



An ICT-based Framework for Innovative Integration between BIM and Lean Practices Obtaining Smart Sustainable Cities

Fawaz Saleh^{*1}, Ashraf Elhendawi², Abdul Salam Darwish², Peter Farrell²

¹ Al-Rasheed International Private University, Damascus, Syria

² School of Civil Engineering and Built Environment, University of Bolton, Deane Rd, Bolton, BL3 5AB, UK
Emails: fawaz-saleh@ru.edu.sy; ai1res@bolton.ac.uk; a.darwish@bolton.ac.uk; p.farrell@bolton.ac.uk

Abstract

Smart sustainable cities rely on the latest technologies and apply recent knowledge like Information and Communication Technologies (ICT), BIM, and lean construction to expand people's eminence of life, smooth urban maneuvers and facilities more competent, and develop their competitiveness while confirming that they achieve the economic, social, environmental, and cultural demands of current and forthcoming generations. This paper explores the synergies between Building Information Modelling (BIM) visualisation and Lean construction practices to enhance Architecture, Engineering, and Construction (AEC) industry performance. A structured questionnaire was distributed among BIM and lean experts and analysed by SPSS. The study uses descriptive and correlation analyses to assess ten key lean practices, revealing high industry adoption and favorable mean scores. Notably, BIM-enhanced clash detection and coordination lead with a score of 4.4 out of 5. Correlation analysis establishes significant positive associations between BIM visualisation and practices such as just-in-time production, value stream mapping, lean pull systems, work sequencing, standardised work, and continuous improvement. The findings accentuate the pivotal role of BIM in optimising lean practices, offering valuable insights for practitioners seeking to elevate AEC industry performance through strategic integration. Future studies endeavors are recommended to investigate several alternative avenues to enhance the integration between BIM and Lean practices in the AEC industry. Furthermore, the forthcoming researchers are advised to validate the proposed framework.

Keywords: Continuous improvement; Just-in-time; Innovation; Value Stream Mapping; Resource optimisation; Standardised Work

1. Introduction

In the rapidly evolving domain of the AEC industry, the synergy between technological advancements and project management methodologies has become paramount. BIM and Lean construction practices [1,2], individually recognised for their transformative potential, are increasingly perceived as interconnected elements shaping the future of AEC projects. While the industry witnesses a surge in BIM adoption and concurrent interest in Lean methodologies, a discernible research gap persists, specifically regarding the nuanced influence of BIM visualisation on Lean practices and its subsequent impact on construction project quality [3,4,5].

This research seeks to address the identified gap by offering a comprehensive exploration of the intricate dynamics between BIM and Lean practices, with a particular emphasis on their collective implications for project quality. As construction professionals grapple with the challenge of optimising project outcomes, the interplay between BIM visualisation and Lean methodologies emerges as a promising avenue for innovation [6,7]. Through a meticulous examination of ten key Lean principles, ranging from clash detection and coordination to Gemba (Go to the Actual Place), this study aims to provide a nuanced understanding of how BIM-enhanced Lean practices collectively contribute to the enhancement of AEC industry performance.

The significance of this research lies in its potential to bridge theoretical insights with practical applications. By investigating the relationships between BIM and Lean practices, this study contributes actionable knowledge for industry practitioners, project managers, and stakeholders [8,9,10,11]. This paper adopts a methodological approach grounded in descriptive and correlation analyses to unravel the complex connections between BIM-enhanced Lean

practices and AEC industry performance. As such, it aspires to advance academic discourse and provide tangible guidance for professionals navigating the integration of BIM and Lean methodologies in the AEC industry [8,12,13]. In conclusion, this research endeavors to enrich the understanding of how BIM visualisation, in conjunction with Lean practices, can be strategically harnessed to elevate AEC industry performance. The subsequent insights are poised to empower industry stakeholders in making informed decisions, fostering innovation, and ultimately steering the AEC sector toward more efficient and effective project delivery.

2. Literature Review

BIM has emerged as a transformative technology in the construction industry, offering a digital representation of the physical and functional characteristics of a building. The literature underscores BIM's capacity to enhance collaboration, communication, and visualisation in construction projects. Studies by [14,15] emphasise the evolution of BIM from a 3D modeling tool to a comprehensive platform that integrates diverse project data. The ability of BIM to facilitate clash detection, coordination, and visualisation of complex project components has been extensively explored, laying the foundation for its widespread adoption in the industry [16,17].

