ENHANCING CONSTRUCTION SAFETY THROUGH DESIGN AND TECHNOLOGY INTEGRATION, CHALLENGES AND OPPORTUNITIES IN PAKISTAN'S BUILDING SECTOR

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DOI: https://doi.org/10.5281/zenodo.20921502

Keywords
Design Integration, Technology Adoption, Design for Safety, Stakeholder Roles and Barriers, Safety Performance.

Article History
Received: 24 April 2026
Accepted: 06 June 2026
Published: 21 June 2026

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Abstract
The construction industry is one of Pakistan's most significant economic and social sectors, but it is also regarded as one of the riskiest because of subpar safety procedures, unequal responsibilities, and insufficient regulatory monitoring. The use of technology in developed nations has favorably and significantly impacted industry production, but it has also led to hazardous working conditions. The concept of Design for Construction Safety (DFCS) has emerged globally as a cutting-edge method to incorporate worker safety considerations at the design stage rather than only during execution. To improve construction safety performance, this study explores the integration of Design for Constriction Safety (DFCS) concepts with emerging technologies like Building Information Modeling (BIM), Internet of things (IoT), Artificial Intelligence (AI), and Extended Reality (XR). Although structured design- safety techniques are provided by worldwide tools such as the DFCS toolbox, CHAIR, DFSP, and Tool-Shed, their local adaption is still restricted. This study employs a quantitative perception-based survey analyzed through questionnaire. This study examined the interrelationships among Design Integration, Technology Adoption, Stakeholder Roles and Barriers, and Safety Performance. The findings contributed to developing a proactive, technology-enabled design-safety framework contextualized for Pakistan's building sector. This research maps with the UNSDGs like SDG3, SDG8, SDG9, SDG11, SDG16, SDG17 and NRP priorities are Human safety, occupational health & infrastructure resilience, Application of science & technology to industry problems, Disaster risk reduction and resilient built environment, Capacity building and higher education research, Direct citation/support.
Keywords: Design Integration, Technology Adoption, Design for Safety, Stakeholder Roles and Barriers, Safety Performance.

INTRODUCTION
Background
This construction industry in Pakistan plays a significant role in gross domestic product growth and creates large-scale employment. Though, it is overwhelmed by high accident rates, poor enforcement of safety codes, and with a perception that safety is solely the responsibility of

contractors. Almost all construction firms in Pakistan adopt reactive safety approach, addressing hazards only after incident happened. In contrast, the Design for Construction Safety (DFCS) idea endorses entrenching safety considerations early in the design stage to reduce hazards before construction starts. Worldwide, DFCS has already been strengthened by using advanced technologies like "BIM, IoT, AI, and XR" which is helpful to enhance visualization, forecast, and monitoring of safety risks throughout the project cycle. However, construction industry in Pakistan has been slow to adopt these technology innovations in DFCS. This research has explored how integrating design and technology improved safety performance and provided a theoretical framework to guide experts and policymakers toward completion of the project safer.

1.1 Problem Statement

Construction Industry is known as hazardous in Pakistan due to poor safety practices followed by the contractors at site, However, it is assumed that the worker safety is the responsibility of the Contractor, but no emphases was given at the part of the designer responsibility to include construction worker safety during design consideration. The aim of the study to find and identify enhancing the construction safety through design and technologies integration, challenges and opportunities in the Building Sector in Pakistan.

1.2 Early Level Strategies for Worker Safety on Project

Most of the mega infrastructure projects are being underway in Pakistan, mainly under initiatives such as CPEC, with several additional projects planned. The recent studies indicate the need for strengthening safety standards, not only for the workers' safety but also for the project's efficiency, cost management, and international credibility (Hussain et al., 2021; Azeem et al., 2024).

Present research emphasizes the need for formal safety assessment frameworks for the successful implementation of safety management systems in construction projects. These assessments promote policy development, benchmarking of safety performance and continuous improvement strategies in the industry (Zhang et al., 2022; Zhou et al., 2023). Recent developments encourage the use of leading indicators such as safety climate assessment, hazard identification and real time site monitoring (Lingard et al., 2021).

Construction industry has very high share of work-related fatalities according to the recent international labor reports. These fatality rates are considerably higher than most of the other sectors (International Labor Organization, 2023). Similarly, studies show that construction workers are more likely to be injured due to prolonged exposure to dynamic and hazardous environments (Kim et al., 2021).

However, such progress may create new safety risks if not properly handled. Developed countries adopted modern technology to increase production (Li et al., 2022). At the start of the development of the project, safety is being given more consideration. Recent interpretations of the time–safety influence curve show that the greatest chance for influence of project safety is in the conceptual planning and design phases, and decreases as the project advances (Gambatese et al., 2021). But really safety planning is typically postponed to the building phase which restricts opportunities for risk reduction and management.

1.3 Concept of Design for Construction Safety

Design for Construction Safety (DFCS) is defined as a systematic process to integrate health and safety in the design phase of construction projects. Its purpose is to avoid or limit hazards through design changes and so reduce the risks while doing construction operations (Toole & Gambatese, 2021).

