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DIGITAL TRANSFORMATION OF THE CONSTRUCTION DESIGN BASED ON THE BUILDING INFORMATION MODELLING

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Abstract:

Background: The construction sector experiences an active digital evolution which Building Information Modelling (BIM) operates as essential technology to enhance design operations and project management and maintain better coordination between teams. **Methods:** The research used a quantitative approach to gather information through structured questionnaires which construction professionals including engineers and architects and project managers completed. The research team used purposive sampling to pick study participants who had direct experience working with BIM systems. The research instrument applied a 5-point Likert scale which evaluated BIM operational methods and fundamental BIM components including design efficiency and clash detection and visualization and collaboration and cost reduction and project success metrics. and Pearson correlation and multiple regression analysis to investigate the connections between different variables. **Results:** Projects that employ BIM will see significantly improved performance (i.e., example; clash detection (86.5%), visualization (84.1%), accuracy of the design (82.2%)). There is a strong positive correlation between BIM elements and the performance of the project as determined by correlation analysis (R=0.79). A regression also indicates that BIM can be accounted for as having contributed to the variations in project performance (R^2=0.62). The role of design efficiency and clash detection are two important BIM elements that have been directly correlated to the success of construction based projects and their performance. **Conclusion:** Therefore, based on the findings of this study, it can be concluded that BIM serves a vital function in enhancing the construction process as well as improving project performance by increasing its efficiency.

Keywords: Building Information Modelling (BIM), Digital Transformation, Construction Industry, Project Performance, Design Efficiency.

1. Introduction

Digital technologies have created a fundamental transformation in the construction industry because

Building Information Modelling (BIM) stands as the most effective tool which transforms conventional construction methods [1]. Building Information Modeling (BIM) creates smart digital models which generate three-dimensional representations that contain all physical and functional details of construction projects [2]. Different project stakeholders including engineers and architects and project managers to share a digital workspace which strengthens their teamwork while they make decisions throughout their project development process [3]. The traditional building methods produce errors and design conflicts and project delays and higher expenses because different stakeholders fail to share information properly and they lack proper coordination [4,5]. The existing limitations block project teams from achieving their goals which results in reduced work efficiency and leads to problems with meeting deadlines and upholding product quality standards [6]. BIM functions as a single storage system which enables all project information to stay updated through real-time access to information. The system unites different elements which help people work better together while it makes construction planning and execution more predictable [2,7].

The worldwide adoption of BIM technology has grown during the last ten years because it helps businesses boost their operational efficiency while they face lower construction-related dangers [8]. Developed nations have established BIM as their official construction method but developing areas start to use BIM through their available technology and their construction team's skills [9]. The construction industry has adopted BIM at different rates but everyone understands it serves as the main engine for digital transformation in their sector [10]. A shared digital model provides all stakeholders with equal access to current data which helps them avoid communication breakdowns while they make better choices [11]. Integrated communication system protects project goals from being disturbed through its ability to handle system changes which maintain project objective alignment [5,12]. Multiple advantages but users face various problems during their BIM adoption process. BIM integration into construction operations becomes slower because these barriers exist in developing nations [13]. The future advancement requires understanding BIM implementation affects project delivery because organizations need to determine their current BIM system adoption level.

The study evaluates BIM operational systems for construction digital transformation through assessment of its user activity and its influence on essential project performance metrics. The research investigates essential elements which include design efficiency together with visualization and collaboration and clash detection and cost reduction. The research reveals how BIM systems improve construction work through their ability to shorten project durations which leads to better project delivery methods. The construction field has experienced a major technological breakthrough through BIM which enables builders to move from established methods toward a unified system that uses data for operation.

2. Materials and Methods

2.1 Research Design and Approach

A quantitative research design to study how Building Information Modelling (BIM) influences construction design processes and their resulting project outcomes. Descriptive explanatory method to study how people use BIM while they worked to identify links between important variables [14]. The research team selected quantitative methods because they enable researchers to measure perceptions through numbers and perform statistical analysis for relationship testing. The research study analyzes construction industry feedback by changing its subjective content into numerical values to conduct organized data examination. We used structured indicators to evaluate BIM-related elements which included design efficiency and clash detection and visualization and collaboration and cost reduction [15]. The method produces consistent results which helps reduce bias and produces more reliable data.

2.2 Study Population and Sampling

Construction professionals work as engineers and architects and project managers to perform their duties through BIM-based design and project execution. These professionals because they possess direct knowledge about construction planning and coordination and implementation processes [16]. Purposive sampling to select participants who possessed both theoretical knowledge about BIM and actual experience working with BIM systems. The research team selects participants who meet specific criteria because this approach leads to better data results from people who understand the study topic well [17]. Different construction sector members who work in various roles at different career stages to provide equal representation of BIM adoption throughout the industry. Confidence in their results through the involvement of experienced professionals who could properly assess real-world BIM application success rates. Industry professionals need to participate in this research because their specialized knowledge will lead to important findings about the industry [18].