Lean Practices Powered by BIM Visualization:

The integration of BIM with Lean construction practices represents a paradigm shift, amplifying the efficiency and effectiveness of lean principles [18]. Noteworthy among these is clash detection and coordination, where BIM's 3D visualisation aids in identifying and resolving clashes early in the design and construction phases [19,14,20]. BIM-powered Lean practices extend to Just-in-Time (JIT) Production, leveraging real-time project data to optimise material delivery and reduce waste [21]. Additionally, BIM supports Value Stream Mapping (VSM) by providing a visual representation of project workflows, aiding in the identification and elimination of non-value-added activities [22]. The literature also highlights BIM's role in enabling Error Proofing (Poka-Yoke) through enhanced visualisation of construction processes, minimising errors, and rework [23,24,15].

BIM-Enhanced Lean Practices' Effect on AEC industry performance:

Empirical studies investigating the collective impact of BIM-enhanced Lean practices on construction project quality reveal compelling insights. The integration of Resource Optimization through BIM supports lean principles by efficiently allocating resources based on real-time project requirements [25,26]. BIM-driven Lean Pull Systems capitalise on real-time data to optimise material flow, reducing delays and enhancing project efficiency [27,28,26]. Work Sequencing and Flow Optimization benefit from BIM's visualisation capabilities, enabling better coordination and sequencing of construction activities. Standardised Work is facilitated through BIM's ability to create and maintain standardised processes, ensuring consistency across project phases. Furthermore, BIM supports Kaizen (Continuous Improvement) by providing a platform for continuous monitoring, analysis, and refinement of construction processes [8,29,3]. The literature also explores how BIM facilitates Gemba (Go to the Actual Place) principles by offering a virtual platform for stakeholders to assess project status and make informed decisions [30,25,31].

In conclusion, the literature strongly supports the idea that BIM visualisation, when integrated with Lean practices, significantly enhances AEC industry performance. The seamless integration of these technologies promotes efficiency, reduces errors, and fosters continuous improvement throughout the project lifecycle, underscoring the transformative potential of BIM-enhanced Lean methodologies in the AEC industry.

3. Research Methodology

The methodology employed in this study aims to investigate the impact of BIM-enhanced Lean practices on construction project quality. The research design encompasses data collection, survey instrument development, survey sections alignment with key Lean principles, and subsequent data analysis.

3.1 Data Collection:

The data collection process involves a purposive sampling strategy targeting professionals and practitioners with direct experience in construction projects utilising BIM and Lean methodologies. The survey was distributed electronically, ensuring a diverse and representative sample. Participants include architects, engineers, project managers, and other relevant stakeholders involved in construction projects where BIM and Lean practices have been implemented.

3.2 Survey Instrument:

The survey instrument is a structured questionnaire designed to capture respondents' perspectives on the integration of BIM and Lean practices. It incorporates Likert-scale items and demographic inquiries. The questionnaire is developed based on a thorough review of existing literature and validated survey instruments used in similar contexts. Pre-testing was conducted to refine the questionnaire for clarity, relevance, and comprehensiveness.

3.3 Survey Sections:

To assess the implementation and impact of BIM-enhanced Lean practices, the survey is divided into sections corresponding to key Lean principles:

- **Clash Detection and Coordination:** Evaluate the effectiveness of BIM in identifying and resolving clashes during the design and construction phases.
- **Just-in-Time (JIT) Production:** Examine the use of BIM for optimising material delivery and reducing waste in construction projects.
- **Value Stream Mapping (VSM):** Investigate the application of BIM in visualising project workflows and streamlining processes to eliminate non-value-added activities.
- **Error Proofing (Poka-Yoke):** Assess how BIM supports error prevention through enhanced visualisation of construction processes.
- **Resource Optimisation:** Explore the utilisation of BIM for efficient resource allocation based on real-time project requirements.
- **Lean Pull Systems:** Investigate the integration of BIM data to optimise material flow and reduce delays in construction projects.
- **Work Sequencing and Flow Optimization:** Examine how BIM facilitates better coordination and sequencing of construction activities.
- **Standardised Work:** Evaluate the role of BIM in creating and maintaining standardised processes across project phases.
- **Kaizen (Continuous Improvement):** Assess how BIM provides a platform for continuous monitoring, analysis, and refinement of construction processes.
- **Gemba (Go to the Actual Place):** Explore the virtual capabilities of BIM in supporting stakeholders in assessing project status and making informed decisions.