DFCS incorporates several approaches such as providing more detailed design drawings and specifications, conducting constructability assessments, and finding possible risks related to design decisions. These techniques help to incorporate the safety of workers proactively in the project life cycle as opposed to reactive measures (Behm & Schneller, 2022). Construction in several developing countries such as Pakistan is largely dominated by unskilled or semi-skilled workers who are mostly job seekers (Rahman et al., 2023). There is also a huge difference between large and small contractors. However, smaller contractors tend to focus more on cost reduction rather than safety compliance, which results in ongoing hazards at construction sites (Ahmed et al., 2022). Housekeeping and site organization have been recognized as the factors affecting construction safety.

Underreporting of accidents remains another major issue. Minor injuries are often ignored or treated informally, while only severe incidents are officially reported due to legal and financial implications. Such methods are hampered by reliance on safety data and the restrictions on preventative action (ILO, 2023; Khan et al., 2022). The development of digital technology, namely, BIM (Building Information Modelling) has a good promise to improve the construction safety management system. BIM acceptability, however, remains inconsistent, with some businesses successfully deploying integrated Building Information Modelling (BIM), while others have yet to embrace BIM (Sacks et al., 2022; Marzouk & Azab, 2023). The construction sector can achieve improved safety performance and reduced workplace incidents via the use of proactive safety management systems (Zhou et al., 2024).

1.4 Significance of the Study

This Study aims to generate evidence-based acumens for key stakeholder such as architects, designer, Project Managers, project owners/client, developers, safety experts, regulatory authorities, and academic institution to support learned decision-making regarding the adoption and implementation of the Design for Construction Safety (DFCS) approach in building projects of construction industry. In the context, of developing countries like Pakistan, construction safety frameworks remain either insufficient or inadequately imposed due to institutional, cost constraints and regulatory limitations as well. The findings are expected to contribute toward improving overall safety performance, minimizing workplace incidents, and promoting proactive approach within the construction sites of Pakistan.

1.5 Research Objectives

The objective of this study is as follows:

1. To evaluate current awareness and practices of Design for Construction Safety in Pakistan's building sector.
2. To identify key challenges and opportunities in integrating technology for design-stage safety.
3. To assess the relationships between design integration, technology adoption and safety performance.
4. To propose a conceptual model for enhancing safety through design and technology integration.

1.6 Research Scope and limitations

Scope of this research is limited as below:

1. The construction of Buildings is limited to the Building Sector of Pakistan
2. All registered firms with Pakistan Council of Architecture and Town Planning.
3. Firms registered with Pakistan Engineering Council
4. Every construction professional who is registered with the Pakistan Engineering Council
5. This study's scope was restricted to identifying opportunities and obstacles for implementing the charter during construction safety design. Pakistan's construction industry using a questionnaire survey.

LITERATURE REVIEW:

Unsafe design elements account for a large percentage of construction industry accidents, according to research conducted globally. According to research from the US, UK and Australia, design related choices may be responsible for as many as 60 % of site deaths. When used in conjunction with the legal frameworks of the UK's Construction Design Management (CDM) rules, the DFCS approach which incorporates risk mitigation and hazard removal into design has demonstrated significant results. The following studies and pertinent literature have been reviewed by me.

The review highlights poor health and safety performance in Ghanaian construction, noting high injury rates (43 per 1 million hours worked) and fatalities three times higher in developing countries than developed ones. It defines DfS as incorporating site safety into design to eliminate hazards early, supported by studies showing design flaws contribute to 42% of fatalities. Barriers emphasized include fragmented construction processes, lack of designer construction knowledge, poor stakeholder communication, insufficient DfS education, regulatory gaps, and cost concerns. (Acheampong et al.,2024)

Over the past decade, construction workers have been blamed for construction accidents; however, recently, the community and business enterprises are taking on more of these responsibilities (Liu et al.,2020).

Several studies on using new technologies for construction health and safety have been conducted and published (Sadeghi et al., 2020).

For instance, Delgado et al. (2020b) investigated the usage landscape of AR and VR in the Architecture, Engineering and Construction (AEC) sectors and formulated a roadmap and research agenda to realize their potential in the AEC sectors. They identified six AR and VR use-cases as follows: stakeholder engagement, design support, design review, construction support, operations and management support and training. Delgado et al. (2020a) studied the factors that limit and drive the adoption of AR and VR in the construction industry. They concluded that the main limitation of adoption is that AR and VR technologies are considered expensive and immature technologies which are not suitable for engineering and construction. However, the main drivers are that AR and VR allow for improvements in project delivery and provision of new and better services.

The construction industry has a poor safety performance record due to the inherently 'dangerous, dirty and difficult (3D) working environments that hamper productivity and create risky working conditions (Yap and Lee 2020).

1.99 deaths in China per day are said to be due to construction accidents (Xu and Xu 2021); while the fatality rate per 100,000 workers in the Malaysian construction industry is 13.44 (Babulal 2020).

Analyzing secondary data (2013–2018) from Malaysia's Department of Occupational Safety and Health (DOSH), construction is the riskiest and most hazardous job category with 145 fatalities reported (Halim et al. 2020). According to the International Labour Organization (ILO), the likelihood of construction workers in the developing world being involved in an occupational fatal accident is almost double their counterparts in developing countries (Nnaji and Karakhan 2020).

2.1 Early Preclusion through Design for Construction Safety

Design for Construction Safety (DFCS) supports proactive identification and mitigation of hazards during project design. Studies by Yap et al. (2024) and fa et al. (2025) emphasize that early-stage design decisions account for a significant proportion of construction hazards. Integrating DFCS within design reviews can reduce on-site accidents and improve communication among stakeholders. However, the lack of regulatory mandates, inadequate coordination, and inadequate training impede the spread of DFCS concepts in emerging economies.

