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The Interplay Between BIM Implementation Level and Perceived Benefits: Insights from Industry Practitioners

Lina GHARAIBEH[a][1], Björn LANTZ [b], Mais JARADAT [c] and Kristina ERIKSSON [d]
[a] *University West, Department of Engineering Science, SE-461 86 Trollhättan, Sweden*
[b] *University West, Department of Engineering Science, SE-461 86 Trollhättan, Sweden*
[c] *University of Jordan, Department of Civil Engineering, Amman, Jordan*
[d] *University West, Department of Engineering Science, SE-461 86 Trollhättan, Sweden*

ORCiD ID: Lina Gharaibeh https://orcid.org/0000-0002-5767-3324
Björn Lantz https://orcid.org/0000-0001-6816-582X
Mais Jaradat https://orcid.org/0000-0002-8320-3473
Kristina Eriksson https://orcid.org/0000-0001-8962-0924

Abstract. This research delves into the tangible economic impact of Building Information Modelling within the Swedish construction industry, with a particular focus on exploring the relationships among the level of BIM implementation, company size, and the perceived benefits derived from BIM. The study's methodology involved conducting a questionnaire survey, from which a dataset of 128 responses was collected for comprehensive analysis. The study's findings challenge prevailing assumptions by suggesting that the size of a company does not necessarily dictate its likelihood of implementing BIM. This contradicts earlier notions that larger companies have a more significant propensity for BIM adoption. Additionally, the research uncovers a positive correlation between higher levels of BIM implementation and the realization of greater benefits. This correlation underscores the potential of BIM in significantly enhancing construction project outcomes. By bridging empirical insights from industry professionals and a robust questionnaire survey, this study provides valuable contributions to the understanding of how BIM can improve performance in the construction sector. These results emphasize the importance of considering BIM's potential benefits beyond the scope of company size and offer fresh perspectives on the dynamics between BIM implementation and perceived advantages in the construction project context.

Keywords. Building information modelling; Implementation; Benefits.

[1] Corresponding Author: Lina Gharaibeh, lina.gharaibeh@hv.se.

1. Introduction

Efficiency is a key driver in the construction industry, where projects are often characterized by complex workflows, tight schedules, and budget constraints [1, 2]. In recent years, Building Information Modelling BIM) has emerged as a powerful technology that revolutionizes how construction projects are planned, designed, and executed [3]. BIM offers a comprehensive and integrated approach to project management, enabling stakeholders to improve efficiency across all stages of the construction lifecycle [4, 5]. Through the utilization of BIM, construction professionals can optimize design iterations, detect clashes and conflicts before construction begins, and enhance project sequencing and scheduling [6, 7, 8, 9]. The ability to visualize the project in a virtual environment enables stakeholders to identify potential issues early on, reducing rework, and saving time and costs [10, 11]. Furthermore, BIM enables real-time information sharing, allowing stakeholders to access accurate and up-to-date project data, which enhances collaboration and coordination throughout the construction process [12, 13, 14].

BIM is attracting increasing attention from both the research and industry sectors, recognized for its potential to significantly enhance construction project performance [4, 15]. Although the advantages of BIM are well-established, evidence of BIMs feasibility for the construction companies have not been verified yet, and the economic return on the investment has not been adequately addressed [16, 17, 18]. Evidence on the feasibility of BIM is crucial as it allows stakeholders to make informed decisions regarding the adoption of BIM technologies [19, 20]. By having evidence on feasibility, decision-makers can assess the financial viability, proactively address challenges, foster collaboration, and optimize BIM implementation strategies, ensuring successful adoption and maximizing the benefits of BIM throughout the entire lifecycle.

Previous research has placed significant emphasis on establishing a connection between the level of development and the benefits achieved through the implementation of BIM [8, 11]. While BIM experts and researchers aim for full BIM implementation, other studies have argued that complete implementation is not a prerequisite for realizing the expected benefits [9, 21]. Instead, even partial utilization of BIM can have a substantial impact on project performance [2, 22]. Likewise, the level of BIM implementation has also been associated with various factors, including company size and the role of the company within the project [23, 24]. Several studies have explored the level of implementation from different perspectives, such as preconstruction versus postconstruction or the perspectives of designers versus contractors [10, 11, 24, 25].

This study seeks to investigate the real-world economic effects of BIM, as narrated, and observed by professionals in the field. It also intends to analyze how the perceived benefits of BIM relate to various factors, particularly the degree of BIM implementation. The data for this research is derived from a questionnaire survey, designed for practitioners within the Swedish construction sector.

