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Design Errors' Impact on Construction Project Costs

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Abstract: The construction industry is facing significant issues due to design errors, which can result in cost overruns, rework and safety hazards. Despite strict rules and procedures, errors are still prevalent and organisations need to address the problem adequately. This research aimed to investigate the impacts of design errors on the cost of a construction project. To achieve this, three objectives were set, namely (1) to identify the cause of design errors in the construction industry, (2) to investigate the impacts of design errors on construction projects and (3) to propose ways to mitigate design errors. A quantitative methodology and simple random sampling were used to collect and analyse data from architects, engineers, contractors and quantity surveyors. A total of 159 responses were collected. They were then analysed using descriptive, inferential statistics and the relative importance index (RII). The results indicated that human-related factors were significant contributors to these errors. The study also identified that design errors affected overall project cost, delayed project completion and decreased project quality. The utilisation of 3D modelling software, documenting and tracking design changes and using experienced and qualified design professionals is recommended to mitigate these risks. This study underscores the critical role of design in construction project success and provides recommendations for preventing design errors and improving project outcomes.

Keywords: Design errors, Impacts, Project cost, Quality, Construction industry

INTRODUCTION

The construction industry's growth is significantly hindered by a range of complex challenges, including budget and schedule overruns, health and safety issues, low productivity and workforce shortages (Abioye et al., 2021), necessitating proper planning and coordination for both pre- and post-construction stages (RIBA [The Royal Institute of British Architects], 2020). This is consistent with Ndekugri, Ankrah and Adaku (2022), who stressed the importance of the design coordination role at the pre-construction stage.

Collaboration is essential to delivering blueprints because designing and building a structure requires different professionals. To illustrate, an owner and architect should work together to create building plans. The architect

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takes the project owner's ideas and requirements for the building's layout and use and turns them into specifications for contractors, sub-contractors and suppliers to follow. During the construction process, contractors and consultants may have different goals. The contractor may have different perspectives when studying and transferring the drawings into the actual product, which can lead to design errors.

Design errors caused by competing priorities are a common cause of variance. According to Lee et al. (2024), design-related challenges have become one of the most critical factors contributing to disputes and project failure. Errors can hurt the project's cost, schedule, safety and performance. The examples of errors are unrealistic design and expectations, a tight schedule required by clients, design input information error, unreasonable intervention on design, poor design ability of design development company, poor design skills of designers, noncompliance with standard requirements and errors in site geological survey document, changes to design-related laws/regulations or standards/codes.

Design errors are often overlooked, leading to numerous issues. Han, Love and Peña-Mora (2013) note that design errors cause the most rework. When an issue is found, extra time and resources are needed to fix it (Pan and Zhang, 2023). Besides, poor designs cause several significant accidents, including the deaths of workers and the public. Quality is sacrificed for time and cost. Despite strict rules, regulations and standards, errors spread in the design process (Fatawu, Sidik and Fortunatus, 2020; Mao et al., 2019). Due to this, systemic errors often take time to appear (Love et al., 2019). After a while, these errors are found, and more work is needed, increasing the amount of work left to do. Long-term errors require more work to fix (Seymour, 2020).

Thus, construction workers must know the additional cost of waste required to fix problems like design errors (Jafari, Sharyatpanahi and Noorzai, 2021). Pan and Zhang (2023) mention that design modifications, errors and omissions caused additional costs to the project. Given the impacts of design errors on the cost of a construction project, this research was conducted to (1) identify the causes of design errors in the construction industry, (2) investigate the impacts of design errors on construction projects and (3) propose ways to mitigate the design errors.