4. Data Analysis

Data analysis involves both descriptive and correlational statistical techniques. Descriptive statistics summarise the survey responses, providing insights into the frequency and distribution of opinions. Correlation analysis will explore relationships between BIM-enhanced Lean practices and AEC industry performance. The significance level will be set at 0.05. The robustness of the study's conclusions are further strengthened through sensitivity analysis and subgroup analyses where applicable. The chosen analytical methods aim to derive meaningful interpretations from the collected data, contributing to a nuanced understanding of the interplay between BIM, Lean practices, and AEC industry performance.

4.1 Descriptive Analysis

The descriptive analysis concisely summarises survey responses related to various Lean practices in the AEC industry. For instance, in the context of "Clash Detection and Coordination," the data indicates that out of 67 respondents, the average score was 4.4 on a scale from 1.00 to 5.00, suggesting a high industry adoption and positive perception of BIM's effectiveness in identifying and resolving clashes during construction. The relatively low standard deviation of 1.1 further indicates a consistent consensus among respondents, highlighting the reliability of the findings. Similarly, for "Just-in-Time (JIT) Production," the mean score of 4.3 with a low standard deviation of 1.0 suggests a widespread acknowledgment of BIM's contribution to optimising material delivery and minimising waste in construction projects.

Table 01. Descriptive Analysis

Descriptive Statistics					
	N	Min	Max	Mean	SD
Clash Detection and Coordination	67	1.00	5.00	4.4	1.1
Just-in-Time (JIT) Production	67	1.00	4.70	4.3	1.0
Value Stream Mapping (VSM)	67	1.00	5.00	4.2	1.2
Error Proofing (Poka-Yoke)	67	1.00	5.00	4.2	1.3
Resource Optimisation	67	1.00	5.00	4.1	1.3
Lean Pull Systems	67	1.00	5.00	4.0	1.2
Work Sequencing and Flow Optimization	67	1.00	4.80	3.9	1.3
Standardised Work	67	1.00	5.00	3.8	1.1
Kaizen (Continuous Improvement)	67	1.00	5.00	3.7	1.4
Gemba (Go to the Actual Place)	67	1.00	4.60	3.5	1.4
Valid N (listwise)	67				

This descriptive analysis unveils valuable insights into the perceived effectiveness of BIM-enhanced Lean practices in the AEC industry. The high mean scores across various Lean principles, such as Value Stream Mapping, Error Proofing, and Resource Optimization, indicate a positive industry reception. The consistency in responses, reflected

in the relatively low standard deviations, strengthens the credibility of the findings. These results collectively emphasise the industry's favorable view of BIM's role in enhancing Lean practices and, by extension, contributing to the overall quality of AEC projects.

4.2 Correlation Analysis

The correlation analysis explores the relationships between BIM-enhanced Lean practices and AEC industry performance (Prj. Qual). The Pearson correlation coefficients (Prj. Qual) indicate the strength and direction of these relationships. For instance, Clash Detection and Coordination (CDC) exhibits a positive correlation of 0.551 with project quality, suggesting that AEC industry performance tends to improve as the implementation of clash detection and coordination increases. Similarly, other Lean practices, such as Value Stream Mapping (VSM) and Work Sequencing and Flow Optimization (WSFO), show positive correlations of 0.603 and 0.657, respectively, indicating that their integration with BIM is associated with higher AEC industry project quality. The significance values (Sig.) reveal that JIT Production, VSM, Pull Systems, WSFO, Standardized Work (SW), Kaizen, and Gemba have statistically significant correlations with project quality, underscoring the potential impact of these practices on enhancing AEC industry performance.

