Exploring the Multidimensional Challenges in Integrating Design for Safety (DfS) in the Ghanaian Construction Industry

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Abstract

Purpose – The uptake of Design for Safety (DfS) practices in developing countries like Ghana has been limited. This research aimed to provide an in-depth understanding of the barriers across regulatory, organizational, cultural, and educational dimensions that restrict DfS assimilation in the Ghanaian construction sector. Identifying the key impediments can inform policy initiatives and industry efforts to facilitate safer construction.

Design/methodology/approach – A postpositive philosophy underpinned the quantitative research. Multi-stage research was used. A comprehensive questionnaire survey was designed and given to 6 industry experts to assess clarity, relevance, and effectiveness after a thorough literature review. 164 professionals were reached to take part in the study using purposive sampling and consequently snowballing. 'Variables' were ranked using mean score ranking and normalization techniques, exploratory factor analysis was then employed to group variables into clusters.

Findings – Emergent findings revealed four distinct clusters of challenges; *1) Design Process and Communication Challenges; 2) Regulatory and Expertise Limitations; 3) Planning and Education Constraints; and 4) Attitudinal and Perception Barriers*. These findings help identify targeted solutions to overcome barriers including developing robust regulatory frameworks, promoting collaboration among stakeholders, and cultivating a positive safety culture.

Originality – This study provides new insights into the integration of DfS in the context of the developing construction industry in Ghana. The study expands the knowledge base to drive further research in enhancing construction safety in developing countries. Practical recommendations for overcoming these challenges are proposed.
Keywords – *Design for Safety, Occupational health and safety, Construction safety.*

1.0 Background

Poor health and safety performance is still a major problem in the construction sector worldwide, with very high rates of work-related illnesses, injuries, and fatalities (International Labor Organization, 2020). In developing countries, the construction sector accounts for three times as many deaths as in developed nations (Okonkwo, 2019). The construction industry in Ghana accounts for only 7% of all jobs, yet it is a major source of workplace dangers, with injury rates of 43 per 1 million hours worked and 63 per 1,000 workers (Boadu *et al*., 2020). The staggering health and safety issues in Ghanaian construction are further highlighted by the severity rate of 418 lost days for every million hours worked. Innovative technologies (Marks and Teizer, 2013; Parn *et al*., 2019), regulatory tools (Van Heerden *et al*., 2018), supply chain integration (Diugwu *et al*., 2013), and safety management techniques (Marks and Teizer, 2013; Diugwu *et al*., 2013) are just some of the methods proposed to enhance construction health and safety (Priyadarshani *et al*., 2013; Boadu *et al*., 2020). However, these have not resulted in the expected changes in developing countries. Design for Safety (DfS), a promising strategy that advocates deliberately addressing potential dangers through design interventions, has been promoted more lately (Toole and Erger, 2018; Manu *et al*., 2019). So far in the Ghanaian construction industries, studies (Manu *et al*., 2021) have mainly focused on design for safety awareness and practice among construction professionals. Design for safety or prevention through design (PtD) is the incorporation of construction site safety into the design of a project. This includes changes to the features of the construction project so that construction site safety is considered; taking a critical look into the preparation of plans and specifications for construction; suggestion of better safety design; and the communication of risks pertaining to the design of the site and the work to be performed (Behm, 2005a). DfS requires engineers and architects to expressly address the safety of construction workers during the design phase to minimize or reduce construction worker hazards (Manu *et al*., 2021). Yu *et al*. (2015) suggest that construction site safety must be clearly considered throughout the design phase through optimized design. It is vital to carefully analyze both temporary and permanent design solutions to enhance the safety of workers during construction and maintenance as well as end users. Lack of safety consideration in design can result in the death of workers (Samsudin *et al*., 2022; Sang *et al*., 2021; Toole *et al*., 2017).