2.2 Role of Advanced Technologies in Construction Safety

The role of advanced technology has transformed the world-wide construction safety practices. BIM assist the engineering, architectural and construction professional to progress towards more automated, more successful and collaborative ways of working (Taat et al., 2022). Apart from the research works which applied computer vision methods, Construction site practices have considered applying different emerging technologies such as BIM, wearable devices that can sense unsafe conditions, while AI-driven analytics can predict possible accidents based on historical patterns (Wang & El-Gohary,2023). XR technologies, including virtual, augmented and mixed reality, improve safety training and worker engagement (Abbasianjahromi, 2023; Polmear & Simmons, 2022).

2.3 Health and Safety Challenges in the Construction Industry

The construction sector continues to have one of the worst rates of occupational accidents and fatalities in the world. Recent figures reveal that construction is responsible for a disproportionate number of workplace injuries, with falls, struck-by occurrences, and equipment-related accidents still being the top causes of fatalities (BLS, 2021; HAS, 2022). Several researchers (Yap et al., 2021; Dobrucali et al., 2022) believe that traditional safety management approaches based on heavy reliance on human inspections, reactive reporting, and compliance-based systems are not enough to cope with the dynamic and complex nature of today's construction projects. The production pressure, disjointed project delivery, and short-term work conditions also wear out safety enforcement, leading to businesses concentrating on efficiency instead of proactive planning for safety (Neale & Gurmu, 2022). Therefore, there is a broad consensus on the need for innovative and technology-based solutions to improve safety and health performance throughout the life cycles of building projects.

2.4 Safety Enhancement through Construction 4.0 Technologies

The idea of Construction 4.0 represents the is based on a confluence of trends and technologies that promise to reshape the way-built environment assets are designed, constructed, and operated. With the pervasive use of Building Information Modelling (BIM), lean principles, digital technologies, and offsite construction, the industry is at the cusp of this transformation (García de Soto et al., 2022). Recent studies emphasize that Construction 4.0 technologies have
highlight the resultant processes and practices that allow us to plan, design, deliver, and operate
built environment assets more effectively and efficiently by focusing on the physical to digital
transformation and then digital-to-physical transformation. (Okpala et al., 2020; Shafei et al., 2025). Current technology makes it possible to track safety more continuously and reduces the need for human observation who can be erroneous.

2.5 Autonomous Construction and Immersive Technologies

Sovereign technologies used in construction (robots and computerized equipment) improve safety at work by replacing humans from unsafe and repetitive operations (Mellenbrink et al., 2020, Chen et al., 2022). Augmented reality and simulation can improve safety performance by providing better ways to learn about safety, identify hazards and understand what is going on around you.

2.6 Empirical Evidence from Developing Countries

Lessons learnt from other developing countries are useful. Shafei et al. (2025) explored Construction 4.0 technologies using the uncertain TOPSIS method and found that IoT, AI and BIM were dire for safety enhancement. Similarly, Yap et al. (2024) explored with respect to Malaysian perspectives, showing that BIM, IoT, and AI based technologies which improve effectiveness of hazard identification and training as well. These findings can increase design process by supported technologies while increasing safety outcomes.

2.7 Improving Construction Worker Safety

Studies conducted by Zhang et al. (2021), Li et al. (2022), and Kim and Park (2023) concluded that proactive hazard identification through digital technologies substantially reduces accident probability on construction sites.

In recent investigations, BIM-supported safety planning facilitates communication between designers, contractors and safety professionals, which leads to better coordination and less harmful behaviors (Choi et al., 2022). Similarly, Wang et al. (2024) revealed that BIM-assisted safety management enhances hazard awareness, increases the effectiveness of educating workers, and decreases safety hazards in projects.

Automated rule-based safety checking has also attracted substantial attention in recent years. Some researchers have combined BIM with occupational safety laws to automatically identify dangers and risky work conditions connected to design. Studies by Luo et al. (2021), Teizer et al. (2022), and Zhou et al. (2024) have shown that the integration of BIM with safety codes and regulations improves compliance monitoring and reduces human error in safety inspections.

2.8 Design for Construction Safety (DFCS)

The term "Design for Construction Safety" (DFCS) describes how safety concerns for construction workers are included into project planning and design. DFCS's primary goal is to reduce or eliminate risks through design choices prior to the start of construction. Many of the hazards in construction are the result of design adoptions such as poor access systems, dangerous structural designs, poor material choices and lack of maintenance alarms (Gambatese and Behm, 2021). Toole et al. (2022) discovered that including safety into the design process results in improved worker safety throughout the life of the project.

2.9 Institutional and Policy Frameworks

Boadu et al. (2022) examined client-led promotion of health and safety in public procurement, showing that integrating safety into procurement decisions strengthens compliance. However, Pakistan's Public Procurement Regulatory Authority (PPRA) and Pakistan Engineering Council (PEC) codes lack clauses mandating safety-by-design reviews.