2. Contextual Background

Gaining a comprehensive understanding of the business advantages associated with BIM plays a pivotal role in guiding organizations' decisions regarding the adoption of BIM technology and its effective implementation [3, 11, 21]. Such insight empowers organizations to conduct a thorough assessment of the potential return on investment (ROI) and determine whether the benefits of BIM outweigh the associated costs [8, 26]. Moreover, a well-rounded understanding of BIM's business benefits equips organizations to formulate a well-defined implementation strategy aimed at optimizing the utilization of BIM and reaping its maximum advantages [19, 27]. For instance, if the primary objective is to reduce construction errors, BIM can be harnessed for the detection and coordination of clashes within the project [28]. Conversely, if the organization's focus lies in curtailing project costs, it may choose to prioritize BIM's utilization for tasks like material optimization and prefabrication [29].

The topic of identifying BIM benefits has been extensively discussed in research; however, its practical application and understanding within the industry remain challenging [1, 27, 30]. Obtaining a realistic perspective based on actual perceived tangible benefits, analyzed from real construction projects, is crucial [13, 31]. The construction industry is increasingly focused on assessing and understanding the feasibility of BIM before making decisions regarding its implementation [17].

There is a lack of research focused on quantifying BIM benefits, despite the importance of providing financial feasibility evidence of BIM, for increasing the level of implementation and encouraging the industry to adopt BIM at higher levels. Addressing these limitations and expanding research efforts can contribute to a better understanding of the investment value of BIM. Increased collaboration between academia, industry, and professional organizations can help establish standardized metrics, share data, and support more extensive studies. This research will present actual empirical perspective from industry practitioners, on the impact of BIM implementation on their projects. The result of this research is expected to enable construction practitioners to understand and realize the financial benefits of BIM and provide a foundation for facilitating informed decision-making when it comes to investing in BIM, and to contribute to achieving a wider adoption of BIM. The research also examines the potential impact of factors that are believed to influence both the level of BIM implementation and the perceived benefits.

The primary objective of the survey is to collect quantitative data related to the concrete advantages of BIM. However, it's essential to recognize and incorporate the theoretical concepts and empirical knowledge gathered from prior literature. This existing knowledge pertains to factors that are suggested to impact both the level of BIM implementation and the subsequent realization of its benefits. To comprehensively address these concerns, descriptive data was also gathered, allowing for the empirical validation of the findings obtained through the literature review and the testing of research hypotheses.

2.1. Hypothesis development

It is imperative to address potential variables or factors that could significantly influence the metrics and values for the tangible measurement of BIM benefits. Previous research has consistently emphasized the direct correlation between the level of BIM implementation and the extent of perceived benefits [8, 11, 21, 26], multiple studies have posited that achieving greater benefits necessitates a higher degree of BIM implementation [32, 33].

Furthermore, it has been argued that larger-scale companies are more inclined to implement BIM at a higher level compared to smaller companies [3, 23, 24]. The preceding literature also indicated a connection between the company's role and the application of BIM. It is suggested that BIM is more frequently used and implemented during the design and construction stage and less among facility management and building operators [21, 25]. Additionally, participants in the interviews highlighted the growing involvement of manufacturers in BIM applications, particularly for offsite construction projects [5, 29]. In light of these observations, three hypotheses were formulated to assess the alignment of the views of participants from the Swedish construction industry with the observations of previous studies:

H1: The level of BIM implementation within companies is positively associated with company size.
H2: The level of BIM implementation is higher among consultants and contractors than in owners, facility managers and manufacturers.
H3: The level of BIM implementation is positively associated with the perceived benefits of BIM.

3. Research Method

The research methodology, as illustrated in Figure 1, adheres to a well-defined sequence designed to achieve the research aim. To initiate the process, an exhaustive literature review was conducted to lay the foundation for the research objectives and hypothesis development. Given the diversity and scope of the Swedish construction industry, the questionnaire survey method was deemed most suitable for gathering insights from a wide array of industry practitioners [34]. This approach resonates with the research's objectives, enabling an all-encompassing and efficient exploration of the perceptions held by professionals within the construction sector regarding the intricate relationship between BIM implementation and its associated benefits. In making this methodological choice, we draw on the insights of [35], emphasizing the appropriateness of a questionnaire-based approach to achieve the study's specific goals [35].