2.3 Data Collection Instrument

Primary data by using a structured questionnaire which they created through their analysis of previous studies about BIM and construction management [19]. Questionnaire contained two primary elements which collected demographic data and information about BIM operations. The demographic section included gender, profession, and years of experience, while the second section measured BIM usage and its impact on project performance. A 5-point Likert scale was used, ranging from 1 (Strongly Disagree) to 5 (Strongly Agree), to capture respondents' perceptions [8,20]. The instrument contained essential variables which included design efficiency and clash detection and visualization and collaboration and project performance and cost reduction. The structured format ensured clarity, consistency, and ease of response for participants. The method allowed researchers to transform qualitative data into numerical codes which they could apply for statistical analysis [21,22].

2.4 Data Analysis and Correlation Model

Statistical methods which included descriptive analysis and inferential statistical techniques to study construction and engineering data. The research team used frequency and percentage and mean values to show how respondents behaved and how they used BIM technology [23]. The research team conducted Pearson correlation analysis to find out how different variables connect with each other [24,25]. The formula for correlation coefficient exists in the following form:

$$r = \frac{\sum(X-\bar{X})(Y-\bar{Y})}{\sqrt{\sum(X-\bar{X})^2 \sum(Y-\bar{Y})^2}}$$

Correlation coefficient exists as r while X represents BIM variables which include design efficiency and clash detection and visualization and collaboration and cost reduction and Y shows the performance of construction projects. The value of r ranges from -1 to +1, indicating negative or positive relationships [26]. Multiple regression analysis to identify how BIM variables together affected the performance of construction projects. Statistical significance through a 95% confidence level which required p-values below 0.05 to produce dependable and trustworthy results [27].

3.Results

3.1 Demographic Distribution of Respondents

Table 1. Demographic Distribution of Respondents

Category	Sub-category	Percentage (%)
Gender	Male	60.5
	Female	39.5

Profession	Engineer	57.8
	Architect	24.9
	Project Manager	17.3
Experience	< 5 years	35.1
	≥ 5 years	64.9

The study on BIM-based digital transformation in construction design collected respondent demographic information which appears in **Table 1.** The study shows that construction industry continues to attract more men than women because 60.5% of respondents were male while only 39.5% were female. The research shows that engineers make up most of the participants at 57.8% while architects represent 24.9% and project managers complete the group with 17.3% which creates a varied sample of essential BIM implementation stakeholders. Most respondents in the study have worked in their profession for more than five years because 64.9% of them. Most respondents in the study have worked in their profession for more than five years because 64.9% of them. The research collected data from experienced workers together with new entrants which establishes strong evidence for BIM adoption effects on construction project outcomes.

3.2 BIM Usage Level Among Respondents

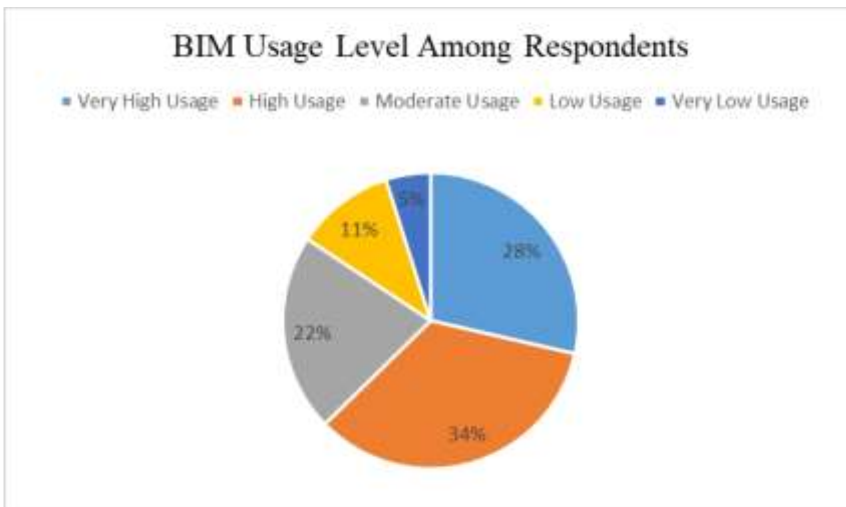

Figure 1. BIM Usage Level Among Respondents.

In **Figure 1** presents data which shows how much Building Information Modelling (BIM) technology users have adopted for their construction design work. The study found that most participants used BIM extensively because 34.1% of them used it at high levels and 28.6% used it at very high levels which shows they adopted BIM technology as standard practice in their work. The data shows that 21.6% of users operate at moderate levels which indicates that a significant number of people remain in their initial stages of adoption. The survey results showed that only 10.8% of participants used BIM tools at minimal levels while 4.9% used them at extremely low levels which shows they did not use BIM tools frequently.

