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Evaluating Building Information Modeling (BIM) for Residential Project Management: A Case Study of the Panorama Twin Towers

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ABSTRACT

In recent years, Building Information Modeling (BIM) has emerged as an innovative technology in the construction industry, playing a crucial role in enhancing project management processes. This study aims to evaluate and assess the impact of BIM on improving residential project management, with a case study of the Panorama Twin Towers in Pasdaran. The research examines the extent to which BIM influences key project management indicators, including cost reduction, schedule control, resource optimization, improved coordination among project stakeholders, and delay mitigation. To analyze the data, linear regression analysis has been employed. Linear regression is a widely used statistical method for examining the relationships between independent and dependent variables, which in this study is utilized to assess the impact of BIM on project management indicators. Data related to project execution were collected, preprocessed, and analyzed using a regression model. The coefficients of this statistical model determined the magnitude and direction of the influence of various variables, revealing with high precision the relationship between BIM implementation and project management enhancement. The modeling results indicate that the adoption of BIM has a significant and positive impact on improving project management processes. According to regression analysis, BIM contributes to project delay reduction, optimization of execution costs, increased scheduling accuracy, minimization of rework, improved coordination among project teams, and overall productivity enhancement. Furthermore, statistical analysis of the regression model suggests that BIM can accurately predict management trends and enhance strategic decision-making. These findings can assist project managers, consulting engineers, and other stakeholders in the construction industry in making more efficient and effective decisions, fostering the broader adoption of BIM in future projects.

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1. Introduction

The construction industry has long been confronted with numerous challenges, including inefficiencies arising from fragmented workflows, reliance on traditional tools such as 2D drawings and manual reporting, and communication gaps among stakeholders. These issues frequently result in project delays, cost overruns, and inconsistent reports. For instance, project managers often organize multi-disciplinary meetings to assess progress, yet these gatherings produce conflicting outcomes due to isolated information sources [1]. Historically, the roots of these problems can be traced back to the pre-digital era, where paper-based documentation dominated, leading to errors in interpretation and coordination. The evolution of digital tools in the late 20th century began to address some of

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these, but it was the advent of Building Information Modeling (BIM) in the early 2000s that marked a paradigm shift. BIM serves as an integrated digital platform that centralizes data for all stakeholders throughout the project lifecycle, enabling real-time collaboration, error reduction, and resource optimization [2]. This technology not only digitizes building elements but also embeds parametric information, transforming static designs into dynamic, intelligent models that adapt to changes seamlessly [3].

Recent advancements in BIM technology have significantly enhanced its role in addressing these challenges, particularly in residential projects where budget and timeline constraints are more stringent. BIM goes beyond mere 3D visualization by incorporating intelligent attributes, such as metadata for materials, costs, and maintenance schedules, into model elements. This rich dataset persists from initial feasibility studies through design, procurement, construction, commissioning, operation, and even demolition phases [4]. Studies conducted between 2023 and 2025 demonstrate that BIM, through virtual clash detection in the design stage, can substantially reduce costly on-site rework and improve interdisciplinary coordination [5]. In high-rise residential developments, BIM has been shown to decrease delays by 20–30% and enhance scheduling accuracy via advanced simulation tools [6]. Moreover, the integration of BIM with virtual reality (VR) technologies, such as smartphone-based VR systems, has opened new avenues for client engagement in residential architecture, allowing immersive walkthroughs that refine designs before physical construction begins [7]. This has proven particularly beneficial in customizing residential spaces to user preferences, reducing post-construction modifications by up to 15% in case studies [8]. In the context of residential project management, the term stakeholder conflict refers to misalignments, disagreements, or incompatibilities in objectives, responsibilities, or decision-making processes among key project participants, including owners, designers, contractors, and consultants. Such conflicts often arise due to fragmented information flows, lack of transparency, and inconsistent interpretations of project requirements. Similarly, stakeholder gaps denote structural or informational discontinuities between stakeholders, manifested as communication breakdowns, delayed information exchange, or insufficient coordination across different project phases. These gaps can negatively affect cost control, schedule adherence, and overall project performance. The implementation of Building Information Modeling (BIM) aims to reduce both stakeholder conflicts and gaps by providing an integrated, data-driven platform that facilitates real-time collaboration, information sharing, and coordinated decision-making throughout the project lifecycle.

Furthermore, the adoption of BIM aligns with global trends toward sustainability and digitalization. By simulating energy performance and material lifecycles early in the process, BIM minimizes environmental impact and lifecycle costs; recent research indicates potential operational savings of 15–30% in residential buildings [9]. Integration of BIM with off-site construction and prefabrication reduces on-site waste and assembly time, as evidenced in systematic reviews of modular residential projects [10]. Analyses from 2024–2025 emphasize that BIM-enabled projects can be completed up to 30% faster, primarily due to proactive conflict resolution and data-driven decision-making [11]. In the context of sustainable civil engineering, BIM facilitates the incorporation of green materials and energy-efficient systems, contributing to lower carbon emissions in residential complexes [12]. For example, strategic frameworks like ADAPTE (Adaptation Process for Existing Buildings) leverage BIM to retrofit older residential structures, aligning them with modern sustainability standards and extending their usability [13]. Additionally, BIM's role in integrating Environmental, Social, and Governance (ESG) factors and Sustainable Development Goals (SDGs) has been highlighted as a key driver for long-term project viability, with studies identifying critical implementation factors such as stakeholder training and policy support [14]. The integration of BIM with emerging technologies such as artificial intelligence (AI) and the Internet of Things (IoT) enables risk prediction, resource optimization, and stricter adherence to scope, cost, time, and quality constraints [15]. AI-enhanced BIM models can automate routine tasks like quantity takeoffs and predictive maintenance, further streamlining residential project workflows [16]. However, barriers such as training requirements, interoperability issues, and initial costs, particularly in developing countries like Iran, have slowed widespread adoption [17]. In high-rise residential projects, BIM reinforces green principles and reduces carbon footprints [18]. Early adoption of BIM in high-rise planning has improved design coordination, time efficiency, and cost control, highlighting its strategic value [19]. Beyond these, the use of digital twins, virtual replicas of physical assets, integrated with BIM, promotes human-centric approaches in supply chains, enhancing collaboration and sustainability in residential construction [20]. Bibliometric analyses of AI in urban planning reveal that BIM serves as a foundational layer for smart city initiatives, where residential management benefits from data analytics for optimized resource allocation [21]. In smart buildings, AI-BIM synergies enable real-time monitoring of energy usage, with recent reviews underscoring their potential in residential IoT ecosystems [22]. Despite these advantages, challenges persist in fully realizing BIM's potential. For instance, in regions with limited digital infrastructure, adoption rates lag due to skill gaps and regulatory hurdles [23]. Global case studies, however, demonstrate that targeted policies and education programs can accelerate uptake, leading to measurable improvements in project outcomes [24]. Looking ahead, the future of BIM in residential construction lies in its convergence with technologies like blockchain for secure data sharing and augmented reality for on-site guidance, promising even greater efficiencies [3].

Despite the increasing adoption of BIM worldwide, its practical role in addressing the managerial challenges of residential construction projects remains insufficiently explored, particularly in developing countries. Residential projects are characterized by tight budgets, strict schedules, high stakeholder involvement, and direct impacts on occupants' quality of life. Traditional management approaches often fail to effectively handle these complexities, resulting in cost overruns, delays, and coordination conflicts. Therefore, evaluating BIM as an integrated project management approach, rather than solely as a design or visualization tool, constitutes the main problem addressed in this study. The Panorama Twin Towers project was selected as a case study due to its scale, functional complexity, and the involvement of multiple stakeholders, making it a suitable and representative context for examining the effectiveness of BIM in improving residential project management processes. This study builds upon these insights to evaluate the impact of BIM on residential project management through a case study of the Panorama Twin Towers in Pasdaran. The research methodology involves data collection via questionnaires, statistical analysis using SPSS software, normality tests, and linear regression modeling to quantify BIM's effects on key indicators such as cost reduction and delay mitigation. Although the advantages of Building Information Modeling, such as cost reduction, time optimization, and improved coordination, have been widely discussed in previous studies, this research offers several distinct contributions. First, it provides an empirical assessment of BIM implementation in a real high-rise residential project within a developing-country context, where institutional, technological, and organizational conditions differ significantly from those typically examined in prior studies. Second, the study proposes a comprehensive conceptual framework that links BIM adoption not only to traditional project management indicators, but also to organizational and socio-environmental dimensions, including fair payment, safe work environment, organizational integration, and capability development. Third, by applying linear regression analysis, this research quantitatively measures the relative influence of BIM-related factors on residential project management performance, moving beyond descriptive evaluations commonly found in the literature. The structure of this paper is as follows: following this introduction, the data analysis section presents demographic profiles, reliability tests, and descriptive statistics; subsequent sections discuss regression models and result interpretations; finally, the conclusion and recommendations outline practical implications and directions for future research.