3.1. Questionnaire Preparation

A comprehensive questionnaire was precisely designed and finalized with the assistance of a professional survey design platform, opting for a web-based format to facilitate seamless distribution and response collection. The utilization of an online survey approach contributed significantly to enhancing the accuracy and validity of the responses. This was achieved by designating questions as obligatory, thereby ensuring that each question received a response and mitigating the risk of incomplete or missing data.

The questionnaire included questions to collect demographic data from the sample and to gauge perceived benefits using 12 predefined items drawn from prior literature. These twelve items are as follows:

- Item 1: BIM can reduce the project duration during the design phase.
- Item 2: BIM can enhance the efficiency of the design.
- Item 3: BIM can reduce tender (Contract/BOQ) prices.
- Item 4: BIM can reduce changes during the construction phase.
- Item 5: BIM can reduce the project delivery duration during the construction phase.

- Item 6: BIM can increase safety on site during the construction phase.
- Item 7: BIM can reduce RFI on site during the construction phase.
- Item 8: BIM can reduce Builders Work in Connection (BWIC) costs during the construction phase.
- Item 9: BIM Can increase possibilities for prefabrication.
- Item 10: BIM can facilitate the creation of as built models.
- Item 11: BIM can reduce energy consumption for new projects during operation.
- Item 12: BIM can facilitate maintenance works.

3.2. Sample Size Determination

The survey aimed to encompass various key stakeholders within the Swedish construction industry, including clients, consultants, designers, manufacturers, suppliers, contractors, as well as facility managers and building operations. To ensure an appropriate sample, the survey was distributed electronically via a web-based platform. The recipients were chosen through a combination of purposive and convenience sampling methods. In the case of purposive sampling, participants were selected based on predefined criteria, which, in this study, focused on individuals within the Swedish construction industry with experience in utilizing BIM.

By applying Cochran's formula [36], with an assumption that half of the construction industry in Sweden is using BIM (p = 0.5) and setting the confidence level at 95% with a 5% precision, we can determine the required sample size. Using the normal tables, the Z-value for a 95% confidence level is 1.96. A random sample of 385 respondents is considered adequate for the desired confidence level and precision.

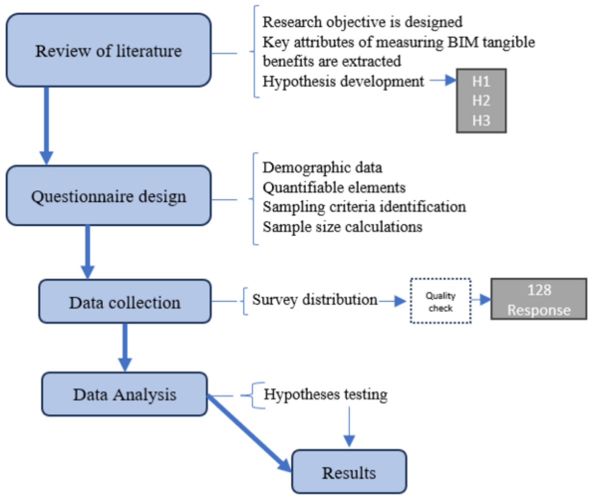

Figure 1: Demonstration of the research methodology.

4. Data Analysis

4.1. Data quality checks

Outliers in a dataset are often defined as data points that significantly deviate from the established data pattern [37]. It's important to note that in this analysis, no outliers were detected, as all maximum values in the conducted tests were found to be below the predefined cut-off thresholds [38]. Consequently, the data analysis can continue without the requirement for additional outlier handling. As emphasized by [38], it is crucial to establish normality to ensure the validity of multivariate test results. To assess normality, one can employ various methods, both empirical and graphical. [39] recommends using P-P plots, where the line's straightness signifies the degree to which a variable's distribution aligns with a normal distribution. The normality assessment approach was conducted, all sub-variable data exhibited a normal distribution pattern.

To assess the validity of the scale, which is rooted in established theoretical constructs and supported by the relevant literature, a confirmatory factor analysis (CFA) was employed as a method to confirm the scale's validity in measuring the perceived benefits associated with BIM [40]. In this study, CFA was conducted to evaluate the congruence between the observed items, comprising twelve elements sourced from previous research, and their corresponding latent variables or dimensions. As a common practice, higher factor loadings signify a more robust connection [41], while any standardized factor loading below the 0.50 threshold is deemed insufficient for measurement purposes.