2.10 International Supportive Tools and Frameworks

Several tools, including the Design for Construction Safety (DFCS) Toolbox, CHAIR, DFSP tools, and the Tool-Shed repository, have been developed worldwide to operationalize DFCS principles. AI based computer vision systems can automatically identify unsafe conditions and behaviors from site images and videos, significantly reducing accident risks through early intervention (Jallow et al., 2022; Zhu et al., 2022). Likewise, big data and predictive analytics enable the analysis of large accident databases to identify developments, fundamental relationships, and high-risk activities (Meng et al., 2022). Zhou et al. (2021) validated that predictive accident models developed from historical data can significantly improve safety planning in metro and infrastructure projects.

2.11 Importance of Design for Construction Safety

Fall from height remains one of the primary causes of fatality in the construction profession. The investigations by Huang et al. (2023) showed that safety-oriented design significantly reduces the fall-related incidents on construction sites.

According to worldwide statistics, construction is still one of the most dangerous sectors in the world. construction operations are dynamic and complicated, exposing construction workers to higher occupational hazards than workers in many other industries (International Labor Organization, 2023; Occupational Safety and Health Administration, 2024).

2.12 DFCS Tools and Technologies

Several digital tools and technologies like BIM, VR &AR, AI and Machine Learning, Digital Twin and IoT that enhance risk assessment, safety communication, and hazard identification facilitate the adoption of modern DFCS.

2.13 Barriers to Design for Construction Safety

Design for Construction Safety (DFCS) is becoming more important, but there are still many obstacles in the way of its application in the construction sector.

Several significant obstacles to DFCS implementation were found in studies by Toole et al. (2022), Behm and Schneller (2022), and Kim et al. (2023). These included a lack of safety expertise, a lack of regulatory enforcement, Worries about legal liability, a lack of coordination between designers and contractors, lack of designer interest, a limited use of digital safety tools, and the financial consequences of additional design efforts.

3. Identified Gaps in Pakistan's Context

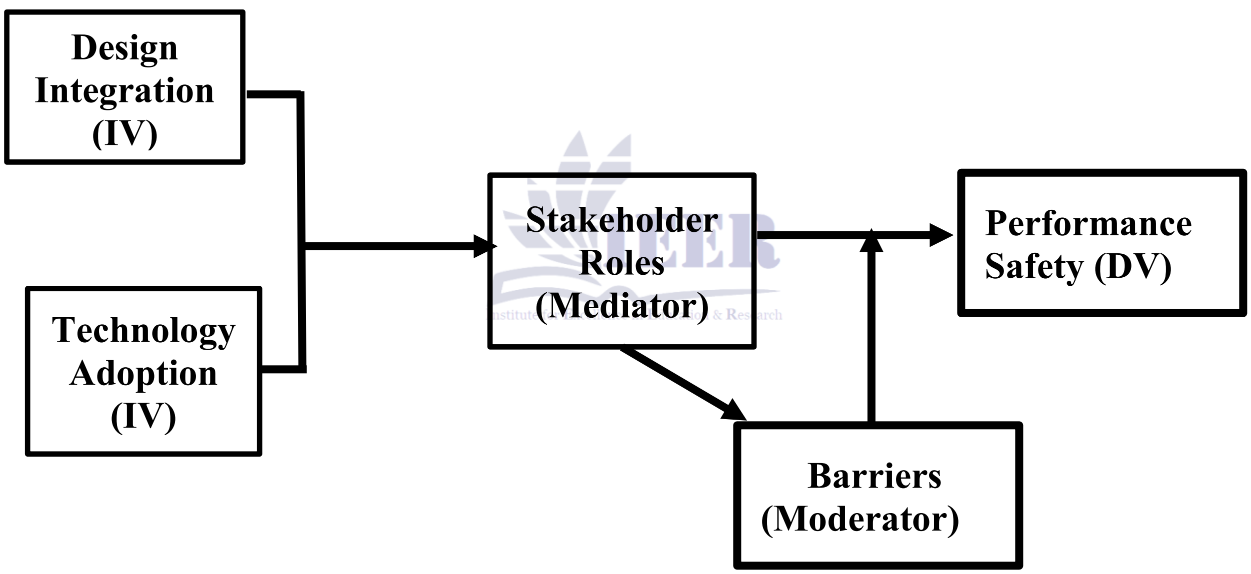
Although DFCS and technology integration are receiving more attention worldwide, there aren't many empirical studies liking design practices to safety performance in Pakistan's construction industry. The impact of managerial or regulatory issues on safety results, as well as the mediating function of technology adoption, are not well studied. By creating and evaluating a conceptual model among these constructions in Pakistan's construction industry, this study closes that gap. The literature also lists additional obstacles, like as:

i. Limited coordination between designers and contractors.
ii. Absence of Designers' Interest and Motivation
iii. Lack of safety training/Knowledge/Awareness in in Construction Process.
iv. Additional costs and liability.
v. Weak contractual and regulatory mandate.
vi. Absence of Safety Tools and Software for Design
vii. Schedule Problems

Furthermore, integrating safety into design techniques in Pakistan is made possible by the building industry's increased understanding of sustainability and quality requirements.

4. Gap Analysis

While design and technology integration for safety management has advanced significantly globally, there is still a dearth of empirical data from Pakistan. The combined impact of institutional variables, technology uptake, and design integration on safety performance has not been well studied. Perception based research examining practitioners' perspectives on the uptake of digital technologies and safety by design methods is also lacking. This gap restricts both theoretical knowledge and useful tactics for improving construction safety in Pakistan's building industry.