2. Methodology

This study adopts a quantitative and applied research methodology to evaluate the impact of Building Information Modeling (BIM) on residential project management processes. A case study strategy is employed to enable an in-depth examination of BIM implementation within a real-world residential high-rise project. Data are collected using a structured, closed-ended questionnaire based on a five-point Likert scale and analyzed using statistical techniques. The methodological framework of the study is designed to ensure reliability, analytical rigor, and alignment between the research objectives, data collection process, and empirical analysis. The conceptual research model is presented in Fig. 1.

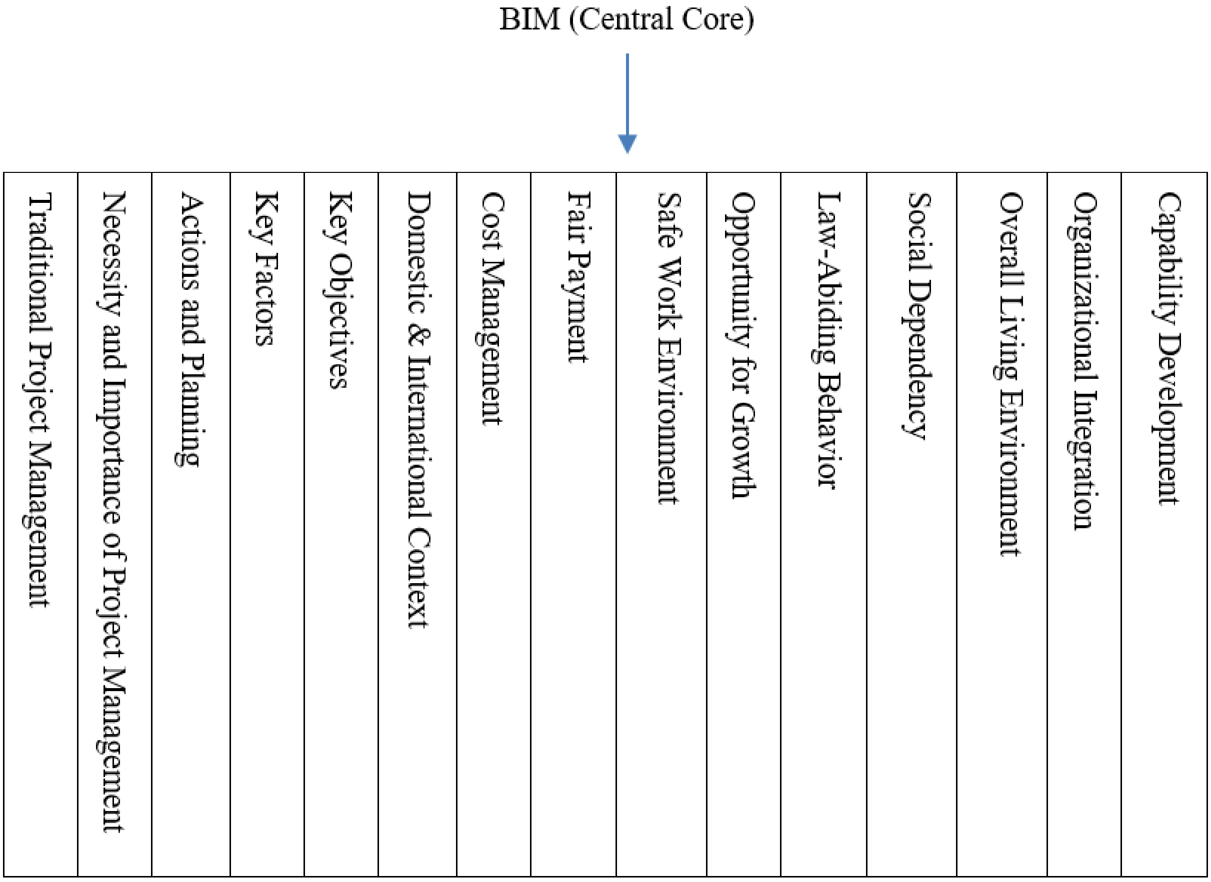

Fig. 1. Conceptual research model.

2.1. Research work

The research workflow of this study is designed to provide a clear and systematic roadmap for evaluating the impact of Building Information Modeling (BIM) on residential project management processes. The workflow begins with the identification of key challenges associated with traditional residential project management practices, followed by a comprehensive review of the relevant literature to establish the theoretical foundation of the study. Based on this review, a BIM-based conceptual framework encompassing factors F1–F15 is developed to guide the empirical analysis. Subsequently, a case study approach is adopted, focusing on the Panorama Twin Towers residential high-rise project. A structured questionnaire comprising 43 Likert-scale items is then designed and administered through face-to-face surveys with managers and engineers during the project execution phase. The collected data are prepared and coded for statistical analysis using SPSS software. Reliability and validity are assessed using Cronbach’s alpha, after which descriptive statistics and linear regression analysis are employed to examine the relationships between BIM adoption and residential project management indicators. Finally, the results are interpreted and discussed in light of existing literature, leading to conclusions and practical recommendations for future BIM implementation. The research methodology is summarized in Fig. 2.

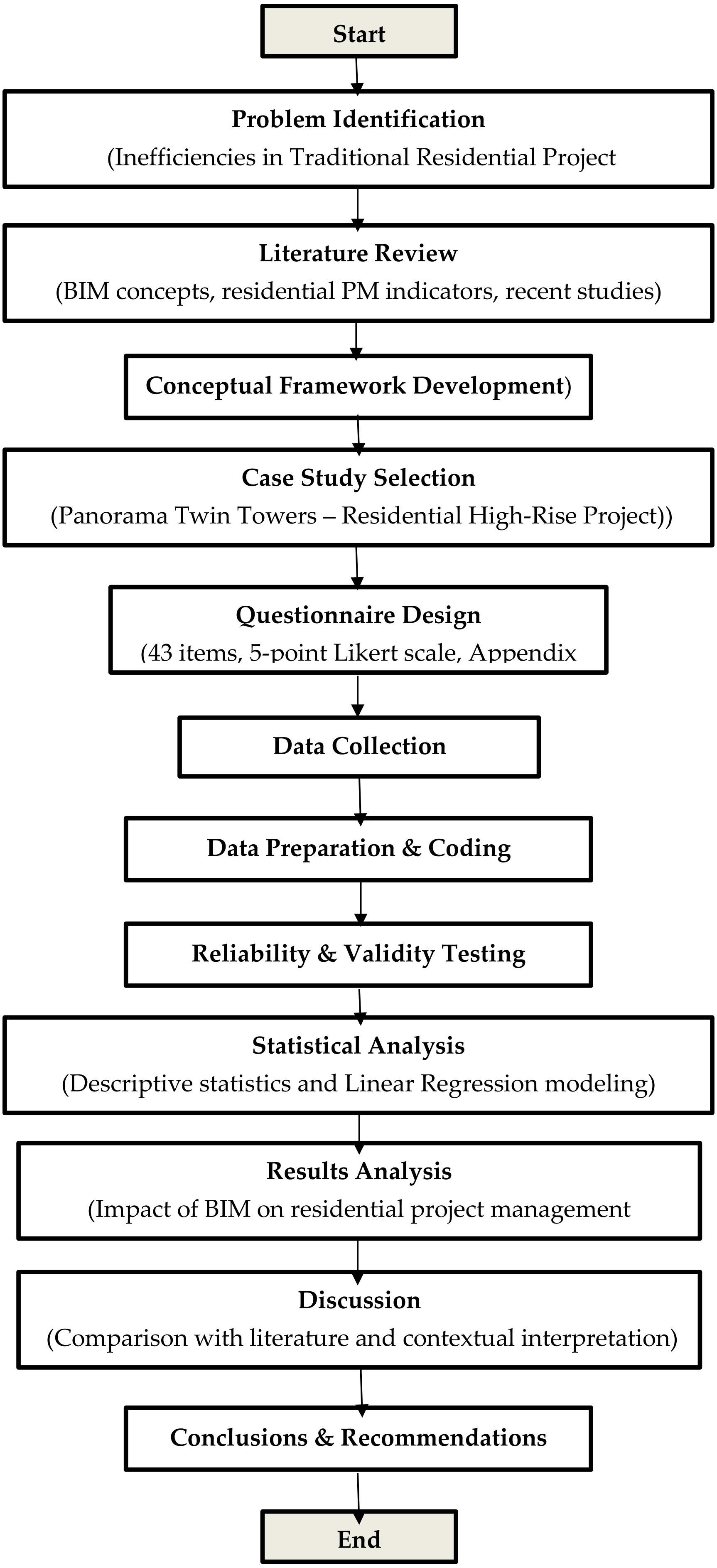

Fig. 2. Research methodology flowchart.