Before conducting the CFA test, a series of prerequisites had to be ensured. These included confirming the absence of missing data, assessing adherence to normality assumptions, identifying, and addressing outliers, and ensuring an adequate sample size, which is typically recommended to be above 100 as a guideline [41]. It's worth noting that all these criteria have been satisfactorily met in the context of this research. For evaluating the model in this research, the established criteria by Hair, Black [38] was followed, after testing the original model, which included all twelve items, it was evident that the model produced poor fit indices, as a result, a decision was made to remove items with loadings below 0.5, specifically items 1, 3, 7, 8, 9, and 11. This adjustment led to a revised model with improved fit indices. Consequently, Model 2 is deemed acceptable and recommended for further analysis.

The research variables' reliability is evaluated using the Cronbach's alpha test. The Cronbach's alpha value of 0.870, surpassing the 0.70 threshold, demonstrates that the variables being studied display acceptable reliability. This reaffirms the variables' consistency and their ability to effectively measure the constructs of interest.

4.2. Demographic information

Figures (2) and (3) display the demographic information related to the research sample. Analyzing this demographic data from valid responses offers a holistic view of the research sample. This not only facilitates valuable comparisons with previous studies but also bolsters the trustworthiness and applicability of the research findings for future investigations.

4.3. Hypotheses Testing

To investigate Hypotheses 1 and 3, a correlation test was utilized, given that the variable being studied is continuous. In contrast, for Hypothesis 2, which involves a combination of categorical and continuous variables, the mean values comparison test was deemed more appropriate.

To investigate Hypothesis 1, which suggests a positive association between the level of BIM implementation within a company and the size of the company, a Pearson Correlation test was conducted. In this analysis, a Pearson Correlation value (r) is considered significant if the associated p-value is less than 0.05. Table (1) illustrates the correlation between the two variables: "Level of BIM Implementation" and "Size of the Company."

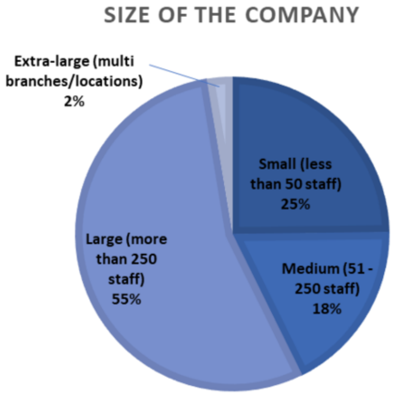

Figure 2: Distribution of the sample by company size. **Figure 3:** Distribution of the sample by company role.

Table 1: Correlation Table for (H1) & (H3).

		level of BIM use at your company
What is the size of your company?	Pearson Correlation	-0.041
	Sig. (2-tailed)	0.659
Level of BIM use at your company?		.343**
		.000

The correlation analysis in Table (1) reveals a Pearson correlation value of -0.041, suggesting a negative correlation between the "Level of BIM Implementation" and the "Size of the Company." However, this correlation lacks statistical significance, with a p-value of 0.659, exceeding the significance threshold of 0.05. Consequently, based on this sample, it can be concluded that there is no significant association between the "Level of BIM Implementation" within a company and the "Size of the Company." Therefore, Hypothesis 1 was not supported, indicating that the level of BIM implementation within a company does not exhibit a positive association with the size of the company in this context.

In the context of Hypothesis 3, where a positive relationship between the level of BIM implementation within a company and the perceived benefit of BIM is posited, the Pearson correlation value (r = 0.343) reveals a statistically significant positive correlation between "Level of BIM Implementation" and "The Perceived Benefits of BIM" (p = 0.000, < 0.05). Based on this sample, it is established that a significant and positive association exists between the "Level of BIM Implementation" within a company and the "Perceived Benefits of BIM." Therefore, Hypothesis 3 is substantiated, affirming the presence of a significant correlation between the level of BIM implementation and the perceived benefits of BIM.

The second hypothesis posits that the categorical variable 'role of company' exerts an influence on the level of BIM implementation. In alignment with prior research findings, our expectation is that within the groups, 'consultants' and 'contractors' will showcase the highest levels of BIM implementation. Anticipated outcomes suggest that these two categories will manifest disparities in BIM implementation levels when compared to the remaining categories, encompassing 'owners,' 'manufacturers,' and 'facility managers.'. Initially, the plan was to employ an analysis of variance [42] for this hypothesis. However, the ANOVA assumptions were evaluated, revealing a violation of the assumption of homogeneity of variances. The Levene's test showed significant results, indicating unequal variances across different groups. Additionally, there were unequal sample sizes within each group. Efforts to use robust alternatives such as the Welch and Brown-Forsythe tests were unsuccessful due to at least one group having zero variance (Pallant, 2020 #20). Consequently, ANOVA was not feasible, and the research turned to an equivalent non-parametric test, the Kruskal-Wallis Test, as a suitable alternative (Pallant, 2020 #20). The Kruskal-Wallis Test allows for the assessment of differences in the scores of a continuous variable across three or more groups without the stringent assumptions of ANOVA.