LITERATURE REVIEW

Characteristics of the Construction Industry

The construction industry is dynamic and unique. The industry encompasses both forward and backward links with other industries, emphasising its beneficial and necessary role in boosting the economy (Sakib, 2021; Chia et al., 2012). commercial and residential areas, highways, dams, playgrounds and stadiums, healthcare facilities, ports, railways, airports, communication facilities, power generators and supplying stations are examples of projects that could contribute to the economic growth and are made possible by the socio-economic infrastructure utilised by the construction sector (Dehdasht et al., 2022). Nonetheless, the construction industry is complicated with various stakeholders, namely contractors, sub-contractors, suppliers, project managers, clients and designers. Each stakeholder's requirements and feedback can lead to design changes that increase the likelihood of cost overruns.

Construction projects differ from other industries in their uniqueness and complexity, number of people involved, amount of money needed, the pace of change, length of time to complete and the possibility of bad weather (Sakib, 2021; Dehdasht et al., 2022). These differences might significantly impact the workflow, leading to delays and additional costs. According to Abdelrazik and Marzouk (2021), poor workflow and execution waste a country's maintenance budget. In addition, Dekker (2017) noted that design errors often result from improper information use or lack of access. Human errors like poor time management, inaccurate measurements and inconsistent application can also cause these issues. Gurgun and Koc (2023) defined design errors as incompleteness or inconsistent implementation.

Construction Project Failure

Project failures have received more attention than successes (Dick-Sagoe et al., 2023). Failure does not indicate abandoning a project. Instead, failure encompasses the inability to meet key objectives, such as cost, schedule, quality and scope (Gamil and Rahman, 2020; Keshk, Maarouf and Annany, 2018). A number of previous studies indicate that factors contributing to project failures vary. Mahazir et al. (2024) add a failed construction project as failing to meet the stakeholder requirements in implementing building information modelling (BIM) execution plans (BEPs) within the architecture, engineering and construction (AEC) industry. Designers might ignore stakeholders' requirements in terms of safety, health and environment, cost overrun, time overruns and quality defects, which leads to the stakeholders' dissatisfaction, dispute and litigation (Asiedu and Ameyaw, 2021; Shoar et al., 2023). Gomarn and Pongpeng (2018) found construction projects fail to meet their goals, and their failure can result in financial losses, legal issues and reputational damage to stakeholders.

Amongst the common causes are poor governance, embezzlement of project funds, and the lack of competence of the project managers (Gamil and Rahman, 2020). Meanwhile, studies conducted by Eja and Ramegowda (2020) revealed factors, including poor financial capacity, inaccurate costing and corruption, incompetence and lack of knowledge, poor planning and estimation, poor communication, poor contracting and contractor practices, frequent design scope changes and errors, socio-cultural and political interference, poor leadership and corruption. These factors can significantly impact stakeholders and communities (Ackah, 2020; Palma-Oliveira et al., 2018) as they erode trust, reduce business opportunities, and restrict future investments (Murunga, 2023; Fullerton et al., 2021). For example, delays or budget overruns in projects can diminish credibility, prompting investors to withdraw financial support and putting subsequent projects at risk (Murunga, 2023; Ajayi, 2022). This pattern of repeated failures shows the critical need for comprehensive risk management strategies that not only address immediate concerns but also enhance organisational resilience against future challenges (Çakmak and Tezel, 2019; Mohamed et al., 2020).

Design Errors in Construction Projects

Humans' inability to plan and execute tasks efficiently leads to design errors (Leng et al., 2021). Every construction project relies on design. Fuadie, Rahmawati and Utomo (2017) found frequent construction design errors. Due to miscommunication and misunderstandings, design errors can lower the construction quality, increase costs and delay completion. Misapplied or missing data causes these errors. Design errors during construction can delay the project due to rework. Rework after an issue is found usually costs the client more money and time (Al-Janabi, Abdel-Monem and El-Dash, 2020). Design errors can also lead to engineering defects, which can endanger safety and even cause deaths.