DfS is a rapidly growing field of construction practice that is supported by law in several nations (Manu, 2019). Even though DfS is not the sole factor affecting safety, researchers believe it is a realistic strategy for enhancing safety on construction sites and preventing accidents (Atkinson and Westall, 2010; Zhou *et al*., 2015). Extensive research demonstrates that design decisions considerably affect construction site safety (Behm, 2005a; Gambatese *et al*., 2008; Tymvios *et al*., 2012; Behm *et al*., 2014). Behm (2005b) discovered that 42% of construction fatalities were attributable to upstream design flaws. Safety can be boosted over a project's lifespan when hazards are identified and eliminated at the design phase through DfS principles. This is more crucial compared to mere hazard mitigation or protection during construction. However, DfS research and adoption has been concentrated in developed nations, with limited attention paid to developing nations where the need is frequently greater (Manu *et al*., 2021; Manu *et al*., 2019). Given the worrying incidences of occupational injuries and fatalities in Ghana's construction industry (Boadu *et al*., 2020), it is necessary to investigate safety solutions such as DfS. However, there is a dearth of research on the barriers local industry practitioners face when integrating DfS into construction project. This knowledge gap must be addressed to increase DfS adoption in the most required areas. Consequently, the objective of this study is to investigate the multidimensional barriers associated with integrating DfS concepts into the Ghanaian construction industry to answer the research question, what are the key challenges that restrict the integration of Design for Safety (DfS) within the Ghanaian construction industry? This paper is structured to first provide an overview of DfS integration within Ghana's construction sector that underscores the study's relevance. This is followed by a detailed description of the quantitative methodology utilized in the study. Key results from the statistical analysis are then presented, centered on ranking challenges and exploring underlying factor groupings. These findings lead into a discussion of the critical impediment clusters and their implications. Conclusions and recommendations aimed at facilitating greater DfS assimilation are outlined, along with limitations and directions for future research.

2.0 Health and Safety Performance of the Ghanaian Construction Industry

Health and safety performance in developing nations is dismal, including Ghana. National indices of occupational injury represent 4.7% of the construction industry (Boadu *et al*. (2021). The accident frequency rate of the construction industry is 65 compared with a national indicator of 43, a percentage of 151% higher (Ghana Statistical Service, 2016). Again, GSS (2016) provides statistics on markers of occupational injury in the construction industry. In 2015, the death incidence rate in Ghana was 63. However, the construction industry reported 86 incidents. The GCI found a 137% increase over the national average, indicating an extremely high accident risk in the industry. According to GCI's 2015 occupational injury report, the recorded accidents on construction sites are only a fraction of the total events that occur (GSS 2015). Some accidents may be unreported for a variety of reasons, including geographical proximity, communication challenges, political influence, cultural barriers, among others (Hamalainen *et al*., 2006). Laryea (2010) claimed that the lack of a strong institutional framework governing construction activities, the poor enforcement of health and safety policies and procedures, and the fact that Ghanaian society does not place a high value on the health and safety of construction workers on site are the primary causes of the poor state of health and safety on Ghanaian construction sites. Eyiah *et al*. (2019) also purported that legislative and regulatory obstacles, among other variables, contribute to Ghana's poor occupational health and safety (OHS) performance.