Table (2) presents the test statistics for the Kruskal-Wallis Test, which was conducted to assess the hypothesis related to differences in the mean levels of BIM implementation across various roles within the project.

Table 2: Test Statistics for Kruskal-Wallis Test (Testing H2).

	level of BIM use at your company?
Chi-Square	19.658
df	4
Asymp. Sig.	.001

In Table (2), the Chi-Square value stands at 19.658 with 4 degrees of freedom (df), and the significance level (Asymp. Sig.) is 0.001, which is less than the 0.05 significance threshold. This significant p-value suggests that there is a statistically meaningful difference in the continuous variable "level of BIM use at your company" across the five groups representing the "Main role of your company." Therefore, confirming the existence of a significant difference in BIM implementation levels based on the company's role within the project.

To pinpoint variations in BIM usage levels within different groups, a post hoc test was executed, employing independent sample non-parametric tests for multiple pairwise comparisons. Significantly differing mean ranks emerged when comparing "Construction contractor" to "Engineering consultant," as well as when comparing "Construction contractor" to "Owner/developer/Client representative." However, it is important to note that no statistically significant differences were detected within the remaining groups, suggesting that the observed disparities lack meaningful significance for conducting a comparison. As a result, Hypothesis 2 was not supported.

5. Discussion

The survey was distributed to a compiled list of potential participants, comprising a total of 204 recipient addresses. Each recipient was encouraged to share the survey with individuals who met the specified criteria of having prior experience with BIM in a Swedish context. Additionally, a digital survey link was publicly shared through professional networks associated with the Swedish construction industry. Subsequently, we received a total of 128 completed surveys following an initial quality check to ensure the responses were complete and accurate. Due to the diverse distribution methods employed, calculating an exact response rate was challenging. However, it is important to note that response rates in the range of 10-12% are not uncommon in research related to construction management [43].

Although the predetermined number of required participants was not reached, the sample size collected for this research is deemed sufficient for several reasons. Firstly, the study's focus is on BIM practitioners in Sweden, a niche or specialized population, where a smaller but relevant sample is considered appropriate. Secondly, practical challenges, such as low response rates and limited participant access, need to be acknowledged. Lastly, the population's homogeneity is a key factor; since this research explores BIM applications in construction processes, where there is little variability, a larger sample might not yield significantly more insights.

Another approach to assessing sample adequacy is benchmarking against similar studies. For example, [44] used a survey with 51 participants to investigate BIM's role in reducing Client-Related Rework [44]. [24] conducted research on BIM implementation in Nepal with a sample of 110 practitioners [24]. [45] assessed the state of the circular economy in the Australian construction industry with 132 survey responses, given the novelty of the topic [45]. Similarly, Sompolgrunk, Banihashemi [46] gathered insights from small and medium-sized construction companies in Australia with a sample of 92 responses. These studies demonstrated that smaller sample sizes can provide valuable information in their respective contexts.

Table 3. summarizes the results of the tested hypotheses, The first hypothesis aimed to examine the belief that a company's size is positively associated with the level of BIM implementation, suggesting that larger companies are expected to have higher levels of BIM implementation. The analysis results failed to support the hypothesis. This implies that within the collected sample, the level of BIM implementation varied, regardless of company size, challenging the notion that company size consistently acts as a constraint against BIM implementation, as suggested in previous literature.

Table 3: summary of hypotheses testing.

Hypotheses	*Result*
H1: The level of BIM implementation within companies is positively associated with company size.	Not supported
H2: The level of BIM implementation is higher among consultants and contractors than in owners, facility managers and manufacturers.	Not supported
H3: The level of BIM implementation is positively associated with the perceived benefits of BIM.	Supported

This result can be viewed as a positive sign that companies are progressing toward BIM implementation, even when they have relatively small business scales. Small to medium-sized companies are also embracing BIM, contributing to a more comprehensive BIM implementation within the Swedish construction industry.