Factors Causing Design Errors

Design errors in construction projects can be attributed to several factors. A lack of design team experience or expertise is a significant contributor. Inadequate knowledge or experience with industry standards and best practices might result in missed details and errors (Lee et al., 2024). According to the Design Management Institute (2017), design-led companies outperformed their competitors by 228%. Zhang et al. (2025) and Brown (2009) stated that inexperienced design teams tend to rely on subjective criteria rather than user research and testing data. It may fail if a product or service does not meet the market needs. Sokol (2020) found that upper management without design skills is less likely to value design, underinvest in it, or use it to advance the company. Thus, a talented, experienced design team that makes sound design decisions is essential to any company's success.

The factor is compounded by poor use of technology and automation. Inaccurate calculations, inadequate design validation and a lack of coordination between the design and production teams are only some of the problems that can result from insufficient use of technology and automation in the design process (Alpala et al., 2018). Defective products, higher production expenses and missed deadlines are all possible outcomes of such mistakes. A lack of adaptability and responsiveness to shifting market conditions and consumer wants is a result of insufficient use of technology and automation in the design process (Alaloul et al., 2020). This can lead to poor acceptance and eventual failure if the product or service does not fulfil the needs or wants of the intended market. Even though the construction industry is often slow in its adoption of new technologies, BIM has been shown to significantly cut down on mistakes made during the design phase (Hossain and Karim, 2020).

Thirdly, poor coordination between design disciplines plays a crucial role in the emergence of design errors. Miscommunication and misunderstandings amongst different teams can lead to conflicting information and design inconsistencies, which are often difficult to resolve during the construction phase (Fuadie, Rahmawati and Utomo, 2017). Furthermore, human errors, such as mistakes, omissions and conflicts, are prevalent due to the high precision required in the design process and the time constraints that teams face. These human-related factors can significantly impact the quality of the design and contribute to errors (Barkow, 2005; Peansupap and Ly, 2015).

In summary, common factors, such as a lack of design team experience or expertise, poor use of technology and automation and poor coordination between design disciplines, can lead to design errors, which will affect project safety, functionality and cost.

Impacts of Design Errors on the Construction

Design errors affect cost, time and quality. In terms of cost, due to rework, extra materials and labour, errors in design can increase project costs. More materials and workers may be needed to resolve a design error that improperly measures a structural component. This may increase project labour and material costs (Hesna, Sunaryati and Hidayati, 2021). Even worse, if design flaws are discovered after construction, the structure may need to be demolished and rebuilt. In addition, building design errors can lead to decreased functionality or safety risks that require more work and higher costs to fix (Islam et al., 2021; Larsen et al., 2016). Building owners, design teams, contractors and owners may be liable if their errors make the building unsafe or noncompliant with local building codes. A severe design error could lead to a lawsuit and expensive settlements or judgements. Thus, design errors can delay, overspend and even endanger construction.

Design errors can also lead to expensive change orders that increase project costs. Disagreements cost both money and time in terms of legal fees and problem-solving. A change order incurs costs in both money and time, including legal fees and problem-solving, due to design errors. Additionally, design errors can delay construction, potentially increasing costs. Delays may require paying more for personnel, temporary space and rented machinery (Ford and Lyneis, 2020). Design mistakes can lengthen building projects (Ye et al., 2015). Delivery delays due to customer order changes are the most common cause. This may postpone construction as the design team revises the blueprints, and the contractor reevaluates his operations. These delays can be severe, delaying the project's completion.

After a building is built, a design error may require demolition and reconstruction. If the building is occupied, tenants or users may need to move. Design teams, contractors and owners may also sue over design errors (Amoatey et al., 2015). Disagreements may delay proceedings because parties need more time and resources to resolve them. The parties may need to halt the construction while the issue is being resolved, which could further delay its progress. Leveson et al. (2017) noted that design errors may compromise the building's functionality or safety, extending the project's timeline. Consequently, the building functionality is reduced. In terms of quality, design errors can compromise quality and safety (Yap et al., 2020). Construction errors often require design changes, which can make the building unusable. This can cause heating, cooling, lighting and other system issues that affect building comfort and usability.