3.3 BIM Impact on Project Performance

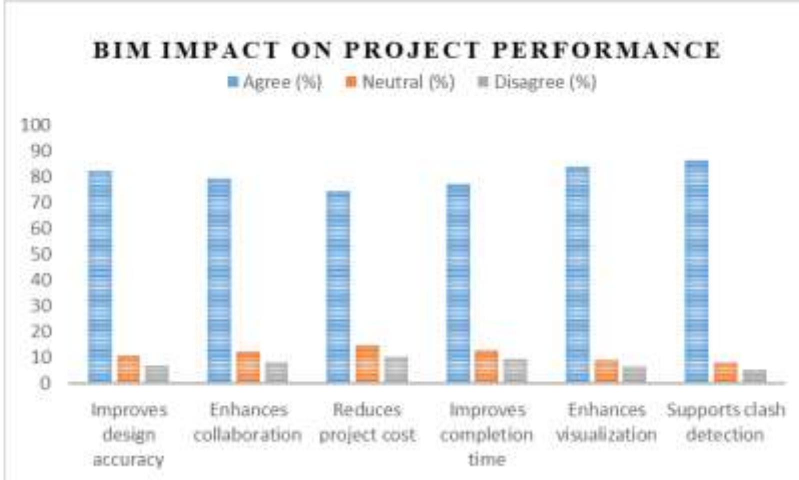

Figure 2. BIM Impact on Project Performance.

The **Figure 2** in Building Information Modeling (BIM) effects on project success through their survey responses. The research results show that every performance metric received strong positive consensus from all respondents. The data shows that most people believe BIM helps them find clashes in their work while showing them better visual representations of their designs. The data shows that users find BIM helpful for making their designs clearer and for finding potential conflicts during the design process. The data shows that users find BIM helpful for making their designs clearer and for finding potential conflicts during the design process. Research participants showed agreement that BIM allows users to detect clashes at a rate of 86.5% and helps them visualize designs better at 84.1%, which shows its ability to improve design visibility and conflict detection. Research participants showed agreement that BIM allows users to detect clashes at a rate of 86.5% and helps them visualize designs better at 84.1%, which shows its ability to improve design visibility and conflict detection. The results showed that 82.2% of participants agreed BIM technology improved their design work accuracy.

3.4 Ranking of BIM Factors

Table 2. Ranking of BIM Factors.

Rank	BIM Factor	Mean Score	Interpretation
1	Clash Detection	4.30	Very High Impact
2	Design Efficiency	4.32	Very High Impact
3	Project Performance	4.25	High Impact
4	Visualization	4.21	High Impact
5	Collaboration	4.18	High Impact
6	Cost Reduction	4.05	Moderate Impact

The **Table 2** shows the main Building Information Modelling (BIM) factors which receive their ranking through average scores and users' opinions about their effect on construction design and project results. The research found that design efficiency (mean = 4.32) and clash detection (mean = 4.30) stand as the most influential elements which both fall under the category of very high impact. The research shows that design efficiency and clash detection work as essential elements which improve design quality while reducing errors. The research identified project performance (4.25) and visualization (4.21) and collaboration (4.18) as top-rated factors which show how BIM improves team coordination and communication and operational efficiency. The research shows that organizations view cost reduction as a moderate factor which affects their operations through indirect financial advantages which become visible after a certain period.

3.5 Correlation Matrix of BIM Variables

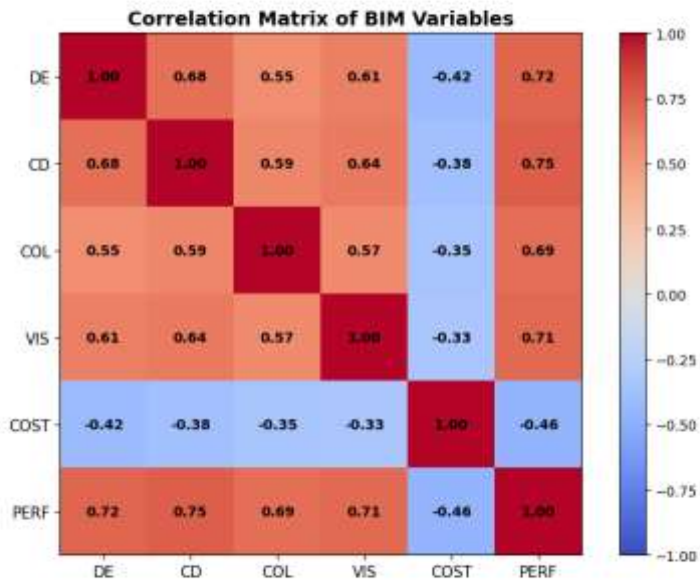

Figure 3. Correlation Matrix of BIM Variables.