2.2. Research design

This study adopts a quantitative research design using a case study approach to evaluate the impact of Building Information Modeling (BIM) on residential project management processes. The research focuses on the Panorama Twin Towers project located in Pasdaran, Iran, as a representative high-rise residential development. A structured questionnaire was employed as the primary data collection instrument to capture the perceptions and experiences of professionals involved in the project.

2.3. Case study description

The Panorama Twin Towers is a large-scale residential construction project characterized by complex coordination requirements, multiple stakeholders, and stringent cost and time constraints. Due to these characteristics, the project provides a suitable context for assessing the effectiveness of BIM in improving residential project management practices. The case study approach enables an in-depth evaluation of BIM implementation within a real-world project environment. The case study implementation is shown in Figs. 3 and 4.

Fig. 3. Implementation of the pasdaran twin towers.

Fig. 4. The twin towers of the Pasdaran.

2.4. Data collection method

Data were collected through a structured, closed-ended questionnaire administered via face-to-face distribution. The target population consisted of engineers, project managers, supervisors, and technical experts directly involved in the Panorama Twin Towers project. This method of administration ensured accurate understanding of the questionnaire items and enhanced the reliability of the collected responses. A total of 120 valid questionnaires were collected and used for statistical analysis.

2.5. Questionnaire design

The questionnaire was designed based on the proposed conceptual model of BIM impacts on residential project management. It consisted of 43 declarative statements grouped into 15 dimensions, including traditional project management practices, cost management, scheduling, safety, fair payment, capability development, and organizational cohesion. All items were measured using a five-point Likert scale ranging from Very Low (1) to Very High (5). No open-ended questions were included.

2.6. Reliability and validity

The reliability of the questionnaire was assessed using Cronbach's alpha coefficient. The results indicate alpha values exceeding the acceptable threshold of 0.70, confirming the internal consistency and reliability of the measurement instrument. These findings support the suitability of the questionnaire for evaluating BIM-related impacts in residential project management studies.

2.7. Data analysis techniques

The collected data were analyzed using SPSS statistical software. Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize respondent characteristics and questionnaire responses. Inferential statistical analyses were conducted using normality tests and linear regression models to examine the relationships between BIM implementation and key residential project management indicators such as cost reduction, delay mitigation, coordination improvement, and productivity enhancement.

The overall research approach follows a structured sequence beginning with the identification of challenges in traditional residential project management, followed by the development of a BIM-based conceptual framework. Subsequently, relevant management dimensions were defined and translated into questionnaire statements. Data were collected through structured questionnaires, and reliability was assessed using Cronbach's Alpha. Normality tests and linear regression analysis were then conducted to evaluate the impact of BIM on residential project management processes, followed by interpretation and discussion of results. Linear regression analysis was employed in this study to examine the relationship between BIM-related factors and residential project management indicators. This method was selected due to its suitability for exploratory studies with moderate sample sizes and its ability to provide clear and interpretable estimates of the magnitude and direction of variable relationships. Unlike Structural Equation Modeling (SEM), which requires strong theoretical assumptions regarding causal pathways and larger sample sizes, linear regression allows for the assessment of individual factor contributions without imposing complex structural constraints. It should be noted that the objective of this research is not to establish definitive causal relationships, but to identify statistically significant associations between BIM implementation and project management performance indicators. The results therefore reflect perceived and experienced impacts of BIM adoption within the case study context, rather than direct cause–effect proof.

3. Data analysis

Data analysis encompasses multiple stages, beginning with the preparation and organization of data required for hypothesis testing, followed by the examination of relationships between variables, and ultimately the comparison of observed results. In this study, the collected sample data were categorized and integrated using statistical methods and software, then analyzed and interpreted. To achieve this, both descriptive and inferential statistics were employed with the assistance of SPSS statistical analysis software. In the descriptive statistics section, key frequency indices including frequency, percentage frequency, central tendency measures, dispersion measures, and bar charts were utilized. In the inferential statistics section, after quantification, statistical tests were applied to evaluate the research hypotheses. The necessary data were collected through a structured questionnaire, and subsequently converted into quantitative variables using statistical methods. This transformation enabled the application of advanced statistical tests, ensuring the practical usability of the research findings. The data for this study were collected through a structured questionnaire administered to professionals directly involved in the Panorama Twin Towers residential project in Pasdaran. The respondents included project managers, site engineers, supervisors, and technical experts who had direct experience with residential project management processes and exposure to BIM-related practices. Questionnaires were distributed during the active execution and management phases of the project to ensure that participants' responses reflected real-time project conditions rather than retrospective judgments. Prior to data collection, the purpose of the study was explained to all participants, and confidentiality of responses was assured. Participation was voluntary, and respondents completed the questionnaires based on their professional experience within the project environment. To enhance data reliability, only completed questionnaires with consistent and valid responses were included in the final analysis. This project-based data collection approach ensured that the findings accurately represent the practical impacts of BIM on residential project management under real operational conditions.

Before conducting the analysis of the collected questionnaires and performing computations using the Analytic Network Process (ANP), this section presents demographic information related to the research sample. The demographic data include gender, age, work experience, level of education, and field of study. These variables are presented in the form of frequency distribution tables and graphical charts to provide a clearer understanding of the sample's characteristics. The selection of sample characteristics in this study was guided by established research in the fields of Building Information Modeling (BIM) adoption and construction project management. Demographic and professional variables such as age, level of education, work experience, and employment-related attributes were selected because previous studies have shown that these factors significantly influence technology adoption, decision-making behavior, and the effectiveness of BIM implementation in construction projects. In particular, professional experience and educational background affect stakeholders' ability to interpret digital models, coordinate project information, and engage in BIM-based workflows. Accordingly, the selected sample characteristics are consistent with prior empirical studies on BIM adoption and project management performance in residential and infrastructure projects, ensuring the comparability and methodological validity of the research findings.

To enhance transparency and reproducibility, the raw format of the questionnaire used for data collection is provided in Appendix A. The questionnaire items were designed based on the proposed conceptual model and measured respondents' perceptions of BIM impacts using a five-point Likert scale ranging from Very Low (1) to Very High (5). The demographic characteristics of the questionnaire respondents are summarized in Tables 1 to 5.

Table 1. Age distribution of questionnaire respondents.

Age group	Frequency	Percentage frequency	Sample percentage	Cumulative percentage frequency
25-35	60	50%	50%	50%
35-45	42	42.9%	42.9%	92.9%
55+	18	7.1%	7.1%	100%
Total	120	100%	100%	100%

Table 2. Frequency distribution of respondents' educational level.

Education level	Frequency	Percentage frequency	Sample percentage	Cumulative percentage frequency
Bachelor's Degree	20	14.3%	14.3%	14.3%
Master's Degree	89	78.6%	78.6%	92.9%
Ph.D.	11	7.1%	7.1%	100%
Total	120	100%	100%	100%

Table 3. Frequency distribution of respondents' work experience.

Years of experience	Frequency	Percentage frequency	Sample percentage	Cumulative percentage frequency
Less than 10 years	60	50%	50%	50%
10-20 years	45	35.7%	35.7%	85.7%
More than 20 years	15	14.3%	14.3%	100%
Total	120	100	100%	100%

Table 4. Frequency distribution of respondents' marital status.

Marital status	Frequency	Percentage frequency	Sample percentage	Cumulative percentage frequency
Single	33	28.6%	28.6%	28.6%
Married	87	71.4%	71.4%	100%
Total	120	100%	100%	100%

Table 5. Frequency distribution of respondents' insurance coverage.

Insurance type	Frequency	Percentage frequency	Sample percentage	Cumulative percentage frequency
Social Security (Tamin Ejtemaei)	98	85.7%	85.7%	85.7%
Health Services Insurance	22	14.3%	14.3%	100%
Total	120	100%	100%	100%

The data collection instrument was a structured, closed-ended questionnaire designed using Likert-scale statements. The questionnaire did not include open-ended questions. Data were collected through face-to-face distribution of the questionnaires among engineers, project managers, and technical staff involved in the Panorama Twin Towers residential project in Pasdaran. This approach ensured clarity of responses and increased the reliability of the collected data.