METHODOLOGY

This study includes the approach towards performance health and safety of worker by known practices after reviewing the in-construction industry, analysis of the current rules & regulations and international construction worker's health and safety codes, Identifying the difference between prescriptive and performance approaches. Feedback from all participants on designing and implementing the legislation and codes based on performance safety. Further identifying the main purpose behind changing the earlier other problem and approaches incurred during implementation process. A survey of performance safety by using Design integration by technology adoption was conducted through the projects stakeholders, like client, architect, designer, engineer, project managers, contactors, etc of the Construction industry for reviewing their opinions on performance safety implementation. Questionnaire survey techniques were used for collecting the required data for this research.

3.1 Design of Research
The initial phase of this research was to study and review the recent published studies in the field of construction management. The literature research emphasized the increasing importance and relevance of Design for Construction Safety (DFCS) in Pakistan's construction sector. To identify current research gaps, especially in the field of construction performance safety, a detailed study of earlier DFCS research was later carried out. This study was assumed to be a quantitative, cross-sectional research design to examine the relationships between **Design Integration** (DI), **Technology Adoption** (TA), and **Safety Performance** (SP), with **Stakeholder Roles** (SR) mediates between design Integration and Performance safety similarly Technology adoption and performance safety and **Barriers (BAR)** act as a moderating relationship**.** A survey-based approach was employed to collect standardized responses from construction professionals in Pakistan's building sector. The quantitative method enables hypothesis testing and statistical validation of the proposed conceptual framework using SPSS software.

3.2 Research Approach
Deductive approach was adopted, in which hypotheses were derived from prior empirical findings and established theories. Data was then analyzed statistically to confirm or refute the hypothesized relationships. The study was based on variance-based techniques suitable for testing mediation and moderation through regression in SPSS.

3.3 Target Population and Sampling Procedure
A **purposive sampling** was employed to select respondents with relevant Knowledge in safety management, design integration, and technology use in construction projects. Target population (Designers, civil engineers, architects, Project Mangers, Client, Consultant, Contractor in Pakistan) is finite "The sample size for the quantitative survey was determined using Yamane's (1967) formula at a 95% confidence level and 5% margin of error."_Therefore, the required sample size for a population of 85,528 at a 95% confidence level and 5% margin of error is approximately **398 respondents**.

3.4 Data Collection Method
For data collection in the form of online questionnaire survey form, a participatory approach was employed. Survey form was developed to attain the opinion of construction industry and academic professionals, safety experts of DFCS as well. Data was collected through a **designed questionnaire** distributed electronically (via Google Forms, email) and in-person.

3.5 Questionnaire Design
The questionnaire developed for experts in the Pakistan Construction Industry (PCI) was designed to attain two primary purposes. Firstly, it was used to validate findings of the initial phase of the research, particularly with respect to existing practices, perceptions, and awareness of Design for Construction Safety (DFCS). Recent methodological studies emphasize the importance of well-structured questionnaires for both validation and exploratory analysis to enhance reliability and applicability of findings (John W. Creswell, 2021).

3.6 Layout of Questionnaire Survey
Previous DFCS-related studies, such as those conducted by John Gambatese and subsequent researchers, have emphasized assessing construction professionals' knowledge, awareness, and willingness to implement safety-oriented design practices. In the present study, elements from earlier validated questionnaires were adapted to ensure consistency and reliability.

Research Instrument and Variables

The questionnaire was developed based on validated scales adapted from previous studies in construction safety and technology integration.

Variable	Type	Example Dimensions / Indicators
Design Integration (DI)	Independent Variable	Integration of safety in design planning, use of design-for-safety principles, collaboration between design and safety teams.
Technology Adoption (TA)	Independent Variable	Use of digital tools (BIM, IoT, AI) for safety monitoring, automation in hazard detection, data-driven safety management.
Safety Performance (SP)	Dependent Variable	Reduction in accident rates, compliance with safety protocols, proactive safety culture.
Stakeholder Roles (SR)	Mediator	Owner involvement, contractor commitment, project team competence, designer/architect engagement.
Barriers (BAR)	Negative Moderator / Control Variable	Cost constraints, skill shortages, weak regulatory enforcement, cultural resistance to technology.

Data Collection

Questionnaire Survey

The data collected from the selected sample vide the internet; professional and personal relations were used. The questionnaire survey was conducted by hand (personal), via internet and telephone/ Mobile. The questionnaire for this survey should be clear and precise and close to the results required. As a result, Designer, Architects, Engineers, Contractors, Project Managers and Safety Professionals were selected from the building construction industry, design and construction companies, and Universities.

Research Limitations

DFCS (Design for Construction Safety) is comparatively new concept in Construction Industry of Pakistan. Mostly Stakeholders were not aware of the primary concept. It is perception that safety is the sole responsibility of the contractors and even not have any idea of designer role for construction worker safety. Hereafter, the concept of Design for construction safety was elucidated in detail for those stakeholders. Therefore, the views obtained in this research by those respondents who have their proactive role for DFCS and other respondents as well for their understanding of the concept, explain it to them and what comes out of it from understanding.