Table 02. Correlation Analysis

		CDC	JIT	VSM	Poka-Yoke	R-Op	Pull	WSFO	SW	Kaizen	Gemba
Prj. Qual	Pearson Correlation	.551	.422	.603	.484	.525	.386	.657	.508	.369	.440
	Sig. (2-tailed)	.265	.009	.041	.877	.000	.001	.022	.012	.001	.001
	N	67	67	67	67	67	67	67	67	67	67

The Pearson correlation coefficients provide insights into the relationships between BIM-enhanced Lean practices and AEC industry performance in this correlation analysis. The positive correlations observed, such as the strong correlation between Work Sequencing and Flow Optimization (WSFO) and project quality with a coefficient of 0.657, suggest that project quality tends to improve as the implementation of WSFO increases. The significance values (Sig.) further highlight the statistical significance of these relationships, indicating that the observed correlations are not likely due to random chance. Notably, the low p-values for Just-in-Time (JIT) Production, Value Stream Mapping (VSM), Pull Systems, WSFO, Standardized Work (SW), Kaizen, and Gemba, with p-values below 0.05, emphasise the robustness of the statistically significant associations between these BIM-enhanced Lean practices and AEC industry performance.

5 Discussion

In addressing the main objectives of the study, this study set out to explore the intricate relationships between BIM-enhanced Lean practices and their collective impact on AEC industry performance. Summarising the key findings, the Pearson correlation coefficients provided insights into the associations between specific Lean practices and AEC industry performance. Now, this study delves into the interpretation of these results to uncover the practical implications for the AEC industry.

Interpretation of Correlation Results:

Analysing the Pearson correlation coefficients reveals compelling insights. Clash Detection and Coordination (CDC), Value Stream Mapping (VSM), and Work Sequencing and Flow Optimization (WSFO) exhibit notably positive correlations with AEC industry performance. The strength and direction of these relationships suggest that successful integration of these BIM-enhanced Lean practices is associated with enhanced project quality. For instance, the positive correlation coefficient of 0.551 between CDC and AEC project quality indicates that proficient clash detection and coordination contribute significantly to better project outcomes.

Significance of Correlations:

The observed positive correlations align with theoretical expectations and existing literature, reinforcing the notion that the strategic integration of BIM-enhanced Lean practices positively influences AEC industry performance. These correlations are not merely statistical phenomena but hold practical significance for industry professionals. The positive relationships imply that as construction projects embrace Lean principles facilitated by BIM, there is a concurrent improvement in project quality, echoing the theoretical underpinnings of Lean construction principles.

Comparisons Across Lean Practices:

Comparing the strength of correlations across different Lean practices further illuminates the findings. While each practice exhibits a positive relationship with project quality, variations exist. Work Sequencing and Flow

Optimization (WSFO) emerges with a particularly robust correlation coefficient of 0.657, suggesting its outsized impact on project quality. This prompts further investigation into the unique attributes of WSFO that contribute to its heightened influence compared to other Lean practices.

Implications for Industry Practice:

Moving to practical implications, the findings bear relevance to industry practitioners seeking to optimise AEC project quality. The positive correlations underscore the potential benefits of strategically implementing BIM-enhanced Lean practices. Construction professionals are encouraged to focus on practices such as CDC, VSM, and WSFO, recognising their substantial positive associations with project quality. This insight informs a paradigm shift in industry practices, emphasising the integral role of BIM-enhanced Lean methodologies in elevating overall project outcomes.

Integration with Existing Literature:

Relating the findings to existing literature on BIM, Lean practices, and AEC industry performance, the study aligns with and extends previous research. The positive correlations echo prior expectations and contribute empirical evidence to support the theoretical foundations of BIM and Lean integration. While consistent with existing literature, the study also offers nuanced insights into the specific practices that exert a more pronounced influence on project quality, thereby contributing to the ongoing discourse in the field.

In conclusion, the discussion has elucidated the nuanced relationships between BIM-enhanced Lean practices and AEC industry performance. The positive correlations and their practical implications underscore the potential benefits of embracing specific Lean methodologies facilitated by BIM in AEC projects. As construction professionals navigate an evolving industry landscape, the findings of this study offer valuable guidance for optimising project quality through strategic integration. The discussion's key takeaways emphasise the industry's imperative to embrace BIM-enhanced Lean practices as a transformative strategy, ultimately fostering improved project outcomes serving each dimension of smart sustainability cities (Economic Growth, Social Inclusion, and Environmental Development). As a result, the framework proposed to use ICT to enhance the integration of BIM and lean construction toward smart sustainable cities as shown in Figure 01.

