Architectural Layout of the First	15/04/2024	58	322,485,000	48	304,114,200	-10	-18,370,800		
3	Replace stone with aluminium facades	02/05/2024	0	0	10	416,340,000	10	416,340,000		
4	dition of Bituminous Insulation Rolls to the Final Roof Cover	07/05/2024	0	0	9	36,100,000	9	36,100,000		
5	Replacement of Marble with ceramic tiles	18/05/2024	7	810,700,000	7	1,125,520,000	0	314,820,000		
Total								979,929,200		

Figure14. A sample change order after filling.

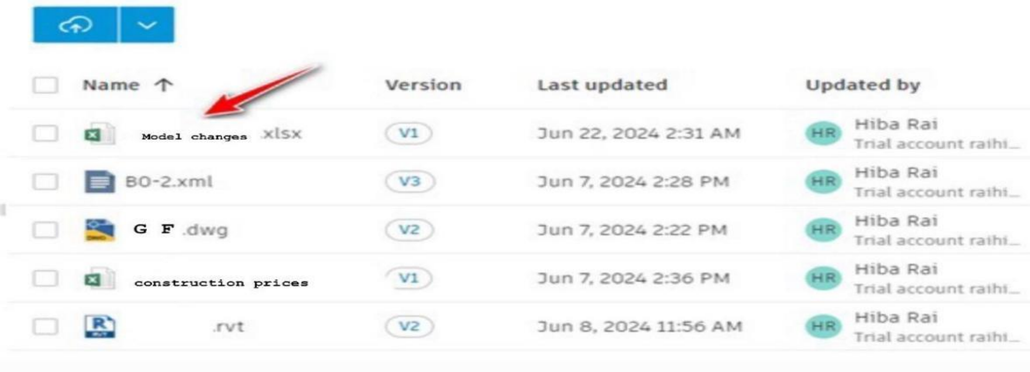


Figure 15. The model sharing via the ACC platform.

5. Results and discussions

Change orders are an inevitable aspect of construction projects, often impacting timelines, costs, and scopes. BIM technologies facilitate the efficient implementation of design modifications, instantly updating quantity schedules to aid in tracking changes related to time and budget. **2.** The Model Compare tool in Revit enables quick and accurate detection of changes between project versions, facilitating the comparison of elements and properties while generating detailed reports. **3.** Integrating BIM and cloud computing allows stakeholders to access virtual construction data and changes in real-time. **4**. This real-time collaboration empowers technical and administrative teams to make quick, informed decisions, improving change management efficiency and reducing errors and delays.**5.**Autodesk Construction Cloud (ACC) enhances visual comparison between 3D models through color-

DOI: https://doi.org/10.54216/IJBES.100105
Received: March 05, 2024 Revised: August 11, 2024 Accepted: November 12, 2024

coding features and allows for the comparison of element properties.**6.** Project management software like Primavera provides accurate estimations and tracking of project costs and durations, helping to minimize budget overruns and contractual delays.**7**.In the case study project, changes resulted in an increased cost of 979,879,700 Syrian Pounds. **8**. Using external cladding stone instead of paint reduced the thermal transmittance coefficient of external walls by 0.137 Watt/(m² Kelvin), increased thermal mass by 6.438 kJoule/Kelvin, and increased thermal resistance by 0.137 m² Kelvin/Watt. **9**. Similarly, using ceramic for floor cladding reduced the thermal transmittance coefficient of tiles by 0.053 Watt/(m² Kelvin), decreased thermal mass by 1.133 kJoule/Kelvin, and increased thermal resistance by 0.010 m² Kelvin/Watt.

6. Conclusion

We have developed a methodology that combines Building Information Modeling (BIM) with the Autodesk Construction Cloud (ACC) to significantly enhance the management of design changes in construction projects. This approach was implemented in the Al-Eddekhar Housing project, where BIM and ACC were used to monitor design changes, cost adjustments, and schedule modifications, ensuring that the project stayed within its time and budget constraints. The results showed that this methodology is highly effective in improving collaboration, reducing errors, and minimizing delays. By modernizing change management processes and enhancing project management practices, the integration of BIM and cloud computing provides substantial benefits in efficiency, collaboration, and control. It is recommended that this research be further expanded to increase its applicability and address any potential limitations. Future studies could explore the integration of additional advanced technologies to enhance the efficiency and effectiveness of BIM and cloud-based approaches in different construction contexts.

References

[1] Shaban, M. H. (2006). Claims in projects due to design errors and change orders. Journal of Construction, (9), Saudi Arabia.

[2] Mustafa, M., & Al-Hariri, M. (2015). A study of the causes of change orders and how to mitigate their negative impact on construction projects. Tishreen University Journal for Research and Scientific Studies, 37.(3)

[3] Shaban, M. (2011). Change order management in construction projects. Journal of Structural Engineering, 15(4), 123-137.

[4] Omran, J., & Haddad, G. (2014). Comparison of Building Information Modeling (BIM) systems with traditional CAD systems in the design phase. Tishreen University Journal for Research and Scientific Studies, 36(4), Syria.