2.1 Challenges in Integrating Design for Safety

Significant research has been conducted on DfS, and the majority of studies have highlighted the significance of enhancing site safety and health through the elimination and mitigation of hazards during design (Behm, 2005b; Gambatese *et al*., 2005; Gangolells *et al*., 2010; Larsen and Whyte, 2013). Despite the implementation of DfS legislation in numerous countries and the results highlighted, there are still problems and hurdles in implementing DfS (Manu *et al*., 2021). Multiple impediments to DfS integration have been mentioned in the literature. Gambatese *et al*. (2005) emphasized that there was a lack of safety consideration during design, with underlying issues including a designer's attitude toward safety, a lack of safety education among designers, and liability concerns. Given that DfS requires incorporating construction knowledge into the design process (Oney-Yazc and Dulaimi, 2015), Gambatese and Hinze (1999) observed that the fragmented character of the construction process hinders the transmission of construction knowledge from the building site to the designers. Thus, designers' lack of awareness of building processes and site risks impedes the implementation of the DfS concept (Weinstein *et al*., 2005; Oney-Yazc and Dulaimi, 2015). Toole (2013) noted that the ineffective communication between designers and other stakeholders was one of the challenges for DfS, a finding that was corroborated by other researchers (Gambatese *et al*., 2017a; Goh and Chua, 2016; Tymvios and Gambatese, 2016). Insufficient knowledge and practice about DfS (Goh and Chua, 2016; Toh *et al*., 2017), a lack of designer knowhow on construction process and employees' safety (Gambatese *et al*., 2005), concerns about cost overruns due to additional safety considerations from DfS (Toh *et al*., 2017), a lack of client's safety commitment (Umeokafor *et al*., 2023a; Goh and Chua, 2016) constitute some of the challenges in integrating design for safety in the construction industry. López-Arquillos *et al*. (2015) found that architects and engineers in Spain are not taught enough about DfS in university courses. Lack of tertiary education on DfS can easily result in insufficient knowledge, attitude, and practices (KAP) to effectively execute DfS. According to some experts, the absence of legislation and regulations mandating designers to consider the safety of construction workers impedes the spread of DfS. (Gambatese *et al*., 2017b; Che Ibrahim and Belayutham, 2023a; Adaku *et al*., 2021). In addition, divergent perspectives on litigation and professional liability negatively impact designers' ability to exercise innovation in design activities (Umeokafor *et al*., 2023b; Tymvios and Gambatese, 2016). Table 1 below presents a summary of the challenges in Integrating Design for Safety identified in literature.

<Insert Table 1 about here>

3.0 Methodology

The study employed the quantitative research technique, grounded in a postpositive philosophy, to rigorously evaluate theories related to the phenomenon being studied (Edwards *et al*., 2020; Ameyaw *et al*., 2023). The first stage of this study consisted of a comprehensive examination of literature, industry reports, and scholarly articles in order to identify and understand the various complex obstacles associated with the integration of Design for Safety (DfS) in the construction sector. A meticulously designed survey instrument was developed to assess and measure the challenges that were identified. The survey was designed to incorporate inquiries that encompass the multifaceted nature of the challenges and capture a wide range of perspectives and experiences within the industry. Bryman (2016), Naoum (2013), and Creswell and Cresswell (2017) have all suggested that the survey method is the most appropriate when a generalized perspective of a phenomenon is desired. Since this study aimed to acquire a broad understanding of the challenges of implementing DfS in the Ghanaian construction industry, a survey was deemed the most appropriate method. In past DfS studies, the survey method was also used to gain a broad understanding of the topic under investigation (Goh and Chua, 2016; Ismail *et al*., 2021).

The questionnaire was structured into two main sections: the first section focused on gathering demographic information about the respondents, while the second section delved into the challenges related to the integration of Design for Safety. In Section 2, participants were instructed to rank using a 5-point Likert scale, with 1 = Strongly disagree 2 = Disagree 3 = Neutral 4 = Agree 5 = Strongly Agree, their level of agreement to the statements presented. The utilization of a 5-point Likert grading scale has the potential to mitigate the challenges associated with central tendency inferences commonly observed in ordinal data. Other researchers have adopted the five-point Likert scale in a similar study (Manu *et al*., 2019; Christermaller *et al*., 2022; Sharar *et al*., 2022). The information from the two sections was compiled into a Google Forms questionnaire and distributed to a number of Ghanaian construction professionals. The Google forms were preferred because manual administration costs are avoided since it may be distributed via the internet while also helping to reach a larger audience (Sanni-Anibire *et al*., 2020).