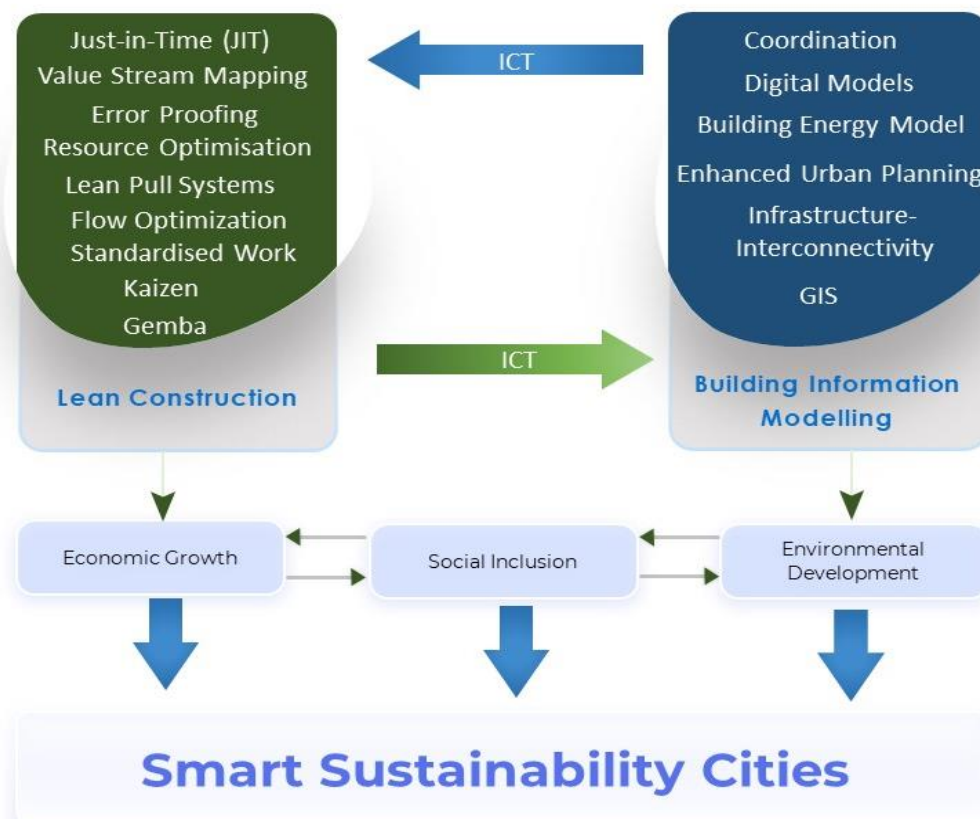


Figure 1: An ICT-based Framework for Innovative Integration between BIM and Lean Practices Obtaining Smart Sustainable Cities

6 Conclusion & Recommendations

Before concluding the study, it is essential to acknowledge its limitations. The research focused on correlations between BIM-enhanced Lean practices and AEC industry performance, but causation cannot be inferred. The study is context-specific and may not capture the diversity of construction projects. Additionally, self-reported survey data may be subject to response bias. Despite these limitations, the findings provide valuable insights into the associations between BIM-enhanced Lean practices and AEC industry performance.

In conclusion, the study sheds light on the interplay between BIM-enhanced Lean practices and AEC industry performance. The positive correlations observed, especially in Clash Detection and Coordination (CDC), Value Stream Mapping (VSM), and Work Sequencing and Flow Optimization (WSFO), indicate that the strategic integration of these practices is associated with improved project outcomes. The findings align with existing literature and highlight the practical significance of adopting BIM-enhanced Lean methodologies in the AEC industry. As construction professionals grapple with the challenges of optimising project quality, the study underscores the potential benefits of embracing specific Lean practices facilitated by BIM.