4. Cronbach’s alpha test

Cronbach was the individual who developed the Cronbach's alpha coefficient. This coefficient is now widely recognized as one of the most commonly used methods for measuring reliability in scientific questionnaires. This measurement method calculates the correlation between two questions that are posed to achieve a specific goal. It is primarily used to assess the reliability, or in other words, the consistency, of questionnaires. In addition to this measurement method, other methods also exist for examining the reliability of questionnaires. In questionnaires, we typically examine several traits. If we evaluate the same traits under the same conditions but at different times, and obtain consistent results, we can conclude that the questionnaire is reliable and valid. Using Cronbach’s alpha, we can gain insights into the opinions and attitudes of respondents. This coefficient helps determine how respondents interpret the questions in the questionnaire. In essence, a group of respondents may have a similar understanding of the questions, and Cronbach's alpha clearly indicates how many individuals share similar attitudes. This coefficient is based on scales, which are sets of numbers that represent quality in measurable terms. The Likert scale is one of the most common scales used in social research. Cronbach’s alpha is a coefficient calculated using established statistical relationships. Cronbach defined a formula for this coefficient, which can be manually applied to assess the correlation between questions. In this relationship, k represents the number of questions. For conducting scientific research, it is advisable not to rely solely on this formula. Using advanced software is a more appropriate option for obtaining accurate results, as it reduces the time needed for analysis. Cronbach’s alpha coefficient was used to evaluate the internal consistency and reliability of the questionnaire. In addition to the descriptive explanation, the mathematical formulation of Cronbach's alpha is presented as follows. The reliability and validity of the questionnaire are presented in Table 6 based on Eq. 1.

$$\alpha = (k / (k - 1)) \times [1 - (\Sigma\sigma^2_i / \sigma^2_t)] \quad (1)$$

where α represents Cronbach's alpha coefficient, k is the number of questionnaire items, σ^2_i denotes the variance of each individual item, and σ^2_t represents the total variance of the summed scale. Values of α greater than 0.70 indicate acceptable reliability.

Table 6. Cronbach's alpha test for questionnaire reliability and validity.

Cronbach's alpha	Number of items
0.728	9
0.733	43

Based on the Cronbach's alpha test, we observe that the alpha value for both questionnaires is greater than 70%, indicating that the Job Performance and Quality of Work Life questionnaires have high reliability and validity. In this section, we will present the frequency and percentage of responses to the questionnaire's questions, along with the mean and standard deviation for each variable. Regarding the coding of the questionnaire questions, it is important to note that since the Likert scale was used to design the questions, with scores assigned as follows:

Very High = 5, High = 4, Average = 3, Low = 2, Very Low = 1

A higher average score for a question or variable, especially approaching 5, indicates that the question or variable is perceived more positively. Descriptions of the sample distributions are given in Tables 7 to 20.

Table 7. Sample breakdown based on building information modeling (BIM) in improving residential project management processes using traditional methods.

F1 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
A1	12%	20%	22.7%	29.3%	16%	1.673	3.173
A2	4%	18.7%	18.7%	30.7%	28%	1.684	1.432
Total		4.605					

In this section, the mean, standard deviation, and percentage of responses to the BIM-related statements for improving residential project management processes using traditional methods are presented. The overall mean of the residential project management variable in traditional methods was calculated to be 4.605. The lowest mean corresponds to statement A2, and the highest mean corresponds to statement A1.

Table 8. Sample breakdown based on building information modeling (BIM) in improving the necessity and importance of residential project management.

F2 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
B1	1.3%	13.3%	17.3%	32%	36%	1.090	3.880
B2	2.7%	14.7%	21.3%	30.7%	37%	1.376	3.720
Total							7.6

In this section, the mean, standard deviation, and percentage of responses to the statements regarding the necessity and importance of BIM in improving residential project management are presented. The overall mean for the necessity and importance of BIM in residential project management was calculated as 7.6. The lowest mean corresponds to statement B2, while the highest mean corresponds to statement B1.

Table 9. Sample breakdown based on building information modeling (BIM) in improving the actions and planning of residential project management.

F3 Statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
C1	1.3%	14.7%	18.7%	22.7%	42%	1.528	3.906
C2	0%	5.3%	24%	17.3%	53%	0.982	4.876
C3	0%	2.7%	37.3%	24%	36%	0.920	3.933
Total							12.267

In this section, the mean, standard deviation, and percentage of responses to the statements regarding the BIM-related actions and planning for improving residential project management are presented. The overall mean for the actions and planning of residential project management was calculated to be 12.267. The lowest mean corresponds to statements C1 and C3, while the highest mean corresponds to statement C2.

Table 10. Sample breakdown based on building information modeling (BIM) in improving key factors of residential project management.

F4 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
D1	1.3%	5.3%	30.3%	30.7%	32%	0.977	3.867
D2	29.3%	26.7%	17.3%	17.3%	9.3%	1.239	2.507
Total							6.373

In this section, the mean, standard deviation, and percentage of responses to the statements regarding key factors in residential project management using BIM are presented. The overall mean for key factors in residential project management was calculated to be 6.373. The lowest mean corresponds to statement D2, while the highest mean corresponds to statement D1.

Table 11. Sample breakdown based on building information modeling (BIM) in improving key Objectives of residential project management.

F5 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
E1	6.7%	8%	30.7%	25.3%	29.3%	1.182	3.627
E2	1.3%	8%	24%	22.7%	44%	1.065	4.000
Total							7.627

In this section, the mean, standard deviation, and percentage of responses to the statements regarding improving key objectives in residential project management using BIM are presented. The overall mean for key objectives in residential project management was calculated to be 7.627. The lowest mean corresponds to statement E1, while the highest mean corresponds to statement E2.

Table 12. Sample breakdown based on building information modeling (BIM) and residential project management in domestic and international contexts.

F6 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
H1	0%	17.3%	32%	21.3%	29.3%	1.087	3.627
H2	1.3%	14.7%	32%	18.7%	33.3%	1.289	3.680
H3	0%	16%	32%	21.3%	30.7%	1.082	3.667
Total							10.973

In this section, the mean, standard deviation, and percentage of responses to the statements regarding residential project management in domestic and international contexts using BIM are presented. The overall mean for key factors in residential project management in both domestic and international contexts was calculated to be 10.973. The lowest mean corresponds to statements H1 and H3, while the highest mean corresponds to statement H2.

Table 13. Sample breakdown based on building information modeling (BIM) and improvement of residential project management costs.

F7 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
K1	13.3%	21.3%	28%	21.3%	21.3%	1.331	3.107
K2	14.7%	14.7%	28%	22.7%	20%	1.322	3.187
Total							6.293

In this section, the mean, standard deviation, and percentage of responses to the statements regarding improving residential project management costs using BIM are presented. The overall mean for residential project management costs was calculated to be 6.293. The lowest mean corresponds to statement K1, while the highest mean corresponds to statement K2.

Table 14. Sample breakdown based on building information modeling (BIM) and improvement of fair payment.

F8 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
L1	8%	26.7%	29.3%	18.7%	17.3%	1.214	1.107
L2	4%	24%	24%	16%	32%	1.277	3.480
L3	0%	22.7%	37%	16%	30%	1.152	3.547
Total							8.133

In this section, the mean, standard deviation, and percentage of responses to the statements regarding fair payment improvement using BIM are presented. The overall mean for fair payment was calculated to be 8.133. The lowest means correspond to statements L1 and L2, while the highest mean corresponds to statement L3.

Table 15. Sample breakdown based on building information modeling (BIM) and improvement of a safe work environment.

F9 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
Q1	0%	22.7%	32%	16%	29%	1.143	3.520
Q2	1.3%	12%	32%	29.3%	25.3%	1.033	3.653
Q3	0%	16%	30.7%	25.3%	28%	1.058	3.653
Total							10.827

In this section, the mean, standard deviation, and percentage of responses to the statements regarding a safe work environment improvement using BIM are presented. The overall mean for a safe work environment was calculated to be 10.827. The lowest mean corresponds to statement Q1, while the highest means correspond to statements Q2 and Q3.

Table 16. Sample breakdown based on building information modeling (BIM) and improvement of growth opportunities.

F10 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
W1	4%	12%	30.7%	33.3%	20%	1.069	3.533
W2	2.7%	14.7%	32%	33.3%	17.3%	1.031	3.480
W3	4%	14.7%	22.7%	34.7%	24%	1.127	3.600
Total							10.613

In this section, the mean, standard deviation, and percentage of responses to the statements regarding growth opportunities improvement using BIM are presented. The overall mean for growth opportunities was calculated to be 10.613. The lowest mean corresponds to statement W2, while the highest mean corresponds to statement W3.

Table 17. Sample breakdown based on building information modeling (BIM) and improvement of law-abiding behavior.

F11 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
R1	9.3%	13.3%	25.3%	25.3%	26.7%	1.276	3.467
R2	1.3%	21.3%	26.7%	13.3%	37.3%	1.226	3.640
R3	0%	20%	46.7%	18.7%	14.7%	0.922	3.280
R4	1.3%	14%	40%	17.3%	25.3%	1.082	3.493
Total							13.580

In this section, the mean, standard deviation, and percentage of responses to the statements regarding law-abiding behavior improvement using BIM are presented. The overall mean for law-abiding behavior was calculated to be 13.580. The lowest mean corresponds to statement R3, while the highest mean corresponds to statement R2.