Pretesting of the survey instrument was conducted by administering it to a specific group of industry experts (6 experts) to assess the clarity, relevance, and effectiveness of the survey questions prior to data collection. These experts, who held roles such as construction safety managers, senior project engineers with a focus on safety protocols, and experienced designers specializing in safety-conscious design practices, helped refine the survey instrument, ensuring that it accurately captured the multifaceted challenges related to the integration of Design for Safety (DfS) in the Ghanaian construction industry. The target population consisted of construction professionals in the construction industry. Such personnel typically possess pertinent safety expertise and experience in their respective firms (Manu *et al*., 2019). Due to the difficulty in determining the population size of construction professionals in Ghana, two sampling techniques were employed. A purposive sampling was employed to select professionals who have in-depth knowledge and expertise in safety in their organizations. The following criteria were applied: Minimum 5 years of professional experience in construction design or engineering; Demonstrated specialized focus in safety protocols and risk mitigation; Completion of an advanced educational or training program related to construction safety. The criteria ensured recruitment of participants possessing both extensive knowledge and substantial practical expertise on safety considerations and hazards in construction project delivery. Snowball sampling was consequently employed, wherein our initial respondents were asked to refer other professionals, who met the study's criteria to participate in the survey. The online nature of the survey instrument made it easy to share to personnel all over the country via email and other online messaging platforms. These strategies allowed the researchers to gather 164 responses.

The data analysis process encompassed the utilization of various statistical analytical techniques, such as reliability analysis, the Shapiro-Wilk test, mean score ranking, normalization value analysis, and exploratory factor analysis using the SPSS version 23 software. SPSS was selected as the most appropriate statistical analysis software because of its widespread use and acceptance across quantitative academic literature focused on construction and engineering topics (Pallant, 2020). The versatility of SPSS allows conducting both preliminary reliability and normality examinations as well as the more advanced multivariate exploratory factor analysis essential for this study. The initial procedure for assessing the reliability of the dataset involved conducting the Cronbach's alpha coefficient reliability test (Tavakol *et al*., 2011). Furthermore, to determine the data's normality, the researchers utilized the Shapiro-Wilk test. This test is deemed suitable for data samples with a size below 2,000, which aligns with the sample size in this study, as Orcan (2020) recommended. The variables are ranked based on mean ranking, standard deviation, and normalization value (NV). The NV involves adjusting the survey items to standardized values between zero and one so that the item that has the greatest mean value converts to one while the lowest mean value is converted to zero. The NV can be computed using the equation below;

$$NV = \frac{(Mean\ value - Min\ mean\ value)}{(Max\ mean\ value - Min\ mean\ value)}$$

An NV ≥ 0.60 was used to detect the critical items (Omer *et al*., 2023). This value also indicates the third level in a five-point Likert scale. The study by Hooper (2012) employed Exploratory Factor Analysis (EFA) to investigate the interconnectedness of the challenges associated with integrating design for safety. This approach makes it possible to discern the underlying constructs among the variables within this section. EFA is a widely employed method in cases where it is necessary to identify and investigate latent constructs that account for the observed variance in a given set of variables. Its purpose is to gain a deeper understanding of the underlying structure of the data by uncovering meaningful patterns and relationships. Hair *et al*. (2014) recommends a minimum of 150 responses for conducting an exploratory factor analysis (EFA). In the present study, the number of responses obtained exceeded this minimum requirement, indicating that the data was suitable for EFA. Furthermore, the guidelines for exploratory factor analysis (cf. ibid) recommend a minimum sample size that is five times larger than the number of variables. Figure 1 below presents a graphical illustration of the Research Methodology Workflow.