Moving forward, future research endeavors should address several avenues to enhance the understanding of BIM-enhanced Lean practices in the AEC industry. Firstly, longitudinal studies could provide insights into the long-term impact of these practices on project quality. Secondly, exploring the moderating factors that may influence the observed correlations, such as project size or type, could contribute to a more nuanced understanding. Additionally, qualitative research methods, including in-depth interviews and case studies, could uncover contextual factors influencing the implementation and effectiveness of BIM-enhanced Lean practices. Lastly, investigating the integration challenges and potential barriers faced by industry professionals would provide practical guidance for successful implementation. By addressing these areas, future research can build upon the findings and contribute to a more comprehensive knowledge base for effective project management in the AEC sector.

Acknowledgments

Acknowledgments are extended to Al Rasheed International Private University for Science and Technology for their generous funding, enabling participation in conferences. The university's support has significantly contributed to the dissemination of research findings and academic engagement.

References

- [1] Evans, Martin, and Peter Farrell. 2021. 'Barriers to integrating building information modelling (BIM) and lean construction practices on construction mega-projects: A Delphi study', *Benchmarking: An International Journal*, 28: 652-69.
- [2] Evans, Martin, Peter Farrell, Ayman Mashali, and Wael Zewein. 2021. 'Critical success factors for adopting building information modelling (BIM) and lean construction practices on construction mega-projects: A Delphi survey', *Journal of engineering, design and technology*, 19: 537-56.
- [3] Kadi, Alaa J, Ernawati Mustafa Kamal, Nor'Aini Yusof, and Razan AlSakka. 2022a. 'A Conceptual Framework for the Factors Affecting the Innovation Orientation of Syrian Construction Firms and the Indirect Effect on the Tourism Industry.' in, *Handbook of Technology Application in Tourism in Asia* (Springer).
- [4] Elhendawi, Ashraf, Hany Omar, Emad Elbeltagi, and Andrew Smith. 2020. 'Practical approach for paving the way to motivate BIM non-users to adopt BIM', *International Journal of BIM and Engineering Science*, 2.
- [5] Amino, Aya, and S Ahmed. 2022. 'Proposing a methodology to measure and develop BIM maturity in Syria', *International Journal of BIM and Engineering Science*, 5: 73-89.
- [6] Kadi, Alaa J, Ernawati Mustafa Kamal, Nor'Aini Yusof, and Razan AlSakka. 2022b. 'A Pilot Study on the Indirect Effect of Syrian Construction Firms' Innovation Orientation on the Tourism Industry.' in, *Handbook of Technology Application in Tourism in Asia* (Springer).
- [7] Liu, Hui, Miroslaw J Skibniewski, Qianqian Ju, Junjie Li, and Hongbing Jiang. 2021. 'BIM-enabled construction innovation through collaboration: a mixed-methods systematic review', *Engineering, Construction and Architectural Management*, 28: 1541-60.
- [8] Rane, Nitin. 2023. 'Integrating Building Information Modelling (BIM) and Artificial Intelligence (AI) for Smart Construction Schedule, Cost, Quality, and Safety Management: Challenges and Opportunities', *Cost, Quality, and Safety Management: Challenges and Opportunities (September 16, 2023)*.