[5] Salameh, D. and Saoud, L., 2024. Proposal for temporary safety facilities for fall protection using 4DBIM to meet OSHA standards. Full Length Article, 8(1), pp.58-8.

[6] Shbeeb, J. and Saoud, L., 2023. Enhancing facility management for buildings using BIM (case study: model of a medical building). International Journal of BIM and Engineering Science, 7(2), pp. 08-24. Doi :https://doi.org/10.54216/IJBES.070201

[7] Khalil, T., & Khalil, A. (n.d.). Cloud computing: Reality and challenges. In Humanities and Pure Sciences Conference: A Vision towards Contemporary Education and Teaching, Duhok University, Iraq.

[8] Shaban, M., & Omran, A. (2023). Development of a methodology for managing change orders in construction projects using cloud computing [Master's thesis]. Al-Baath University, Syria.

[9] Shker, Y. and L. Saoud (2023). "The Integration between Building Information Modelling and Scrumban. Case Study: FD3 Commercial Building in Damascus." International Journal of BIM and Engineering Science.

[10] Shaban, M.H. and Elhendawi, A., 2018. Building Information Modeling in Syria: Obstacles and requirements for implementation. International Journal of BIM and Engineering Science, 1(1), pp.42-64.

[11] Saleh, F., Elhendawi, A., Darwish, A.S. and Farrell, P., 2024. A Framework for Leveraging the Incorporation of AI, BIM, and IoT to Achieve Smart Sustainable Cities. Journal of Intelligent Systems and Internet of Things, 11(2), pp.75-84.

[12] Chong, H., Wong, J.S., Wang, X., 2014. "An explanatory case study on cloud computing applications in the built environment". Automation in Construction 44, pp. 152–162. doi: 10.1016/j.autcon.2014.04.010

[13] Ahmed, S., Dlask, P., Selim, O. and Elhendawi, A., 2018. BIM performance improvement framework for Syrian AEC companies. International Journal of BIM and Engineering Science, 1(1), pp.21-41.

DOI: https://doi.org/10.54216/IJBES.100105
Received: March 05, 2024 Revised: August 11, 2024 Accepted: November 12, 2024

[14] Elhendawi, A., Omar, H., Elbeltagi, E. and Smith, A., 2020. Practical approach for paving the way to motivate BIM non-users to adopt BIM. International Journal of BIM and Engineering Science, 2(2).

[15] Hassan, B., Omran, J. and Saoud, L., 2016. Management of Design Changes within Building Information Models by Using Design Structure Matrix. Tishreen University Journal-Engineering Sciences Series,, 38(3).

[16] Omran, J., Hassan, B., Saoud, L. (2017). "Tracking the Spread of Design Changes within a Building Information Modeling Environment," Tishreen University Journal for Research and Scientific Studies - Engineering Sciences Series, Vol. 39, No. 2.

[17] Saoud, L. A., J. Omran, B. Hassan, T. Vilutienė and A. Kiaulakis (2017). "A method to predict change propagation within building information model." Journal of Civil Engineering and Management 23(6): 836-846.

[18] Shaban, M., B. Al-Hassan and A. S. Mohamad (2024). "Digital transformation of quality management in the construction industry during the execution phase by integration of building information modeling (BIM) and cloud computing." Building Engineering 2(1): 1132-1132.

[19] Moayeri, Valeh. 2017. 'Design change management in construction projects using Building Information Modeling (BIM)', Canada: Concordia University.

[20] Cheng. J.C and Kumar. B, (2012), "Cloud Computing Support for Construction Collaboration", Mobile and Pervasive Computing in Construction, pp. 237.

[21] Saleh, F., Elhendawi, A., Darwish, A.S. and Farrell, P., 2024. An ICT-based Framework for Innovative Integration between BIM and Lean Practices Obtaining Smart Sustainable Cities. Fusion: Practice and Applications (FPA), 68

[22] Elhendawi, A.I.N., 2018. Methodology for BIM Implementation in KSA in AEC Industry. Master of Science MSc in Construction Project Management), Edinburgh Napier University, UK

[23] Elhendawi, A., Smith, A. and Elbeltagi, E., 2019. Methodology for BIM implementation in the Kingdom of Saudi Arabia. International Journal of BIM and Engineering Science, 2(1).

[24] Evans, M., Farrell, P., Elbeltagi, E., Mashali, A. and Elhendawi, A., 2020. Influence of partnering agreements associated with BIM adoption on stakeholder's behaviour in construction mega-projects. International Journal of BIM and Engineering Science, 3(1), pp.1-20

[25] Elgendi, A.F., Elhendawi, A., Youssef, W.M.M. and Darwish, A.S., 2021. The Vulnerability of the Construction Ergonomics to Covid-19 and Its Probability Impact in Combating the Virus. International Journal, 4(1), pp.01-19.

DOI: https://doi.org/10.54216/IJBES.100105
Received: March 05, 2024 Revised: August 11, 2024 Accepted: November 12, 2024