<Insert Figure 1 about here>

4.0 Results

4.1 Demographic Background of Respondents

The results obtained indicated that the most common job title was construction manager, with 35% (frequency (f) = 58). This was followed by civil engineers 16% (*f* = 26), safety officer 16% (*f* = 26), architect 18% (*f* = 30), and quantity surveyor 15% (*f* = 24). This distribution indicates that the sample included professionals with diverse roles and responsibilities in the construction industry. A significant proportion of the sample size had 1-5 years of experience 45% (*f* = 74). This was followed by 6-10 years 27% (*f* = 44), 11-15 years 9% (*f* = 14), less than 1 year 18% (*f* = 30) and more than 15 years 1% (*f* = 2). This diverse range of level of experience aligns with the recommendation of Leksakundilok (2004) that a diverse range of experience is crucial for ensuring that the respondents are representative of the population being studied. The most common educational level was an undergraduate degree, 52% (*f* = 86). This was followed by a master's degree 34% (*f* = 56), high school diploma or equivalent 6% (*f* = 10). PhD 5% (*f* = 8) and HND 2% (*f* = 4). The large number of respondents with an undergraduate or postgraduate degree suggests that the sample consisted of highly educated construction industry professionals.
Analysis of the demographic data shows that the survey sample included construction professionals with diverse job roles, concentrated in the early and middle stages of their careers, and largely holding academic undergraduate or postgraduate qualifications. The sample is reasonably representative of professional occupations within the construction sector. The dominance of undergraduate qualified respondents is logical given the strong emphasis on construction related university programs and the geographic setting of the study. The prevalence of 1-5 years of experience also reflects normal patterns of entrance, progression and attrition within the industry.

4.2 Statistical Pretesting of Dataset

The Cronbach's alpha test was to test the reliability of the scale. The instrument demonstrated a high level of reliability, as indicated by the overall alpha coefficient of 0.934, with 21 items, well above the recommended 0.70 Ekanayake *et al*. (2023). The findings indicated that the p-value for all 21 challenges were below the required threshold of 0.05 for establishing normality with each recording a p-value of 0.00. These results suggest that the collected data does not follow a normal distribution and hence statistical tools that do not rely on the normality of data can be used.

4.3 Ranking the Challenges in Integrating Design for Safety

Mean ranking, standard deviation, and the normalization technique were computed to rank the Challenges in Integrating Design for Safety. Table 2 below shows the results of the mean ranking, standard deviation, and NV

<Insert Table 2 about here>

4.4 Exploratory Factor Analysis

Principal components analysis was performed on the 'challenges' using SPSS version 23. The KMO measure of sample adequacy was calculated to be 0.847, over the minimum ideal value of 0.70. Bartlett's test for sphericity produced a value of 2062.225 with a significance level of 0.000. The variables had an average communality of 0.620 with 0.463 and 0.845 being the least and highest extracted communalities (refer to the Table 3 below). Additionally, all of the extracted variables can be shown to have eigenvalues of 0.50 or above, which, according to Fields (2010), suggests that they are suitable for processing and analysis subsequently. The rotated component matrix data presented on the Table below, shows a four-factor component solution that explained 61.55% of the overall variation was explained. The first component explained 43.68% of the variation, followed by 7.32% by the second, 5.73% by the third, and 4.81% by the fourth. According to Pallant (2016), the total variation explained should be greater than the minimal suggested proportion of 50%.

<Insert Table 3 about here>

5.0 Discussion

Figure 2 illustrates the optimal number of components derived from the dataset through exploratory factor analysis. The graph illustrates the eigenvalues of each component on the x-axis, plotted against their respective component numbers on the y-axis. The eigenvalue serves as a quantitative indicator of the extent to which each component accounts for the variance, with larger eigenvalues signifying more substantial contributions to the overall variance. The scree plot presented below reveals that a total of four components exhibited eigenvalues equal to or greater than 1. This finding suggests that these particular components accounted for a significant portion of the overall variance observed in the dataset. As a result, the main clusters for further analysis were chosen to be these four components.

<Insert Figure 2 about here>

Component 1 ***Design Process and Communication Challenges***

The first component accounts for 43.69% of the variance and includes 10 variables related to design process and communication issues. The key challenges in this factor relate to the *complexity of design for safety technologies/software (61.6%), lack of information on effectiveness of design for safety (53.6%), insufficient motivation and knowledge of designers (75.4%, 75.1%), unclear safety responsibilities (66.1%), and limited preconstruction collaboration (57.0%).* Additionally, results from the means ranking and normalization analysis indicates that a majority (44.4%) of the critical variables belong to this component (CH10, CH12, CH6 and CH11), this shows the criticality of this component as a challenge to integrating DfS.