The second hypothesis sought to examine differences in means across various professional roles, specifically testing claims from previous literature that BIM implementation is more prevalent among consulting companies and contractors, as opposed to other roles such as owners, manufacturers, and facility managers. However, this hypothesis was not supported, as no statistically significant differences were identified among these groups. This result suggests that BIM implementation within the sampled population is not contingent on the company's role. It can be viewed as a positive indicator that BIM is gaining traction across all project stakeholders and is not confined solely to design-related tasks.

The literature has consistently linked the extent of perceived benefits of BIM with the level of implementation, suggesting that incomplete BIM implementation could restrict the advantages it offers to the industry. Hypothesis 3, which assessed the positive relationship between implementation level and perceived benefits, was supported, affirming this association. Respondents from companies with a relatively high level of BIM utilization reported elevated levels of BIM benefits across the twelve items used to evaluate BIM feasibility for their projects.

6. Conclusion

This study had the objective of investigating the tangible economic consequences of BIM, as reported, and observed by professionals in the industry. It also aimed to analyze the connection between perceived BIM benefits and various factors, with a particular emphasis on the extent of BIM implementation. Data for this research was gathered through a questionnaire survey administered to practitioners within the Swedish construction sector.

From the previous literature, twelve items were identified as metrics to assess BIM benefits, and these items were subsequently validated through a questionnaire within the Swedish construction industry. The questionnaire was employed to test predefined hypotheses based on prior literature findings. Firstly, the degree of BIM implementation showed variations irrespective of a company's size, which contradicts the prevailing idea that company size invariably acts as a barrier to BIM implementation, as proposed in earlier research. The analysis further substantiated the positive connection between greater degrees of BIM implementation and enhanced perceived benefits. The findings of this study add to the existing body of knowledge concerning the promotion and endorsement of BIM's potential for improving construction project outcomes and achieving higher levels of performance. These results also align with previous literature, affirming that higher levels of BIM implementation indeed yield greater benefits.

The research outcomes emphasize the necessity for additional investigations regarding the quantification of the economic value of BIM. The industry could greatly benefit from further research that delves into the benefits of BIM in a more in-depth manner, utilizing real-world case studies for a comprehensive analysis. This research offers a firsthand empirical insight from industry practitioners regarding the influence of BIM implementation on their projects. The anticipated outcome of this research is to equip construction practitioners with the knowledge to comprehend and appreciate the financial advantages of BIM. It will establish a basis for making informed decisions regarding investments in BIM and ultimately contribute to the broader adoption of BIM within the industry.