Data Analysis Techniques

Data analysis was conducted using **SPSS** for mediation and moderation testing. A quantitative, hypothesis-driven approach was selected to statistically validate the impact of **Design Integration** and **Technology Adoption** on **Safety Performance**, while accounting for the mediating roles of **Stakeholder Roles** and moderating role of **Barriers**. The results of these analyses were prepared.

RESULTS & DISCUSSION

This study proposed procedures for analyzing and interpreting the data to be collected. Data analysis and its results are discussed in this chapter. The research data was collected and developed through the questionnaire survey. The study was undertaken to identify the barriers and recommendations required for developing a framework for the effective implementation of Design for Construction Safety (DFCS). A questionnaire survey was conducted to examine the existing practices and attitudes within the construction industry regarding worker safety through design. The goal was to create workable system that. could be put into place within the current limitations and working conditions of Pakistani construction projects. The thorough analysis competing for this study is presented in the parts that follow. With stakeholders Role (SR) acting as mediating factor and Barriers (BAR) acting as moderating factors, the objective is to experimentally examine the proposed correlations between Design Integration (DI) Technology Adoption (TA), and Safety Performance (SP). The analysis was conducted using SPSS-style statistical techniques including response analysis, descriptive statistics, reliability analysis, correlation analysis, and factor analysis.

Reliability Analysis

The Cronbach's Alpha value obtained from the questionnaire responses is -0.000. This indicates that the questionnaire possesses acceptable to excellent internal consistency and reliability for further statistical analysis. The reliability69 analysis further confirms that the questionnaire was suitable for measuring the variables related to DFCS implementation, technological adoption, stakeholder responsibilities, and project safety performance. Therefore, the collected data can be considered dependable for conducting descriptive and inferential statistical analysis.

Descriptive Statistics

Descriptive statistics were conducted to determine central tendency and variability of questionnaire responses.

Variable	Mean	Std. Dev.	Minimum	Maximum
DI1. Safety considerations are incorporated during	3.79	1.27	1	5
DI2. Design drawings include safety-related specifications	3.74	1.32	1	5
DI3. Hazard identification is conducted before con	3.77	1.28	1	5
DI4. Designers collaborate with contractors to add	3.64	1.35	1	5
DI5. Lack of DFCS regulations limits safety integration in design	3.70	1.33	1	5
DI6. Limited safety knowledge among designer's hind	3.74	1.27	1	5
DI7. Integrating safety into design increases project cost and time	3.81	1.28	1	5
TA1. BIM is used to identify construction hazards	3.70	1.34	1	5
TA2. Digital tools are used for safety planning an	3.67	1.35	1	5
TA3. VR or digital training tools improve	3.71	1.33	1	5

hazard r				
TA4. The organization invests in technology to imp	3.70	1.30	1	5
TA5. High initial cost discourages adoption of safety technologies	3.74	1.31	1	5
TA6. Lack of technical expertise limits effective	3.78	1.28	1	5
TA7. Resistance from management or workforce affects technology implementation	3.75	1.31	1	5
SR1. Designers have a professional responsibility	3.82	1.28	1	5
SR2. Contractors actively participate in design-stage safety discussion	3.76	1.29	1	5
SR3. Clients prioritize safety during project plan	3.83	1.29	1	5
SR4. Government agencies effectively enforce safety regulation	3.90	1.25	1	5
SR5. Lack of clear contractual responsibility limits accountability	3.72	1.32	1	5
SR6. Weak coordination among stakeholders affects	3.84	1.26	1	5
SR7. Organizational culture does not prioritize safety at the design stage	3.67	1.33	1	5
PS1. Integrating safety in design reduces construction accidents	3.77	1.29	1	5
PS2. Technology adoption improves hazard detection	3.77	1.25	1	5

PS3. Stakeholder collaboration improves site safety performance	3.87	1.21	1	5
PS4. Safety-oriented practices reduce project delays caused by accidents	3.54	1.38	1	5