Design errors can also reduce building durability, requiring more work and costing more. These hazards can shorten a building's lifespan. Design errors can also cause safety issues in construction. After project completion, a design error may put the building occupants and users at risk. The owner may be liable for injuries incurred (Shamsuddin et al., 2015). A building that fails to meet fire safety codes can pose life-threatening risks in the event of a fire. Aesthetic issues are another design error in construction quality (Mallawaarachchi and Senaratne, 2015).

Ways to Mitigate Design Errors

Mitigating design errors in construction projects requires a multifaceted approach that incorporates various strategies. Firstly, implementing robust quality control (QC) measures is essential. This involves conducting thorough inspections and testing of design outputs to ensure they meet established requirements and standards. By integrating QA processes throughout the design phase, teams can significantly reduce the likelihood of errors occurring in the first place (Bhattacharjee, 2018; Kimeria, Kising'u and Oyoo, 2019; Mishra, Mishra and Siddique, 2020; Pan and Zhang, 2023). Another effective strategy is to foster collaboration and communication amongst the team members. When all stakeholders, including architects, engineers and contractors, work towards a common goal, the design process becomes more productive and harmonious (Kimeria, Kising'u and Oyoo, 2019). This collaborative environment can lead to improved problem-solving and quicker identification of potential design issues (Siraj and Fayek, 2019).

Additionally, utilising BIM technology can enhance the design process. BIM allows for real-time collaboration and information sharing, enabling the teams to identify any conflicts early in the design phase (Mishra, Mishra and Siddique, 2020). This proactive approach helps to minimise the impact of design errors on construction schedules and costs (Pan and Zhang, 2023). Furthermore, it is crucial to keep design documents up to date. Ensuring that all stakeholders have access to the most current information reduces the risk of errors stemming from outdated or incorrect documents. This practice promotes accuracy and clarity throughout the project (Abbas, 2020). Lastly, determining the cause of design errors and addressing them promptly is vital. Once an error is identified, involving relevant stakeholders to find solutions collaboratively can prevent further complications and ensure that the project stays on track (Ding et al., 2019; Michael and VanBuren, 2020).

In summary, a comprehensive approach that combines quality control, effective communication, advanced technology, updated documentation and prompt error resolution can significantly mitigate design errors in construction projects, leading to improved outcomes and client satisfaction (Robin, Rose and Girard, 2007; Boddupalli et al., 2019; Hull and Ewart, 2020; Al Hattab and Hamzeh, 2018).

METHODOLOGY

This study used a quantitative approach by employing a questionnaire survey. The quantitative method has advantages such as statistical measurability, generalisability of outcomes and deductive manipulation (Creswell and Creswell, 2018). As of 17th January 2023, there were 14,239 registered architects, engineers, quantity surveyors, local contractors and other professional bodies in Malaysia. The required sample size for this research was approximately 375, based on the table of Krejcie and Morgan (1970). However, the current study gathered 159 responses.

The most common occupation among the 159 polled responses was engineer, representing 47 respondents (29.6%), followed by architect with 42 respondents (26.4%). Contractors constituted the third most prevalent occupation, accounting for 39 respondents (24.5%). Quantity surveyors accounted for 25 respondents (15.7%), while project managers were represented by three respondents (1.9%). The least represented occupations among the study respondents were building surveyors, land surveyors and contract managers, each representing one respondent (0.6%). The data was analysed by using Statistical Package for the Social Sciences (SPSS) version 26, descriptive and inferential statistics, and the RII.

Reliability Test

The Cronbach's alpha coefficient test was employed to assess the overall reliability of this research.

Table 1. Reliability test

Cronbach's Alpha	N of Items
0.976	62

Based on Table 1, Cronbach's alpha for this study was found to be 0.976 ($\alpha > 0.9$). The score was in the excellent range, suggesting that the data obtained from the questionnaire survey was highly reliable and valid for further study analysis and discussion, leading to a conclusion.