Table 18. Sample breakdown based on building information modeling (BIM) and improvement of social dependency.

F12 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
Y1	0%	18.7%	49.3%	22.7%	9.3%	0.863	3.227
Y2	14.7%	20%	30.7%	14.7%	20%	1.324	3.053
Y3	10.7%	20%	28%	25.3%	16%	1.230	3.160
Total							9.440

In this section, the mean, standard deviation, and percentage of responses to the statements regarding social dependency improvement using BIM are presented. The overall mean for social dependency was calculated to be 9.440. The lowest mean corresponds to statement Y2, while the highest mean corresponds to statement Y1.

Table 19. Sample breakdown based on building information modeling (BIM) and improvement of the overall living environment.

F13 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
U1	13.3%	18.7%	25.3%	17.3%	25.3%	1.371	3.227
U2	6.7%	17.3%	22.7%	21.3%	32%	1.287	3.547
U3	1.3%	20%	33.3%	13.3%	32%	1.177	3.547
Total							10.320

In this section, the mean, standard deviation, and percentage of responses to the statements regarding improvement of the overall living environment using BIM are presented. The overall mean for the overall living environment was calculated to be 10.320. The lowest means correspond to statements U1 and U2, while the highest mean corresponds to statement U3.

Table 20. Sample breakdown based on building information modeling (BIM) and improvement of capability development.

F15 statements	Very low	Low	Somewhat	High	Very high	Standard deviation	Mean
M1	1.3%	17.3%	22.7%	40%	18.7%	1.028	3.573
M2	1.3%	20%	14.7%	40%	24%	1.096	3.653
M3	6.7%	20%	14.7%	29.3%	29.3%	1.287	3.547
M4	2.7%	18.7%	24%	13.3%	41.3%	1.258	3.720
Total							14.493

In this section, the mean, standard deviation, and percentage of responses to the statements regarding capability development using BIM are presented. The overall mean for capability development was calculated to be 14.493. The lowest mean corresponds to statement M3, while the highest mean corresponds to statement M4. The analysis of mean values across different dimensions demonstrates that BIM has a particularly strong influence on capability development, law-abiding behavior, and safe work environments. These results indicate that BIM adoption enhances not only technical performance but also organizational and regulatory compliance in residential projects.

5. Assessment of data normality

As previously discussed, when selecting a statistical test, it is essential to determine whether parametric or non-parametric tests should be used. This decision relies on evaluating the normality of the data. One of the primary methods for this assessment is the Kolmogorov-Smirnov (K-S) test. Hypotheses of the Kolmogorov-Smirnov Test: Null Hypothesis (H_0): The distribution of the research variables is normal. Alternative Hypothesis (H_1): The distribution of the research variables is not normal. By conducting the K-S test, we can determine whether the data follows a normal distribution, which directly influences the selection of statistical analysis methods. If the data is normally distributed (H_0 is accepted), parametric tests can be used. However, if the data is not normally distributed (H_1 is accepted), non-parametric tests should be applied. The K-S test for normality of the variables is shown in Table 21.

Table 21. Kolmogorov-Smirnov test for normality of variables.

Variable	Z-statistic	Significance level (Sig)	Result
Residential project management in traditional methods	1.325	0.06	Normal
Necessity and importance of residential project management	1.491	0.023	Normal
Actions and planning in residential project management	1.725	0.005	Non-Normal
Key factors in residential project management	1.956	0.001	Non-Normal
Key objectives in residential project management	1.62	0.011	Non-Normal
Residential project management in domestic and international contexts	1.113	0.154	Normal
Residential project management costs	1.095	0.182	Normal
Fair payment	0.878	0.724	Normal
Safe work environment	1.055	0.216	Normal
Growth opportunities	0.919	0.367	Normal
Law-abiding behavior	1.386	0.043	Non-Normal
Social dependency	1.265	0.082	Normal
Overall living environment	1.144	0.146	Normal
Organizational integrity and cohesion	1.022	0.247	Normal
Capability development	1.112	0.169	Normal

5.1. Implications of data normality results

The Kolmogorov–Smirnov test results indicate that while some variables do not follow a normal distribution, the majority of the constructs meet the normality assumption. This supports the robustness of the regression models applied in this study and justifies the use of both parametric and non-parametric statistical techniques.

6. Analysis of the Kolmogorov-Smirnov test for normality

1. Based on the Kolmogorov-Smirnov normality test, the following observations can be made:

For the variables related to actions and planning, key objectives, key factors, and law-abiding behavior, the significance level is below 5%, indicating that the data do not follow a normal distribution. Therefore, the null hypothesis (H_0) is rejected, and we can accept the alternative hypothesis (H_1: The data are not normally distributed) with 95% confidence.

2. For the remaining variables, the significance level is equal to or greater than 5%, indicating that the data follow a normal distribution.

3. Since the significance level for most variables is greater than 0.05, we do not reject the null hypothesis (H_0) and accept that the distribution of these variables is normal.

7. Linear regression analysis

As previously observed, the 15 dimensions contributing to the impact of Building Information Modeling (BIM) on improving residential project management (case study: Panorama Twin Towers, Pasdaran) were identified through Pearson correlation analysis. Now, we will conduct a linear regression test to develop a predictive linear equation that models the relationship between the dependent variable (residential project management) and the independent variable (BIM implementation). This analysis will help us construct an appropriate structural equation for forecasting the influence of BIM on project management. For this purpose, linear regression analysis is employed to formulate the residential project management process and its 15 dimensions, which include:

- Residential project management in traditional methods
- Necessity and importance of residential project management
- Actions and planning in residential project management
- Key factors in residential project management
- Key objectives in residential project management
- Residential project management in domestic and international contexts
- Residential project management costs
- Fair payment
- Safe work environment
- Growth opportunities
- Law-abiding behavior
- Social dependency
- Overall living environment
- Organizational integrity and cohesion
- Capability development
- Through linear regression modeling, we aim to establish a predictive equation that explains how BIM contributes to improving these key aspects of residential project management.

To examine the relationship between BIM implementation and residential project management performance, a linear regression model was employed. The general form of the regression equation used in this study is expressed as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_n X_n + \varepsilon \tag{2}$$

where in Eq. 2, Y represents the dependent variable (overall residential project management performance), X_1 to X_n denote independent variables related to BIM implementation factors, β_0 is the intercept, β_1 to β_n are regression coefficients indicating the magnitude of influence of each variable, and ε represents the error term. Prior to interpreting the regression results, key diagnostic tests were conducted to validate the underlying assumptions of the linear regression models. Multicollinearity among independent variables was assessed using the Variance Inflation Factor (VIF), with all values remaining below the commonly accepted threshold, indicating no severe multicollinearity issues. Model goodness-of-fit was evaluated using the coefficient of determination (R^2 and adjusted R^2), which reflects the proportion of variance in the dependent variables explained by BIM-related factors. In addition, residual diagnostics were examined to assess normality, linearity, and homoscedasticity, confirming the suitability of the regression models for inferential analysis. The linear regression for BIM is shown in Table 22.

Table 22. Linear regression for BIM in improving residential project management process in domestic and international contexts.

Test	Unstandardized coefficients (B)	Standardized coefficients (Beta)	t	sig
Constant	133.620	-	34.165	0.000
Management in domestic and international contexts	1.606	0.749	4.650	0.000

Linear Regression Test: Building Information Modeling (BIM) in Improving Residential Project Management Process in Domestic and International Contexts and Overall Living Environment Given that the sig value is below 0.05, the corresponding B coefficient can be included in the structural equation. Based on the linear regression results, the predictive model for forecasting the residential project management process both domestically and internationally (Y) using BIM modeling (X) is formulated as Eq. 3.

$$Y = 133.620 + 1.606x_1 \tag{3}$$

This equation represents how BIM (X) influences the management process (Y) in both domestic and international residential projects. Now, for the overall living environment in conjunction with BIM, you would perform a similar regression test to establish the relationship between BIM and the overall living environment (Z) in the project management process. The process would involve analyzing the relationship between BIM and this additional dimension (living environment), using the same statistical framework. If you would like to extend this model to the living environment, you could proceed with the regression analysis as follows:

$$Z = [\text{Constant}] + [\text{Beta coefficient for BIM impact on the living environment}] \times X \tag{4}$$

Table 23. Linear regression test: building information modeling (BIM) in improving residential project management process in domestic and international contexts and overall living environment.