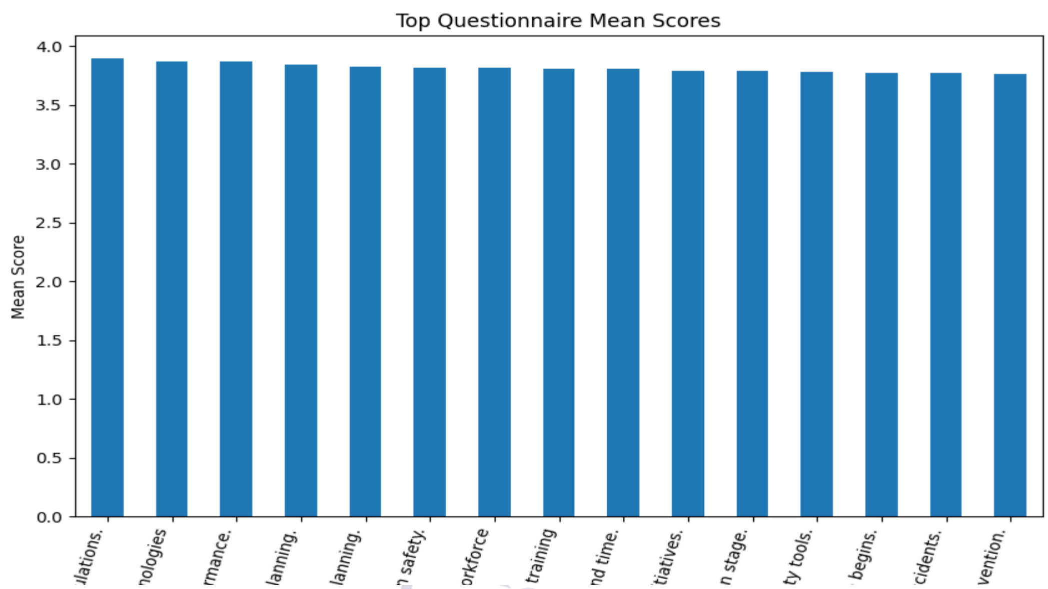


Figure 4.5: Top Mean Scores

Descriptive statistics were applied to determine the central tendency and variability of response to all variables in the questionnaire. Mean value of most of the variables were between 3.50 and 3.90 indicating that respondents mostly agreed that the importance of DFCS processes and construction safety measures. Among the Design Integration (DI) variables, the statement "Integrating safety into design increases project safety" received the highest mean value M= 3.81. Thus, it shows a considerable agreement among the respondents on the positive impact of safety conscious design techniques. "Safety considerations are included during design" had a mean of 3.79, indicating that respondents realize the importance of safety inclusion in the planning and design stages of projects.

Under the "Technology Adoption (TA)" categories, respondents agreed that lack of technical skills and the high initial expenses are key barriers to the adoption of safety technology in building projects. The variable "lack of technical expertise limits effective technology use" had a mean value of 3.78. the variable "Resistance from management or workforce affect technology adoption" obtained a mean value of 3.75.

Of the Stakeholder responsibility (SR) variables, "government agencies effectively enforce safety regulations" had the highest mean score of 3.90, followed by "Weak coordination among stakeholders affect safety implementation" with a mean value of 3.84. The finding indicates that stakeholder participation and regulatory enforcement are critical to improve safety performance in construction.

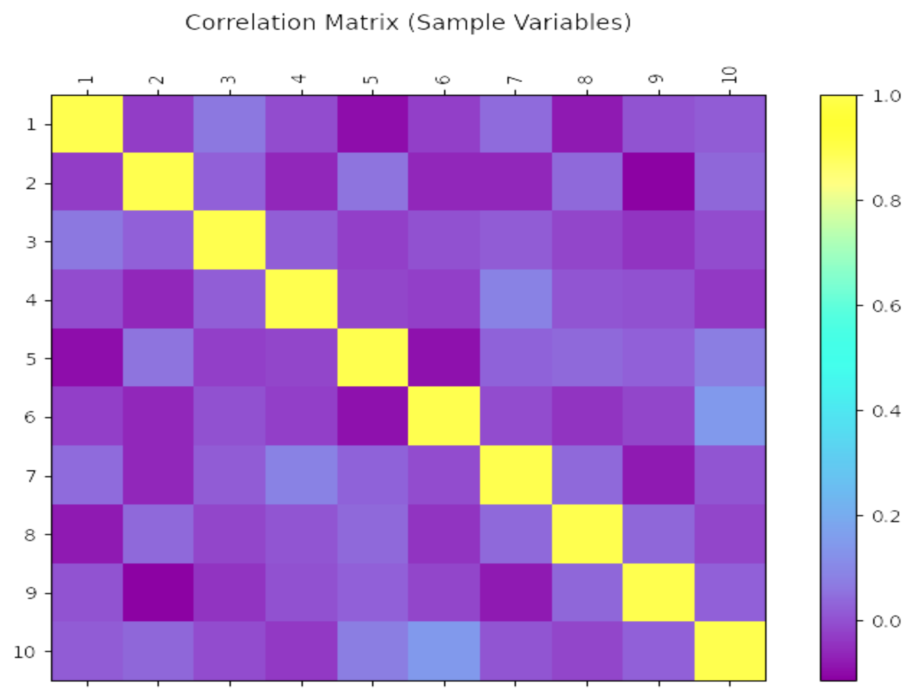
For the Performance Safety (PS) variables, "Stakeholder collaboration improves site safety" had a high mean score of 3.87, suggesting the positive influence of collaboration among project participants on safer construction settings.

The standard deviation values were at 1.21 and 1.38, which shows that the respondents had mediated variety in their beliefs. Overall, the descriptive study shows a good opinion towards DFCS deployment and safety integration procedures in the Pakistani Construction industry.

Correlation Analysis

The correlation between major variables concerning construction safety measures and DFCS implementation were examined using correlation analysis.

Correlation analysis was performed to study factors related to DFCS implementation and safety performance. The analysis shows that design integration methods, technology adoption and stakeholders' responsibilities are favorably related to improved construction safety performance. The results show that businesses embracing safety-oriented design processes and using emerging digital technologies such as BIM and virtual safety tools tend to deliver better safety outcomes in building projects. In addition, good stakeholder collaboration and regulatory enforcement have a positive effect on project safety performance.



Regression Analysis Interpretation

Regression analysis was performed to investigate the effect of DFCS related variables on project performance safety.

The Analysis revealed that:

- Design Integration significantly improves safety performance
- Technology Adoption positively affects hazard prevention
- Stakeholder coordination improves implementation effectiveness
- Safety culture influences project outcomes

The regression findings confirm that proactive safety planning during design stages can reduce construction risks and improve project efficiency.