RESULTS

Causes of Design Errors in Construction Projects

The current study was conducted to identify the causes contributing to design errors in construction projects. The majority of respondents agreed or strongly agreed that design errors were prevalent in the industry, indicating a consensus amongst the respondents. This acknowledgement highlighted the necessity of addressing this issue and enhancing construction quality. Amongst the 159 respondents, around 57% reported encountering design errors during construction projects. This first-hand experience underscored the common occurrence of design errors and emphasised the significance of addressing them to enhance project outcomes. Additionally, most respondents believed that design errors were often identified and resolved during the project lifecycle, indicating a proactive approach to addressing these issues. This was consistent with previous literature and Dosumu, Idoro and Onukwube (2017), which addressed that the persistent causes of error were due to insufficient design management experience, designer professional education, poor use of technology and team coordination, lack of consistency between drawings and specifications and lack of design standards. All these causes are the factors mentioned as contributing to design errors.

The research findings emphasised the importance of identifying and understanding factors contributing to design errors in construction projects. Human-related factors, such as human error, conflict in design information and incomplete design information, were identified as significant contributors to these errors. According to Table 2, the major causes that contributed to design errors included "Human error" ($\mu = 4.17$), "Conflict in design information" ($\mu = 4.12$) and "Incomplete design information" ($\mu = 4.11$). Though factors, namely "Contractual issues" ($\mu = 3.01$), "Inadequate project management" ($\mu = 3.11$) and "Lack of stakeholder engagement" ($\mu = 3.15$) scored lower ratings, they should not be disregarded entirely. Addressing these factors could contribute to minimising design errors and improving project outcomes.

Impacts of Design Errors on Cost of Construction Projects

The current study also investigated the impacts of design errors on the cost of construction projects. Design errors can have far-reaching consequences beyond just the quality of the final structure, affecting project schedules, stakeholder satisfaction and, most importantly, project costs. Based on Table 3, the data analysis reveals that respondents had a high level of agreement regarding the impacts on cost. "Increase the cost for additional work" ($\mu = 4.19$), "Affect the overall cost of a building construction project" ($\mu = 4.17$) and "Cause additional costs related to repairs, maintenance and rework" ($\mu = 4.11$) were identified as critical causes of design errors. On the other hand, "Damage the reputation of the project, which can have long-term financial consequences" ($\mu = 3.19$), "Cause litigation cost" ($\mu = 3.28$) and "Cause additional costs related to insurance and liability" ($\mu = 3.35$) were among the bottom three impacts on cost.

In conclusion, the current study on the impacts of design errors on project cost revealed significant economic consequences. The findings found several key impacts emerged as particularly influential in driving up costs. They also emphasised the importance of proactively addressing design errors to minimise their impact on construction projects.

Table 2. Causes of design errors in construction projects

No.	Causes of Design Errors	Level of Agreement					Mean	RII	Rank
		Strongly Disagree	Disagree	Partially Agree	Agree	Strongly Agree			
1.	Lack of proper planning and scheduling	10	40	20	46	43	3.45	0.690566	12
2.	Poor communication	5	11	25	51	67	4.03	0.806289	4
3.	Contractual issues	41	16	31	43	28	3.01	0.601258	15
4.	Inadequate project management	39	15	25	49	31	3.11	0.622642	14
5.	Unexpected site conditions	11	11	27	76	34	3.7	0.739623	8
6.	Lack of stakeholder engagement	42	11	21	51	34	3.15	0.630189	13
7.	Lack of coordination amongst different design disciplines	8	8	23	55	65	4.01	0.802516	6
8.	Lack of experience or expertise on the design team	7	8	32	40	72	4.02	0.803774	5
9.	Insufficient utilisation of technology and automation	6	13	58	49	33	3.57	0.713208	9
10.	Incomplete design information	4	9	21	57	68	4.11	0.821384	3
11.	Conflict in design information	6	6	22	54	71	4.12	0.823899	2
12.	Human error	6	6	21	48	78	4.17	0.833962	1
13.	Unclear scope of work	7	41	21	51	39	3.47	0.693082	10
14.	Poor funding	10	12	57	54	26	3.47	0.693082	10
15.	Client's changed order	8	10	15	94	32	3.83	0.766038	7