Test	Unstandardized coefficients (B)	Standardized coefficients (Beta)	t	sig
Constant	117.310	-	26.509	0.000
Residential project management in domestic and international contexts (x_1)	1.615	0.291	0.481	5.543
Overall living environment (x_2)	1.571	0.248	0.480	5.305

Interpretation of the Results:

Both Residential Project Management in Domestic and International Contexts (x_1) and Overall Living Environment (x_2) have significant positive impacts on the project management process with sig values less than 0.05, indicating that their B coefficients can be included in the structural equation. Linear regression based on Eq. 4 and Table 23 shows the results mentioned in Eq. 5. The regression equation for predicting the residential project management process (Y) in terms of BIM, domestic/international project management (x_1), and overall living environment (x_2) is formulated as follows:

$$\mathrm{Y} = 117.310 + 1.615\mathrm{x}_1 + 1.571\mathrm{x}_2 \tag{5}$$

This equation shows that BIM (through x_1 and x_2) significantly influences the management process both in domestic/international contexts and in the overall living environment of residential projects. The coefficients (1.615 and 1.571) reflect the strength of this influence.

Table 24. Linear regression test: building information modeling (BIM) in improving residential project management process in domestic and international contexts, overall living environment, and fair payment.

Test	Unstandardized coefficients (B)	Standardized coefficients (Beta)	t	sig
Constant	107.484	-	21.761	0.000
Residential project management in domestic and international contexts (x_1)	1.555	0.271	0.463	5.746
Overall living environment (x_2)	1.595	0.263	0.487	6.055
Fair payment (x_3)	1.010	0.283	0.283	3.573

Interpretation of the Results:

All the variables in Table 24 (Residential Project Management in Domestic and International Contexts (x_1), Overall Living Environment (x_2), and Fair Payment (x_3)) have significant impacts on project management with sig values below 0.05, meaning their B coefficients can be included in the structural equation. The regression equation for predicting the residential project management process (Y) with respect to BIM is formulated as Eq. 6.

$$\mathrm{Y} = 107.484 + 1.555\mathrm{x}_1 + 1.595\mathrm{x}_2 + 1.010\mathrm{x}_3 \tag{6}$$

This equation indicates that BIM significantly influences the project management process through domestic/international project management (x_1), overall living environment (x_2), and fair payment (x_3). The coefficients (1.555, 1.595, and 1.010) represent the respective strength of influence of each variable on the overall management process.

Table 25. Building information modeling (BIM) in improving residential project management process in domestic and international contexts, overall living environment, fair payment, and growth opportunities.

Test	Unstandardized coefficients (B)	Standardized coefficients (Beta)	t	sig
Constant	87.030	-	14.123	0.000
Residential project management in domestic and international contexts (x_1)	1.645	0.239	0.490	6.894
Overall living environment (x_2)	1.847	0.238	0.564	7.769
Fair payment (x_3)	1.387	0.261	0.395	5.310
Growth opportunities (x_4)	1.228	0.263	0.357	4.678

Interpretation of the Results based on Table 25:

All the variables (Residential Project Management in Domestic and International Contexts (x_1), Overall Living Environment (x_2), Fair Payment (x_3), and Growth Opportunities (x_4)) have significant impacts on project management, as indicated by the sig values below 0.05, meaning their B coefficients can be included in the structural equation. The regression equation for predicting the residential project management process (Y) with respect to BIM is formulated as Eq. 7.

$$Y = 87.030 + 1.645x_1 + 1.847x_2 + 1.387x_3 + 1.228x_4 \tag{7}$$

This equation shows that BIM significantly influences the project management process through domestic/international project management (x_1), overall living environment (x_2), fair payment (x_3), and growth opportunities (x_4). The coefficients (1.645, 1.847, 1.387, and 1.228) represent the strength of influence of each variable on the overall management process.

Table 26. Linear regression test: building information modeling (BIM) in improving residential project Management Process in Domestic and International Contexts, Overall Living Environment, Fair Payment, Growth Opportunities, and Capability Development.

Test	Unstandardized coefficients (B)	Standardized coefficients (Beta)	t	sig
Constant	75.832	-	12.292	0.000
Residential project management in domestic and international contexts (x_1)	1.597	0.215	0.475	7.420
Overall living environment (x_2)	1.840	0.214	0.562	8.590
Fair payment (x_3)	1.344	0.236	0.383	5.706
Growth opportunities (x_4)	1.212	0.237	0.352	5.123
Capability development (x_5)	0.857	0.206	0.265	4.158

Interpretation of the Results based on Table 26:

All the variables (Residential Project Management in Domestic and International Contexts (x_1), Overall Living Environment (x_2), Fair Payment (x_3), Growth Opportunities (x_4), and Capability Development (x_5)) have significant impacts on project management, as indicated by the sig values below 0.05, meaning their B coefficients can be included in the structural equation.

The regression equation for predicting the residential project management process (Y) with respect to BIM is formulated as Eq. 8.

$$Y = 75.832 + 1.597x_1 + 1.840x_2 + 1.344x_3 + 1.212x_4 + 0.857x_5 \tag{8}$$

This equation shows that BIM significantly influences the project management process through domestic/international project management (x_1), overall living environment (x_2), fair payment (x_3), growth opportunities (x_4), and capability development (x_5). The coefficients (1.597, 1.840, 1.344, 1.212, and 0.857) represent the strength of influence of each variable on the overall management process.

8. Purpose and importance of regression analysis

The main objective of the regression method is to predict one or more dependent (criterion) onstructs based on one or more independent (predictor) constructs. This method evaluates the simultaneous impact of multiple predictor variables on a dependent variable. Unlike correlation analysis, which only considers pairwise relationships, regression analysis takes into account all variables collectively, allowing for a comprehensive examination of their combined effects.

9. Key applications of regression analysis

Predicting dependent variables using independent variables. Assessing the combined effect of multiple independent variables on a single dependent variable. Utilizing in Path Analysis, which helps in identifying direct and indirect relationships between variables. With the advancement of statistical methods and the emergence of Partial Least Squares (PLS) and Structural Equation Modeling (SEM), the use of traditional regression analysis has declined in some cases. However, regression analysis remains an essential tool in statistical research, particularly when the objective is to develop predictive models and assess the strength of relationships between variables in various scientific and applied fields. The linear regression model for all the variables considered is shown in Fig. 26 and Eq. 9.

Table 27. Linear regression model for all dependent variables related to building information modeling (BIM) in improving residential project management processes.

Regression Test	Unstandardized coefficients (B)	Standard error	Standardized coefficients (Beta)	t	Sig
Constant	3.847	3.000	-	1.282	0.205
X1 - Management Status	1.100	0.074	0.328	14.773	0.000
X2 - Overall Living Environment	1.038	0.073	0.317	14.286	0.000

X3 - Fair Payment	1.210	0.083	0.345	14.612	0.000
X4 - Growth Opportunities	1.032	0.068	0.300	15.122	0.000
X5 - Capability Development	1.055	0.063	0.327	16.821	0.000
X6 - Necessity and Importance	0.928	0.105	0.181	8.857	0.000
X7 - Organizational Integrity and Cohesion	0.943	0.073	0.249	12.856	0.000
X8 - Law-Abiding Behavior	1.025	0.078	0.258	13.221	0.000
X9 - Key Factors	1.239	0.118	0.194	10.465	0.000
X10 - Actions and Planning	1.118	0.092	0.267	12.098	0.000
X11 - Social Dependency	1.036	0.085	0.262	12.225	0.000
X12 - Cost Management	1.018	0.088	0.236	11.576	0.000
X13 - Maintenance Management	0.897	0.081	0.215	11.007	0.000
X14 - Safe Work Environment	0.752	0.095	0.181	7.948	0.000

$$Y=3.847+1.100x1+1.038x2+1.210x3+1.032x4+1.055x5+0.928x6+0.943x7+1.025x8+1.239x9+1.118x10+1.036x11+1.018x12+0.897x13+0.752x14 \tag{9}$$

9.1. Discussion of regression results

The dependent variables examined in this study are grounded in a multi-layered conceptual framework of BIM-enabled project management. These variables are not treated as isolated or redundant outcomes, but as complementary dimensions reflecting different levels of BIM influence. Technical and operational variables capture BIM's direct effects on project execution processes, such as coordination, cost management, scheduling accuracy, and rework reduction. In contrast, organizational and socio-environmental variables, including organizational cohesion, social dependency, law-abiding behavior, fair payment, and overall living environment, represent indirect outcomes arising from improved transparency, information integration, and collaborative decision-making enabled by BIM. The findings of this study extend existing BIM literature by demonstrating that the impact of BIM in residential project management is not limited to technical and operational improvements. In contrast to many previous studies that focus primarily on cost and schedule performance, this research highlights the multidimensional influence of BIM on managerial, organizational, and human-centered factors. The results indicate that BIM functions not only as a digital modeling tool, but also as an integrative management mechanism that enhances coordination, transparency, and organizational capability in residential construction projects. The regression analyses confirm that BIM has a significant and positive impact on residential project management across multiple dimensions. The increasing explanatory power of the models, as additional variables are introduced, indicates that BIM functions as a multidimensional management framework rather than a single technological solution. Variables such as overall living environment, fair payment, and capability development show strong coefficients, highlighting BIM's influence on social, financial, and human-capital-related outcomes in residential projects.