References

[1] Sheikhkhoshkar M, Khanzadi M, Banihashemi S. BIM Applications Toward Key Performance Indicators of Construction Projects in Iran. International Journal of Construction Management. 2018;20.10.1080/15623599.2018.1484852
[2] Kim H, Kim S-K, Kang L-S. BIM performance assessment system using a K-means clustering algorithm. Journal of Asian Architecture and Building Engineering. 2020;20:1-10.10.1080/13467581.2020.1800471
[3] Gharaibeh L, Matarneh ST, Eriksson K, Lantz B. An Empirical Analysis of Barriers to Building Information Modelling (BIM) Implementation in Wood Construction Projects: Evidence from the Swedish Context. Buildings. 2022;12(8):1067
[4] Honnappa D, Padala SPS. BIM-based framework to quantify delays and cost overruns due to changes in construction projects. Asian Journal of Civil Engineering. 2022;23(5):707-25.10.1007/s42107-022-00451-x
[5] Cucuzza M, Di Stefano AG, Iannaccone G, Masera G, editors. A BIM-enabled Decision Support System to support large-scale energy retrofitting processes and off-site solutions for envelope insulation. IOP Conference Series: Earth and Environmental Science; 2022.10.1088/1755-1315/1101/4/042031
[6] Daszczyński T, Ostapowski M, Szerner A. Clash Cost Analysis in Electrical Installations Based on BIM Technologies. Energies. 2022;15(5).10.3390/en15051679
[7] Zakeri SMH, Tabatabaee S, Ismail S, Mahdiyar A, Wahab MH. Developing an MCDM Model for the Benefits, Opportunities, Costs and Risks of BIM Adoption. Sustainability (Switzerland). 2023;15(5).10.3390/su15054035
[8] Toan NQ, Van Tam N, Diep TN, Anh PX. ADOPTION OF BUILDING INFORMATION MODELING IN THE CONSTRUCTION PROJECT LIFE CYCLE: BENEFITS FOR STAKEHOLDERS. Architecture and Engineering. 2022;7(1):56-71.10.23968/2500-0055-2022-7-1-56-71
[9] Krystallis I, Papadonikolaki E, Locatelli G, Iuorio O, editors. Towards a methodology for quantifying the benefits of BIM. Proceedings of the 2019 European Conference on Computing in Construction; 2019; Crete, Greece.10.35490/EC3.2019.138
[10] Oesterreich TD, Teuteberg F. Looking at the big picture of IS investment appraisal through the lens of systems theory: A System Dynamics approach for understanding the economic impact of BIM. Computers in Industry. 2018;99:262-81.https://doi.org/10.1016/j.compind.2018.03.029
[11] Sánchez O, Castañeda K, Herrera RF, Pellicer E, editors. Benefits of Building Information Modeling in Road Projects for Cost Overrun Factors Mitigation. Construction Research Congress 2022: Project Management and Delivery, Controls, and Design and Materials - Selected Papers from Construction Research Congress 2022; 2022.10.1061/9780784483978.049
[12] Hosseini MR, Banihashemi S, Chileshe N, Oraee M, Udeaja C, Rameezdeen R, et al. BIM adoption within Australian Small and Medium-sized Enterprises (SMEs): an innovation diffusion model. Construction Economics and Building. 2016;16:71-86.10.5130/AJCEB.v16i3.5159
[13] Hasanain FA, Nawari NO. BIM-based model for sustainable built environment in Saudi Arabia. Frontiers in Built Environment. 2022;8.10.3389/fbuil.2022.950484
[14] Seghier TE, Lim YW, Harun MF, Ahmad MH, Samah AA, Majid HA. BIM-based retrofit method (RBIM) for building envelope thermal performance optimization. Energy and Buildings. 2022;256.10.1016/j.enbuild.2021.111693
[15] Hussain M, Zheng B, Chi HL, Hsu SC. Automated and continuous BIM-based life cycle carbon assessment for infrastructure design projects. Resources, Conservation and Recycling. 2023;190.10.1016/j.resconrec.2022.106848
[16] Harris M, Ismail E, Hussain AH. Business value of BIM in Malaysia's AEC industry: Preliminary findings. Malaysian Construction Research Journal. 2015;16(1):31-41
[17] Kim YO, Lee DH, Park DH. A Case Study on BIM Object-Based Earned Value and Process Management in Highway Construction. KSCE Journal of Civil Engineering. 2022;26(2):522-38.10.1007/s12205-021-1348-3
[18] Kim S, Chin S, Han J, Choi C-H. Measurement of Construction BIM Value Based on a Case Study of a Large-Scale Building Project. Journal of Management in Engineering. 2017;33.10.1061/(ASCE)ME.1943-5479.0000551