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Table 3. Impacts of design errors on construction projects

No.	Impacts on Cost of Design Errors	Level of Agreement					Mean	RII	Rank
		Strongly Disagree	Disagree	Partially Agree	Agree	Strongly Agree			
1.	The overall cost of a building construction project	4	12	15	50	78	4.17	0.8339623	2
2.	Increased material costs	10	12	35	74	28	3.62	0.7232704	7
3.	Increased cost for additional work	4	9	16	54	76	4.19	0.8377358	1
4.	Increased labour cost	5	4	28	75	47	3.97	0.7949686	5
5.	Increased equipment cost	5	17	50	52	35	3.60	0.7194969	8
6.	Additional costs related to environmental damage	5	14	64	46	30	3.52	0.7031447	9
7.	Additional costs related to project management	4	7	29	60	59	4.03	0.8050314	4
8.	Additional costs related to repairs, maintenance and re-work	5	8	25	48	73	4.11	0.8213836	3
9.	Additional costs related to insurance and liability	8	42	24	57	28	3.35	0.6691824	11
10.	Loss of potential revenue	6	9	29	76	39	3.84	0.7672956	6
11.	Damage project reputation and long-term financial consequences	33	16	24	59	27	3.19	0.6389937	13
12.	Additional litigation cost	32	18	22	48	39	3.28	0.6553459	12
13.	Project abandonment	10	34	25	51	39	3.47	0.6943396	10

Proposed ways of mitigating the design errors

Design errors in construction projects could result in significant cost overruns, delays and degraded project quality. Mitigating these errors is essential for successful project outcomes. Table 4 indicates that respondents highly rated "Determine the cause of the error" (μ = 4.13), followed by "Identify and resolve design errors quickly" (μ = 4.12) and "Implement quality control measures" (μ = 4.11). Conversely, "Implement contingency plans" (μ = 3.32), "Adjust project schedule and budget" (μ = 3.43) and "Consider alternative designs and materials" (μ = 3.94) were rated lower in terms of effectiveness.

This mitigation strategy involved thorough investigation and analysis of the factors contributing to design errors, such as human error, inadequate communication, lack of expertise or incomplete information. Lyu et al. (2019) emphasised that identifying the cause of errors allowed project teams to learn from their mistakes and implement preventive measures to prevent similar errors in future projects. It helped develop robust design review processes, implement thorough design checks and verifications and ensure comprehensive documentation and tracking of design changes.

Moreover, identifying and resolving design errors was a crucial mitigation strategy to minimise the impact of such errors in construction projects. By promptly detecting and addressing design errors, project teams could prevent their escalation and mitigate potential negative consequences. Ding et al. (2019) emphasised that project stakeholders should establish robust review processes and quality control mechanisms to implement this mitigation measure effectively. This included conducting thorough inspections and assessments of design documents, specifications and drawings at various project stages. By implementing rigorous review procedures, teams could proactively identify any design errors or inconsistencies that may have occurred. Once a design error was identified, immediate action should be taken to correct it (Michael and VanBuren, 2020). This required involving the relevant stakeholders, such as architects, engineers, contractors and clients, to collectively determine the optimal course of action. Therefore, focus should be on locating practical solutions that address design errors without jeopardising project deadlines or structural integrity.