Table 3. Regression Model Summary.

Model	R	R^2	Adjusted R^2	F-value	Sig.
Model 1	0.79	0.62	0.60	52.84	0.000

In **Table 3** and **Figure 3** present the regression model summary which shows how BIM elements affect construction project success metrics. The model establishes a strong positive relationship through R = 0.79 which proves independent BIM variables strongly affect the dependent variable. The coefficient of determination (R^2 =0.62) shows that 62% of project performance changes become explainable through the chosen BIM elements which show strong explanatory abilities. The model shows reliability because the adjusted R^2 value of0.60 stays unchanged when the system counts its predictors. The research model shows an F-value of 52.84 which stands as a high number while the Sig. = 0.000 value proves the model achieves statistical significance at 95% confidence level.

4. Discussion

The research findings show Building Information Modelling (BIM) technology enhances construction design methods and produces better results in construction projects. The study reveals that construction industry maintains its traditional male dominance because researchers found 60.5% male workers and 39.5% female workers in the industry. The workforce distribution shows that male employees continue to dominate the industry because they primarily perform technical work and field-based duties [3,28]. The professional background of respondents shows that engineers form the largest group with 57.8% while architects make up 24.9% and project managers represent 17.3%. The information shows that most of the data comes from people who actively participate in design work and planning activities and execution tasks, which produces answers based on technical knowledge and real-world experience. The study shows that most respondents 64.9%, have at least five years of work experience, but the rest, 35.1%, have less than five years of experience. The team consists of experienced professionals and new team members who provide a complete assessment of BIM implementation because they bring both hands-on experience and fresh industry perspectives [29].

The research findings show that the analyzed environment has already achieved a high level of digital adoption based on their BIM usage patterns. The study showed that 34.1% of respondents used BIM frequently while 28.6% of respondents used it at a very high level which demonstrates that many professionals now use BIM as a regular part of their work activities. Organizations have started to use this technology for their operations while they also dedicate resources to fully implement it into their construction processes [5,13,30]. BIM remains unequal because moderate users make up 21.6% of users while low users represent 15.7% of the population. Organizations experience different levels of implementation because they possess different amounts of resources and they provide various training options and they have different software tool access and institutional backing. BIM technology now operates at a higher level but the building sector continues to implement it through progressive adoption methods [31].

The results related to project performance clearly show that BIM has a strong positive influence on multiple aspects of construction work. The highest level of agreement is observed in clash detection (86.5%) and visualization (84.1%), highlighting BIM's effectiveness in identifying design conflicts and improving visual understanding of projects before construction begins. Designers can improve their decision-making during the design phase through this system because it helps them prevent rework [7]. Communication system between engineers and architects and project managers becomes better through BIM because 79.5% of people agree with this statement which shows BIM helps them communicate effectively through digital platforms. The use of BIM technology leads to improved project delivery times according to 77.3% of respondents and it also decreases project expenses according to 74.6% of respondents. BIM become apparent during extended construction projects because the system shows strong results for design and coordination enhancement.

BIM factors further explains the relative importance of different dimensions of BIM application. The evaluation shows that design efficiency achieves the top average rating of 4.32 which makes it the most important factor while clash detection follows closely with a mean score of 4.30. The research shows that BIM achieves its best performance through enhancing design quality and reducing construction mistakes which occur during the initial stages of building projects [32]. The three main factors which influence BIM success include project performance (4.25), visualization (4.21), and collaboration (4.18) through their ability to improve stakeholder coordination and communication and workflow efficiency. Cost reduction area achieved a 4.05 score which proves it stands at a lower position because financial gains do not become obvious right away. The financial advantages of cost reduction appear after companies finish their implementation process while their organizational structure reaches maturity and their projects become more extensive [3]. BIM factors directly affect how well construction projects perform according to the research findings [33]. The research findings demonstrate that better BIM implementation leads to improved project results through their established strong positive relationship. The research results prove that BIM functions as a vital tool which helps construction teams achieve better operational efficiency through improved design precision and reduced mistakes and enhanced teamwork and accelerated project completion.

5. Conclusion

This study demonstrates that Building Information Modelling (BIM) provides essential benefits which improve construction design workflows and improve all aspects of project delivery. Industry professionals use BIM for their work because they want to improve their design work and their ability to identify clashes and their visualization capabilities and teamwork skills. Project accuracy while it reduces errors and improves coordination which results in faster project completion. The cost advantages from this approach seem to be minimal but organizations need to wait for extended periods before they start seeing these advantages.

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