[19] Love PED, Simpson I, Hill A, Standing C. From justification to evaluation: Building information modeling for asset owners. Automation in Construction. 2013;35:208-16.https://doi.org/10.1016/j.autcon.2013.05.008
[20] Construction M-H. SmartMarket Report: The Business Value of BIM. 2009.
[21] Ardani JA, Utomo C, Rahmawati Y, Nurcahyo CB, editors. Review of Previous Research Methods in Evaluating BIM Investments in the AEC Industry. Proceedings of the 5th International Conference on Sustainable Civil Engineering Structures and Construction Materials; 2022 2022//; Singapore: Springer Singapore;
[22] Chen X, Qi W, Hu W, editors. Cost-Effective Analysis and Calculation of Energy Performance Using Insight Tool in BIM. 2022 IEEE 2nd International Conference on Electronic Technology, Communication and Information, ICETCI 2022; 2022.10.1109/ICETCI55101.2022.9832241
[23] Bosch-Sijtsema P, Isaksson A, Lennartsson M, Linderoth HCJ. Barriers and facilitators for BIM use among Swedish medium-sized contractors - “We wait until someone tells us to use it”. Visualization in Engineering. 2017;5(1):3.10.1186/s40327-017-0040-7
[24] Paneru S, Ghimire P, Kandel A, Thapa S, Koirala N, Karki M. An Exploratory Investigation of Implementation of Building Information Modeling in Nepalese Architecture–Engineering–Construction Industry. Buildings. 2023;13:552.10.3390/buildings13020552
[25] Pudael I, Latief RU, Burhanuddin S, editors. Study on the Implementation of the Combination of 2 BIM and ERP Systems to Improve Project Cost Estimation Accuracy at the Auction Stage. IOP Conference Series: Earth and Environmental Science; 2022.10.1088/1755-1315/1117/1/012013
[26] Barlish; K, Sullivan; K. How to measure the benefits of BIM — A case study approach. Automation in Construction. 2012;24:149-59.https://doi.org/10.1016/j.autcon.2012.02.008
[27] PWC. BIM Level 2 Benefits Measurement Application of PwC’s BIM Level 2 Benefits Measurement Methodology to Public Sector Capital Assets. 2018.
[28] Ham N, Moon S, Kim JH, Kim J-J. Economic Analysis of Design Errors in BIM-Based High-Rise Construction Projects: Case Study of Haeundae L Project. Journal of Construction Engineering and Management. 2018;144:05018006.10.1061/(ASCE)CO.1943-7862.0001498
[29] Tang Q, editor Research on the construction of prefabricated building supply chain information management platform based on BIM technology. Proceedings - 2022 3rd International Conference on Education, Knowledge and Information Management, ICEKIM 2022; 2022.10.1109/ICEKIM55072.2022.00156
[30] Qian AY. Benefits and ROI of BIM for Multi-disciplinary Project Management. National University of Singapore; 2012.
[31] Yu J, Wang J, Hua Z, Wang X. BIM-based time-cost optimization of a large-span spatial steel structure in an airport terminal building. Journal of Facilities Management. 2022;20(3):469-84.10.1108/JFM-12-2020-0097
[32] Lee M, Lee U-K. A FRAMEWORK FOR EVALUATING AN INTEGRATED BIM ROI BASED ON PREVENTING REWORK IN THE CONSTRUCTION PHASE. JOURNAL OF CIVIL ENGINEERING AND MANAGEMENT. 2020;26:410-20.10.3846/jcem.2020.12185
[33] Walasek D, Barszcz A, editors. Analysis of the Adoption Rate of Building Information Modeling [BIM] and its Return on Investment [ROI]. Procedia Engineering; 2017.10.1016/j.proeng.2017.02.144
[34] Brick J, Kalton G. Handling Missing Data in Survey Research. Statistical methods in medical research. 1996;5:215-38.10.1177/096228029600500302
[35] Bryman A, Bell E. Business Research Methods: Oxford University Press; 2015.
[36] Cochran WG. Sampling technique. Third ed. New York: John Wiley & Sons.; 1977.
[37] Rousseeuw PJ, van Zomeren BC. Unmasking Multivariate Outliers and Leverage Points. Journal of the American Statistical Association. 1990;85(411):633-9.10.1080/01621459.1990.10474920
[38] Hair J, Black w, Babin B. Multivariate Data Analysis: A Global Perspective: Pearson Education; 2010.
[39] Garson D. Testing statistical assumptions. Asheboro, : NC: Statistical Associates Publishing; 2012.
[40] Said H, Badru BB, Shahid M. Confirmatory Factor Analysis (Cfa) for testing validity and reliability instrument in the study of education. Australian Journal of Basic and Applied Sciences. 2011;5:1098-103
[41] Harrington D. Confirmatory factor analysis: Oxford university press; 2009.
[42] Lechhab N, Iordanova I, Forgues D. Evaluation of the Return on Investment of BIM—The Case of an Architectural Firm. Lecture Notes in Civil Engineering2023. p. 431-43.10.1007/978-981-19-1029-6_33
[43] Bing L, Akintoye A, Edwards PJ, Hardcastle C. The allocation of risk in PPP/PFI construction projects in the UK. International Journal of Project Management. 2005;23(1):25-35.https://doi.org/10.1016/j.ijproman.2004.04.006

[44] Abdelbary M, Edkins A, Dorra E. Reducing CRR in fast-track projects through BIM. Journal of Information Technology in Construction. 2020;25:140-60.10.36680/j.itcon.2020.009
[45] Ghafoor S, Hosseini MR, Kocaturk T, Shooshtarian S, Arnel T, King D, et al. Unlocking the Power of the Circular Economy in the Australian AEC Industry: A Journey through Attitudes, Barriers and Enablers2023.
[46] Sompolgrunk A, Banihashemi S, Hosseini MR, Golzad H, Hajirasouli A. An integrated model of BIM return on investment for Australian small- and medium-sized enterprises (SMEs). Engineering, Construction and Architectural Management. 2022.10.1108/ECAM-09-2021-0839