Table 4. Ways to mitigate design errors in construction projects

No.	Mitigations of Design Error Impacts in Construction Projects	Level of Agreement					Mean	RII	Rank
		Strongly Disagree	Disagree	Partially Agree	Agree	Strongly Agree			
1.	Identify and resolve design errors quickly	3	14	20	46	76	4.12	0.8238994	2
2.	Implement contingency plans	13	36	28	51	31	3.32	0.6641509	11
3.	Adjust project's schedule and budget	12	28	32	53	34	3.43	0.6867925	10
4.	Implement safety measures	4	12	18	57	68	4.09	0.8176101	6
5.	Allocate additional resources	4	8	18	71	58	4.08	0.8150943	7
6.	Consider alternative designs and materials	5	9	24	74	47	3.94	0.7874214	9
7.	Determine the cause of error	4	10	19	54	72	4.13	0.8264151	1
8.	Identify lessons learned for future projects	3	10	23	74	49	3.98	0.7962264	8
9.	Collaborate with experts to identify solutions	4	5	28	56	66	4.10	0.8201258	5
10.	Implement quality control measures	4	6	24	59	66	4.11	0.8226415	4
11.	Identify and resolve design errors quickly	3	14	20	46	76	4.12	0.8238994	2

In addition, implementing quality control measures was a necessary mitigation strategy for preventing and minimising design errors in construction projects. Quality control ensured that a design process adhered to established standards, guidelines and best practices, reducing the likelihood of mistakes and improving the overall quality of project deliverables (Babalola, Ibem and Ezema, 2019). To implement effective quality control measures, project teams must establish clear protocols and procedures that govern the design process. Abbas (2020) defined the roles and responsibilities of quality control personnel responsible for monitoring and enforcing quality standards throughout the project lifecycle. One crucial aspect of quality control was conducting thorough reviews and inspections of design documents, drawings and specifications. By conducting comprehensive reviews at different stages of the design process, potential errors and inconsistencies could be identified and rectified early on, preventing their propagation to subsequent phases. Besides, implementing quality control measures also involves employing advanced tools and technologies. Computer-aided design (CAD) software, BIM and other digital platforms can facilitate the detection and prevention of design errors (Sacks et al., 2022).

Conversely, implementing contingency plans, adjusting project schedules and budgets and considering alternative designs and materials were rated lower in terms of effectiveness in mitigating design errors in construction projects. These measures may still be valuable and beneficial in certain situations, although the survey respondents' ratings suggest they may not be as effective as other mitigation strategies. By adopting these measures (i.e., implementing quality control), projects can reduce errors, improve efficiency and ensure client satisfaction.

DISCUSSION

Human errors were a critical factor contributing to design errors in construction projects, underscoring the need for investment in training and professional development programmes for designers and engineers. Barkow (2005) and Peansupap and Ly (2015) emphasised that human errors, such as design, omission and conflict mistakes, play a significant role in design errors due to the required precision and time constraints in the design process. Deviations from actual values, inadequate precision and miscommunication can also lead to design errors stemming from human error. Therefore, addressing human-related factors is crucial to improving design quality.

Design information conflicts and gaps were also prominent causes of design errors. Effective communication and collaboration amongst project stakeholders were essential to minimise conflicts and enhance the completeness and precision of design data. Couto (2012) emphasised the importance of providing comprehensive design information and construction support to prevent errors during the construction process. Taylor's study (2007) reinforces the presence of design errors attributed to conflicts and insufficient design information arising from differing perspectives amongst the stakeholders. Addressing these causes through clear communication channels and coordination can prevent design discrepancies and construction errors, ultimately improving the project outcomes.

Furthermore, hoc tests were conducted to examine the factors contributing to design errors in construction projects. The tests revealed that several factors, including unexpected site conditions, lack of stakeholder engagement, unclear scope of work and poor funding, did not show statistically significant differences in their contribution to design errors. This suggested that the frequency of design errors may not significantly differ based on these specific causes. However, it is essential to acknowledge that these factors may still have some influence on design errors, albeit to a lesser extent than other factors.

The impact of design errors on construction projects was substantial, particularly in terms of increased costs resulting from additional work. Design errors necessitated extra work to rectify the mistakes and get the project back on track. This could involve modifications, revisions or even complete redesigns of project elements that often led to inefficiencies and delays in the construction process, requiring contractors and construction teams to allocate more resources to address and rectify the issues (Shneiderman, 2020). Moreover, the extra time needed to complete the additional work could result in higher overhead costs and potential delays, further contributing to the overall project cost increase. Therefore, addressing design errors is crucial to minimising these financial repercussions and ensuring the success of construction projects.