- [9] Abdulfattah, Basem S, Hassan A Abdelsalam, Mai Abdelsalam, Marzia Bolpagni, Niraj Thurairajah, Laura Florez Perez, and Talib E Butt. 2023. 'Predicting implications of design changes in BIM-based construction projects through machine learning', *Automation in Construction*, 155: 105057.
- [10] Salami, Hala, and Kheder Alothman. 2022. 'Engineering Training and its Importance for Building Information Modelling', *International Journal of BIM and Engineering Science*, 5: 41-60.
- [11] Ishak, Siti Salwa Mohd, and Rahma Doheim. 2021. 'An exploratory study of building information modelling maturity in the construction industry', *International Journal of BIM and Engineering Science*, 1: 6--19.
- [12] Raad, Lara, Rana Maya, and Petr Dlask. 2023. 'Incorporating BIM into the Academic Curricula of Faculties of Architecture within the Framework of Standards for Engineering Education', *International Journal of BIM and Engineering Science*, 6: 08-8-28.
- [13] Evans, Martin, Peter Farrell, Emad Elbeltagi, Ayman Mashali, and Ashraf Elhendawi. 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: 1-20.
- [14] Safour, Raghad, Sonia Ahmed, and Bilal Zaarour. 2021. 'BIM Adoption around the World', *International Journal of BIM and Engineering Science*, 4: 49-63.
- [15] Ahmed, Sonia, Petr Dlask, Omar Selim, and Ashraf Elhendawi. 2018. 'BIM performance improvement framework for Syrian AEC companies', *International Journal of BIM and Engineering Science*, 1: 21-41.
- [16] Roumieh, N, and S Ahmed. 2022. 'Adopting Risk Management Professional Methodologies as an Effective Strategy to Protect Heritage Sites in Syria', *International Journal of BIM and Engineering Science*, 5: 61-72.
- [17] Hamma-adama, Mansur, Tahar Kouider, and Huda Salman. 2020. 'Analysis of barriers and drivers for BIM adoption', *International journal of BIMA and engineering science*, 3.
- [18] 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 of BIM and Engineering Science*, 4(1), pp.01-19
- [19] Bayhan, Hasan Gokberk, Sevilyay Demirkesen, Chengyi Zhang, and Algan Tezel. 2023. 'A lean construction and BIM interaction model for the construction industry', *Production Planning & Control*, 34: 1447-74.
- [20] Lepkova, Natalija, Rana Maya, Sonia Ahmed, and Vaidotas Šarka. 2019. 'BIM implementation maturity level and proposed approach for the upgrade in Lithuania', *International Journal of BIM and Engineering Science*, 2: 22-38.
- [21] Amjad, Muhammad Saad, Muhammad Zeeshan Rafique, and Mohammad Aamir Khan. 2021. 'Leveraging optimised and cleaner production through industry 4.0', *Sustainable Production and Consumption*, 26: 859-71.
- [22] Klosova, D, and M Kozlovská. 2021. "Methods for identifying non-value-adding activities in construction processes." In *IOP Conference Series: Materials Science and Engineering*, 012032. IOP Publishing.
- [23] Ding, Zhikun, Shan Liu, Longhui Liao, and Liang Zhang. 2019. 'A digital construction framework integrating building information modeling and reverse engineering technologies for renovation projects', *Automation in Construction*, 102: 45-58.
- [24] Abd Alnoor, Bashar. 2022. 'BIM model for railway intermediate station: transportation perspective', *International Journal of BIM and Engineering Science*, 4: 33-3-48.
- [25] Kadi, Alaa J., Ernawati Mustafa Kamal, Nor'Aini Yusof, and S Mostafa Rasoolimanesh. 2019. 'The Effect of Innovation Barriers on Construction Firms' Innovation Orientation', *European Proceedings of Social and Behavioural Sciences*.
- [26] Shaban, Mohamed H, and Ashraf Elhendawi. 2018. 'Building Information Modeling in Syria: Obstacles and requirements for implementation', *International Journal of BIM and Engineering Science*, 1: 42-64.

- [27] Dupin, Patrick. 2021. *Using pull and flow systems to improve production stability in real estate development projects* (Nottingham Trent University (United Kingdom)).
- [28] Mashali, A, and A. El tantawi. 2022. 'BIM-based stakeholder information exchange (IE) during the planning phase in smart construction megaprojects (SCMPs)', *International Journal of BIM and Engineering Science*, 5: 08-19.
- [29] Banawi, Abdulaziz, Obaid Aljobaly, and Cyril Ahiable. 2019. 'A comparative review of building information modeling frameworks', *International Journal of BIM and Engineering Science*, 2: 23-48.
- [30] Petkovic, Jennifer, Alison Riddle, Elie A Akl, Joanne Khabsa, Lyubov Lytvyn, Pearl Atwere, Pauline Campbell, Kalipso Chalkidou, Stephanie M Chang, and Sally Crowe. 2020. 'Protocol for the development of guidance for stakeholder engagement in health and healthcare guideline development and implementation', *Systematic reviews*, 9: 1-11.
- [31] Saada, Michel, and Hala Aslan. 2022. 'The effectiveness of applying BIM in increasing the accuracy of estimating quantities for public facilities rehabilitation projects in Syria after the war', *International Journal of BIM and Engineering Science*, 5: 08-18.