CONCLUSION & RECOMMENDATIONS

The Comments and contributions of the suggested research are included in this study. It also identifies the practical, theoretical and policy implications that will flow from the findings. The objective was to synthesize how the research adds to the knowledge of the interaction between Design Integration (DI), Technology Adoption (TA), Safety Performance (SP) and the mediating effects of Stakeholders Roles (SR) and moderating effect of Barriers (BAR) in the building sector of Pakistan.

SUMMARY:

Pakistan's construction industry continues to be plagued by recurring safety problems, frequently stemming from poor design coordination, inadequate use of technology and poor stakeholder engagement.

The study experimentally explored the joint impact of design integration and technology adoption on safety performance with the enabling and restricting roles of stakeholders and organizational constraints.

The conceptual framework consists of five basic constructs:

1. Design Integration (DI) - Independent Variable
2. Technology Adoption (TA) - Independent variable
3. Safety performance (SP) - Dependent variable
4. Stakeholder Roles (SR) - Mediator
5. Barriers (BAR) - Moderator

MAJOR FINDINGS OF THE STUDY

The key outcomes from the study of the questionnaire are stated below:

1. Strong support from construction practitioners on the use of DFCS.
2. It is believed that the identification of hazards at the design stage is critical to accident reduction.
3. BIM, VR and digital technology can be used to improve constructions safety.
4. High cost of implementation and lack of technical skills impede the technology adoption.
5. Stakeholder coordination and contractual responsibilities are major influences on the implementation of safety.
6. Effective government regulatory enforcement is viewed as crucial for the successful implementation of DFCS.
7. Safety oriented design strategies boost the overall project performance and reduce accidents.
8. The respondents are overwhelmingly supportive of the inclusion of DFCS in engineering and construction education.
9. Week safety culture and reporting systems continue to be major challenges in the sector.
10. There are enormous opportunities for improving the construction safety performance in the future in Pakistan Through digital transformation.

RECOMMENDATIONS

Based on the examination of the questionnaire and the statistical results, the following recommendations are suggested:

Regulatory Recommendations

- Government agencies should develop mandatory DFCS guidelines.
- Safety regulations should be strictly enforced during design and planning stages.
- Construction contracts should clearly define safety responsibilities.

Educational Recommendations

- DFCS & BIM-based safety training should be part of engineering curriculum.
- Professional training programs should be organized for designers and contractors.
- Awareness seminars should be conducted regarding safety-oriented design practices.

Technological Recommendations

- Construction organizations should adopt BIM and digital safety tools.
- Investment should be increased in digital hazard simulation technologies.
- Organizations should improve technical training for employees.

Organizational Recommendations

- Companies should promote strong safety culture.
- Stakeholder coordination mechanisms should be strengthened.
- Accident reporting systems should be improved.
- Safety performance indicators should be developed for project monitoring.

Research Recommendations

- Future research should explore the application of DFCS in different construction sectors.
- Future research should examine cost benefit of implementation of DFCS.
- Comparative studies between developed and developing countries are needed.

I. Integrate Safety in design phase

The project managers and architects must be close coordination and have the responsibility of supervising the building of a structure during design phase.

II. Promote Technology Adoption.

Digital technologies including Building Information Modeling (BIM), AI, drones and wearable sensors, may enhance the project safety of building, monitoring, risk detection, and supervision.

III. Maximize Stakeholders' Engagement.

It may help to create a comprehensive safety plan by collaboration between owners, contractors, architects and designers that encourages a culture of shared responsibility for safety of all the stakeholders.

IV. Address Organizational Barriers

The government may assist individuals as well as firms get over their fear of technology with financial incentives, educate workers.

V. Enhance Rules and Regulations

To encourage modern safety Techniques, Government may conduct safety design assessments and revise their safety policies , digitalize safety processes and update national safety rules and legislation to promote innovation.

VI. Training &Capacity Building

A training program for the construction crew should be provided, including risk reduction measures and digital safety management systems.

Future Research Directions

- Future studies may adopt a **mixed-method approach** by combining surveys with interviews to gain deeper insights into stakeholder behavior.
- Comparative studies can be conducted across different regions or project types to examine contextual variations in safety culture.
- Longitudinal studies could explore the long-term impact of technology integration on safety outcomes over project life cycles.

CONCLUSION

The statistical analysis shows that the data obtained from the questionnaire is reliable and acceptable for advanced statistical analysis. The results show that application of DFCS, digital technologies and proactive safety measures are favorably contributing to improve safety performance in the Pakistani construction projects.

The reliability analysis, descriptive statistics, correlation matrix and factor analysis confirm the validity of the research framework and research objectives.

The analysis confirms that Design Integration strongly supports the change from reactive safety management to proactive design-led strategies in Pakistan's building industry, directly or indirectly through Technology Adoption, which boosts Safety Performance.

It provides thorough statistical analysis and interpretation of questionnaire data received from the Pakistani construction industry on Design for Construction Safety implementation.

The data indicates that the respondents are very much in favour of incorporation of safety in the design and planning phases of the project. The findings affirm that the implementation of DFCS, stakeholder participation and digital technology significantly impact on the construction safety performance.

However, practical adoption of DFCS methods in Pakistan is still hampered by lack of legislation, poor technical skills, weak organizational culture and financial limits.

In conclusion, the results validate the significance of safety-oriented design techniques and provide a comprehensive framework to enhance construction safety management in future building projects.

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