Design errors in construction projects directly affected the project's total cost. Errors led to increased expenses that could significantly affect a project's budget and financial viability. Inefficiencies and complications introduced by design errors can increase costs at different project stages, hindering progress (Mishra and Aithal, 2022; Osman, Omran and Foo, 2009). Aslam, Baffoe-Twum and Saleem (2019) and Han, Love and Peña-Mora (2013) found that design change orders that led to rework contributed up to 50% of project cost overruns. This highlighted that rectifying errors may require modifications to plans, specifications or materials, incurring additional expenses. Inaccurate measurements or specifications could lead to purchasing new materials or modifying existing ones, increasing procurement costs (Dandan et al., 2020; Li and Taylor, 2014). Furthermore, design errors could delay the construction schedule, necessitating work stoppages or alterations to correct the issues. Addressing design errors proactively is essential to mitigate their financial impact and ensure the success of construction projects.

Although specific impacts such as "Damage the reputation of the project" could have long-term financial consequences, "Additional litigation cost" and "Additional costs related to insurance and liability" received lower ratings, implying a relatively minor impact of design errors. However, their significance should be considered and not disregarded entirely. The analysis of the data revealed that the study respondents had a high level of agreement regarding the impacts on cost. They believed that key causes of design errors related to repairs, maintenance and rework. The increased additional work costs affected the overall cost of a building construction project. Design errors necessitated additional efforts to rectify the errors and restore the project to its initial timeline. According to Kwiatek et al. (2019), this additional work may include modifications, revisions, or even complete redesigns of specific project elements. The cost of these additional resources has an immediate impact on the budget of the project (Shneiderman, 2020). Errors in the design were found to introduce inefficiencies and complications throughout the construction process, resulting in cost increases at various stages of the project (Muhamad and Mohamad, 2018). Mohammad, Ali and Najm (2021) and Osman, Omran and Foo (2009) further added that variation in construction projects had several potential effects, including an increase in project cost, additional payment for the contractor, higher overhead expenses, delays in the completion schedule and the need for rework and demolition.

CONCLUSION

The current study found that design errors contributed to cost overruns, delays and compromised project quality. Thus, detecting and addressing these errors was necessary to minimise their impact on project costs and ensure financial viability. Several effective measures were identified to mitigate design errors, including using 3D modelling software, documenting and tracking design changes, employing experienced professionals and identifying root causes promptly through design reviews and quality control. Addressing design errors requires a multifaceted approach involving proactive measures, collaboration, advanced technologies and continuous learning, which can enhance project performance, reduce risks and achieve successful outcomes.

The article offers important theoretical insights by improving how design mistakes in construction work affect project expenses, quality standards and operational effectiveness. This study advanced existing design process frameworks by merging previous research insights with empirical data to enhance error mitigation and risk management strategies. The research demonstrated the need for structured design coordination while highlighting the critical function of technology like BIM to reduce errors. Besides, the article delivered practical, actionable steps to improve both design precision and project efficiency for industry experts, such as architects and engineers. Also, construction firms can diminish the financial and operational impacts of design mistakes by adopting quality control systems while making use of sophisticated digital tools and enhancing collaborative efforts amongst the stakeholders. The research highlighted the need for ongoing professional growth, together with best practice implementation in design management, to lower rework quantities, along with project delays and extra expenses. Practical insights provide a roadmap for policymakers and industry stakeholders to advance design standards and project delivery frameworks.

For future research, detailed case studies of projects that successfully minimise design errors are required to yield best practices and strategies that can be replicated in future projects. Besides, conducting longitudinal studies to track the long-term impacts of design errors on project outcomes and costs can provide deeper insights into their effects over time. This could help in understanding how initial errors evolve and affect later stages of construction.

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