9.2. Main findings and practical implications of BIM adoption

The main findings of this study indicate that Building Information Modeling (BIM) plays a critical role in enhancing residential project management beyond mere technological improvement. While the descriptive statistics and regression analyses quantify BIM's effects, the underlying results reveal several strategic insights relevant to both theory and practice. First, the consistently high mean values across key factors, including planning and execution (F3), management objectives (F5), and coordination in domestic and international contexts (F6), demonstrate that BIM is not limited to design-stage benefits. Instead, it functions as an integrative management platform that improves decision-making accuracy throughout the project lifecycle. This finding highlights BIM's capacity to reduce fragmentation in traditional residential project management, where isolated information sources often lead to delays and inefficiencies. Second, the results related to cost management (F7) and delay mitigation confirm that BIM adoption contributes to more effective resource allocation and schedule control. Although cost-related indicators show moderate mean values compared to planning and coordination factors, this suggests that BIM's financial benefits are primarily realized indirectly through reduced rework, improved clash detection, and enhanced coordination among stakeholders rather than immediate cost reduction alone. Third, the findings associated with fair payment, safe working environments, and organizational integration (F8 and subsequent factors) indicate that BIM adoption also has important socio-organizational implications. By increasing transparency in information flow and task responsibilities, BIM supports fairer payment structures, safer work environments, and stronger organizational cohesion. These outcomes extend the contribution of BIM beyond technical efficiency, positioning it as a tool that enhances the overall quality of project governance in residential developments. Finally, the regression analysis confirms a statistically significant and positive relationship between BIM implementation and overall residential project management performance. This relationship suggests that BIM can serve as a predictive and strategic decision-support tool for project managers, particularly in complex high-rise residential projects such as the Panorama Twin Towers. Collectively, these findings demonstrate that BIM adoption leads to multidimensional improvements- technical, managerial, and organizational—thereby validating its strategic importance for modern residential project management. The main findings of this study reveal that the impact of Building Information Modeling (BIM) on residential project management extends beyond numerical improvements in cost and time indicators and encompasses broader managerial and organizational dimensions. While the statistical analyses quantify these effects, the results collectively indicate BIM's role as an integrative management framework in residential projects. Based on the descriptive statistics (Tables 7–11), BIM demonstrates its strongest influence on planning and execution processes, management actions, and key project objectives. High mean values observed in factors related to actions and planning (F3) and management objectives (F5) confirm that BIM significantly enhances decision-making accuracy, coordination of activities, and alignment of project goals. This finding suggests that BIM is most effective when applied as a proactive planning and control tool rather than being limited to design visualization. The findings related to coordination in domestic and international project management contexts (F6) further emphasize BIM's capability to reduce fragmentation among stakeholders. The relatively consistent mean values across statements H1–H3 indicate that BIM improves information transparency and communication flow, which are critical challenges in high-rise residential projects. This reinforces the argument that BIM functions as a shared information environment that supports integrated project delivery. In terms of cost management (F7), the results show moderate mean values compared to planning-related factors. This suggests that BIM's financial benefits are primarily realized indirectly through reduced rework, improved coordination, and better planning accuracy rather than immediate cost reductions alone. Consequently, cost optimization should be interpreted as an outcome of improved managerial processes enabled by BIM. Importantly, the findings associated with fair payment, safe working environment, organizational integration, and capability development (F8 and subsequent factors) highlight BIM's socio-managerial implications. As reflected in Tables 14 and 15, BIM contributes to increased transparency, clearer role definitions, and improved information accessibility, which in turn support fairer payment mechanisms, safer work environments, and stronger organizational cohesion. These results align with the conceptual BIM evaluation framework presented in the study, demonstrating that BIM adoption positively affects both technical performance and the quality of organizational and working conditions in residential projects. Overall, the regression analysis confirms a significant and positive relationship between BIM implementation and residential project management performance. The main findings indicate that BIM adoption leads to multidimensional improvements—technical, managerial, and organizational, thereby validating its strategic importance for complex residential developments such as the Panorama Twin Towers.

9.3. Generalizability and case study limitations

This research is based on a single high-rise residential project, which inherently limits the statistical generalizability of the findings. The Panorama Twin Towers project is located in an urban context and is characterized by a relatively large scale, complex coordination requirements, and a structured management system. These project-specific characteristics may influence the observed impact of BIM on project management outcomes. However, the objective of this study is not statistical generalization, but analytical generalization. The identified relationships between BIM implementation and improvements in cost control, scheduling accuracy, coordination, and organizational integration are likely to be transferable to residential projects with similar characteristics, particularly in developing-country contexts where traditional management practices and digital transformation challenges are comparable. Factors such as project location, organizational structure, level of BIM maturity, and stakeholder experience can affect the extent to which BIM delivers performance improvements. For instance, large-scale residential developments with multiple stakeholders and complex interfaces are more likely to benefit from BIM-based coordination and information integration than smaller projects. Therefore, while the quantitative results are specific to the studied case, the underlying mechanisms through which BIM enhances project management remain relevant for a broader range of residential projects.

10. Limitation

The study relies on self-reported questionnaire data, which may be subject to perceptual and response bias. However, this approach is commonly used in construction management research due to the limited accessibility of objective performance records. To mitigate this limitation, the questionnaire was distributed among experienced professionals, including project managers, site engineers, and technical staff directly involved in the execution of the Panorama Twin Towers project. Future studies may enhance robustness by integrating objective performance metrics or adopting mixed-method approaches combining quantitative and qualitative data.

11. Conclusion

The findings of this research indicate that Building Information Modeling (BIM), as an innovative technology in the construction industry, has a significant impact on improving the management of residential projects. Using the Analytic Network Process (ANP), the key factors influencing the successful implementation of BIM were identified and weighted. The results suggest that BIM contributes to reducing execution costs, optimizing project scheduling, enhancing construction quality, improving coordination among project stakeholders, and minimizing execution conflicts. Additionally, this technology increases information transparency, enhances workforce productivity, and improves decision-making processes in construction projects. Statistical analyses and ANP computations revealed that the most critical factors for successful BIM implementation include: Optimization of execution costs; improved coordination and communication among stakeholders; reduction of errors and rework; enhanced accuracy in design and execution; improved project planning and control processes. Furthermore, case study analyses demonstrated that construction projects utilizing BIM have superior performance in resource management, waste reduction, and final quality compared to traditional projects. Recommendations: Based on these findings, it is recommended that BIM be adopted as a standard approach in residential projects, with necessary measures taken to promote awareness, provide training, and develop both software and hardware infrastructure. The following practical recommendations can help accelerate BIM adoption:

- Developing specialized training programs for project managers and engineers

- Establishing supportive regulations and policies to facilitate BIM integration
- Integrating BIM with other project management systems to enhance efficiency
- Future research directions
- Future studies can focus on:
- Operational challenges of BIM implementation
- Acceptance and adoption rates of BIM across various projects
- Its impact on overall construction industry productivity
- Comparisons between BIM and other project management methodologies
- Additionally, research on BIM applications in infrastructure projects, public buildings, and commercial constructions could further expand its practical use cases.
- Final thoughts

These conclusions are strongly supported by the descriptive and regression analyses presented in this study, which demonstrate BIM's multidimensional impact on residential project management performance. This study emphasizes that BIM should not be regarded merely as a technological tool but as a transformative shift in the construction industry. The adoption of BIM in residential projects can lead to:

- Optimized resource management
- Cost reduction
- Increased productivity
- Overall project performance enhancement
- Ultimately, BIM plays a crucial role in modernizing and advancing the construction industry, paving the way for a more efficient, cost-effective, and sustainable future in project management.

Statements & Declarations

Author contributions

Masoud Ahmadvand: Investigation, Formal analysis, Data curation, Software, Writing - Original Draft.

Hossein Eghbali: Project administration, Resources, Writing - Review & Editing.

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Data availability

The data presented in this study will be available on request from the corresponding author.

Declarations

The authors declare no conflict of interest.

Appendix A – Raw questionnaire format

Please indicate the extent to which you believe Building Information Modeling (BIM) contributes to each of the following aspects of residential project management.

Scale:

1 = Very Low 2 = Low 3 = Moderate 4 = High 5 = Very High

F1. BIM in Traditional Project Management

- A1. BIM reduces errors compared to traditional project management methods.
- A2. BIM improves coordination among project stakeholders compared to traditional approaches.

F2. Necessity and Importance of BIM

- B1. BIM is essential for improving residential project management efficiency.

- B2. BIM plays a key role in modern residential construction projects.

F3. Actions and Planning

- C1. BIM improves planning accuracy in residential projects.
- C2. BIM enhances scheduling and sequencing of construction activities.
- C3. BIM supports better decision-making during project execution.

F4. Key Factors

- D1. BIM improves cost control in residential project management.
- D2. BIM reduces rework and construction conflicts.

F5. Key Objectives

- E1. BIM contributes to achieving project objectives within the planned timeframe.
- E2. BIM improves quality management in residential projects.

F6. Domestic and International Contexts

- H1. BIM facilitates alignment with international project management standards.
- H2. BIM improves coordination in complex residential projects.
- H3. BIM supports benchmarking against global best practices.

F7. Project Management Costs

- K1. BIM reduces overall residential construction costs.
- K2. BIM improves financial control during project execution.

F8. Fair Payment

- L1. BIM improves transparency in payment processes.
- L2. BIM supports timely payments to contractors and suppliers.
- L3. BIM reduces disputes related to financial claims.

F9. Safe Work Environment

- Q1. BIM enhances safety planning in construction sites.
- Q2. BIM reduces workplace accidents.
- Q3. BIM improves hazard identification and risk management.

F10. Growth Opportunities

- W1. BIM enhances professional skill development.
- W2. BIM creates new career opportunities in project management.
- W3. BIM supports organizational learning.

F11. Law-Abiding Behavior

- R1. BIM improves compliance with construction regulations.
- R2. BIM supports adherence to legal and contractual requirements.
- R3. BIM reduces violations during project execution.

F12. Social Dependency

- Y1. BIM enhances collaboration among project stakeholders.
- Y2. BIM strengthens trust and interdependence within project teams.

F13. Overall Living Environment

- U1. BIM improves environmental quality in residential projects.
- U2. BIM enhances sustainability performance of residential buildings.
- U3. BIM contributes to better living conditions for occupants.

F14. Organizational Integrity and Cohesion

- O1. BIM improves organizational coordination.
- O2. BIM enhances communication across project teams.

F15. Capability Development

- M1. BIM improves technical capabilities of project teams.
- M2. BIM enhances problem-solving skills.
- M3. BIM supports innovation in residential project management.
- M4. BIM strengthens long-term organizational competencies.

References

[1] Bakhtiari, A., Naghash Toosi, H., Sebt, M. H. A practical implementation method for risk management process and its application in construction project management – Case study: 1000-unit residential complex. In: The First National Conference on Engineering and Management of Infrastructures; 2009 Oct 23–24; Tehran, Iran. p. 10–19.

[2] Gharaibeh, L., Matarneh, S., Lantz, B., Eriksson, K. Quantifying the influence of BIM adoption: An in-depth methodology and practical case studies in construction. Results in Engineering, 2024; 23: 102555. doi:10.1016/j.rineng.2024.102555.

[3] Succar, B. Building information modelling framework: A research and delivery foundation for industry stakeholders. Automation in Construction, 2009; 18: 357–375. doi:10.1016/j.autcon.2008.10.003.

[4] Wang, T., Chen, H.-M. Integration of building information modeling and project management in construction project life cycle. Automation in Construction, 2023; 150: 104832. doi:10.1016/j.autcon.2023.104832.

[5] Parsamehr, M., Perera, U. S., Dodanwala, T. C., Perera, P., Ruparathna, R. A review of construction management challenges and BIM-based solutions: perspectives from the schedule, cost, quality, and safety management. Asian Journal of Civil Engineering, 2023; 24: 353–389. doi:10.1007/s42107-022-00501-4.

[6] Das, K., Khursheed, S., Paul, V. K. The impact of BIM on project time and cost: insights from case studies. Discover Materials, 2025; 5: 25. doi:10.1007/s43939-025-00200-2.

[7] Stabryła, R., Grudzińska, M. Smartphone-Based Virtual Reality in Residential Architecture: Enhancing Spatial Understanding Through Immersive BIM+ VR Visualization. Sustainability, 2025; 17: 9959. doi:10.3390/su17229959.

[8] Jang, Y., Park, J., Kim, Y., Yu, K.-H. Energy Savings, Carbon-Equivalent Abatement Cost, and Payback of Residential Window Retrofits: Evidence from a Heating-Dominated Mid-Latitude City—Gyeonggi Province, South Korea. Buildings, 2026; 16: 71. doi:10.3390/buildings16010071.

[9] Kaur, R., Mwambegele, B. J., Abraham, A. G., Basheer, S. A., Garia, S. A comprehensive review on building information modelling (BIM), its implementations and applications. Discover Civil Engineering, 2025; 2: 177. doi:10.1007/s44290-025-00342-5.

[10] Torres, K., Sánchez, O., Castañeda, K., Noguera, M., Carrasco-Beltrán, D., Vidal-Méndez, S., Lozano-Ramírez, N. E. Exploring the knowledge structure of building information modeling (BIM) adoption in construction scheduling: A bibliometric analysis from 2008 to 2024. Ain Shams Engineering Journal, 2025; 16: 103446. doi:10.1016/j.asej.2025.103446.

[11] Pérez, Y., Ávila, J., Sánchez, O. Influence of BIM and Lean on mitigating delay factors in building projects. Results in Engineering, 2024; 22: 102236. doi:10.1016/j.rineng.2024.102236.

[12] Ligarda-Samanez, C. A., Huamán-Carrión, M. L., Cabel-Moscoso, D. J., Marlene Muñoz Sáenz, D., Antonio Martinez Hernandez, J., Garcia-Espinoza, A. J., Fermín Calderón Huamaní, D., Carrasco-Badajoz, C., Pino Cordero, D., Sucari-León, R., Aroquipa-Durán, Y. Technological Innovations in Sustainable Civil Engineering: Advanced Materials, Resilient Design, and Digital Tools. Sustainability, 2025; 17: 8741. doi:10.3390/su17198741.

[13] Erdene, K., Kim, B.-G., Lee, S.-H. ADAPTE Process-Based Strategic Framework Development for National BIM Adoption: The Case for Sustainable Advancement in Mongolia. Sustainability, 2026; 18: 71. doi:10.3390/su18010071.

[14] Jing, W., Alias, A. H. Key Factors for Building Information Modelling Implementation in the Context of Environmental, Social, and Governance and Sustainable Development Goals Integration: A Systematic Literature Review. Sustainability, 2024; 16: 9504. doi:10.3390/su16219504.

[15] Attia, A. R. The impact of integrating artificial intelligence and Building information modeling (BIM) systems on the development of construction methodologies. Journal of Umm Al-Qura University for Engineering and Architecture, 2025; 16: 1537–1554. doi:10.1007/s43995-025-00193-2.

[16] Si, S., Yao, Y., Wu, J. Artificial Intelligence in Urban Planning: A Bibliometric Analysis and Hotspot Prediction. Land, 2025; 14: 2100. doi:10.3390/land14112100.

[17] Ghorbanalipour, R., Ahmadvand, A., Ahmadvand, M., Eghbali, H. Designing human health risk management model for dam construction projects. Civil Engineering Journal, 2018; 4: 2173–2185. doi:10.28991/cej-03091148.

[18] Raza, M. S., Tayeh, B. A., Abu Aisheh, Y. I., Maglad, A. M. Potential features of building information modeling (BIM) for application of project management knowledge areas in the construction industry. Heliyon, 2023; 9: doi:10.1016/j.heliyon.2023.e19697.

[19] Omrany, H., Ghaffarianhoseini, A., Chang, R., Ghaffarianhoseini, A., Pour Rahimian, F. Applications of Building information modelling in the early design stage of high-rise buildings. Automation in Construction, 2023; 152: 104934. doi:10.1016/j.autcon.2023.104934.

[20] Okimi, T. O. Human centric digital twins for sustainable supply chain in construction. Smart Construction and Sustainable Cities, 2025; 3: 31. doi:10.1007/s44268-025-00078-2.

[21] Luan, B., Feng, X. Artificial intelligence in Smart Buildings: a bibliometrics-based visualization analysis. Journal of Asian Architecture and Building Engineering, 2025; 1–25. doi:10.1080/13467581.2025.2552448.

[22] Sacoto-Cabrera, E. J., Perez-Torres, A., Tello-Oquendo, L., Cerrada, M. IoT, AI, and Digital Twins in Smart Cities: A Systematic Review for a Thematic Mapping and Research Agenda. Smart Cities, 2025; 8: 175. doi:10.3390/smartcities8050175.

[23] Chen, Y., Baddeley, M. Collaborative Building Information Modelling (BIM): Insights from Behavioural Economics and Incentive Theory. London (UK): Royal Institution of Chartered Surveyors (RICS); 2015. Report No.: 20200.

[24] Smith, P. BIM Implementation – Global Strategies. Procedia Engineering, 2014; 85: 482–492. doi:10.1016/j.proeng.2014.10.575.