This component embodies a set of challenges that primarily revolve around the intricacies of incorporating safety measures within the design phase and the communication gaps within the construction project lifecycle. The subjects of Design Process and Communication are of paramount importance. In literature, Design Process and Communication Challenges in integrating design for safety are not unique to a specific domain but are prevalent across various industries and sectors (Wang *et al*., 2019; Jin *et al*., 2019; Baas *et al*., 2022). Therefore, in order to tackle these challenges effectively, it is imperative to adopt a multidisciplinary approach that encompasses the involvement of stakeholders from various domains and the utilization of suitable communication tools, technologies, and methodologies. An illustration of the application of Building Information Modeling (BIM) and 4D modeling can be observed in the assessment of construction risks and the enhancement of collaboration among stakeholders, as demonstrated by Jin *et al*. (2019). Risk assessment methodologies, such as the Analytic Hierarchy Process (AHP), have the potential to assist in the process of choosing safety devices and assessing the effectiveness of safety systems (Gleirscher, 2020). This finding suggests that a multidisciplinary approach to safety management is needed by involving all stakeholders on the project. This integrated approach through collaboration at the design stage can help improve safety on construction projects

Component 2 ***Regulatory and Expertise Limitations***

The second component explains 7.32% of the variance and contains 6 variables related to regulatory issues and expertise gaps. Key challenges include *Limited or no construction experience (59.1%), Absence of regulatory requirements (55.7%), Narrow specialisation of construction in design (67.6%), Extensive upfront investment required (69.0%), Doubts regarding reliability of software for design for safety (54.8%), Clients' influence (66.1%).* Two of the critical variables (CH8 and CH16) from the ranking of the variables belong to this component suggesting how important and critical the challenges in this component are. This component, underscores the crucial role of regulations and expertise in promoting safety within design processes. This is consistent with the findings of (Poghosyan *et al*., 2018), who highlighted the need for considering safety requirements and regulations in the design process. Additionally, Sharar *et al*. (2022) in their study on the construction industry in Kuwait discussed the importance of addressing regulatory requirements and the influence of clients in promoting safety in design. This finding emphasizes the importance of considering safety requirements and regulations, addressing barriers to implementation, involving clients, and promoting expertise and professionalism in the design process to help enhance the integration of design for safety and improve safety outcomes in the construction industry. It indicates that stronger regulations, construction knowledge, and enhanced software reliability may help overcome expertise-related barriers.

Component 3 ***Planning and Education Constraints***

The third component accounts for 5.73% of the variance and has 3 variables related to project planning and education limitations. The main challenges are *Increases duration of planning phase of projects (60.0%), Unavailability of industry standards codes or guides on DfS (79.3%), Limited education and training (57.5%).* Two of the key variables (CH21 and CH18) identified in the variable ranking analysis are in this component, indicating the significance and criticality of the challenges associated with this component. This component points to scheduling and guideline constraints as well as knowledge gaps due to limited educational opportunities. This is consistent with (Christermaller *et al*., 2022) where they found that there is a need for increased awareness and education on DfS principles among designers in Malaysia. The implications of these findings are significant for the construction industry. By implementing DfS principles, designers can proactively identify and mitigate safety hazards in the design phase, leading to safer construction projects. Instituting design for safety earlier in project timelines, developing codes and standards, and more training could help address these planning and education-related barriers. Additionally, overcoming these challenges requires streamlining the planning process through adequate guidelines and investing in educational initiatives to enhance safety knowledge and skills among industry professionals.

Component 4 ***Attitudinal and Perception Barriers***
The fourth component explains 4.81% of the variance and contains the single variable of *Designer's attitude towards the concept (87.4%).* From the mean ranking and normalization, the highest ranked challenge is in this group. This shows how critical Attitudinal and Perception Barriers are as a challenge to DfS integration. This cluster delves into the psychological and perceptual aspects influencing DfS integration. It primarily focuses on the designer's attitude towards the concept of safety. Attitudes and perceptions significantly impact the extent to which designers embrace and prioritize safety in their designs. The implications of these findings are significant as they highlight the need to address attitudinal barriers in various domains. In the construction industry, addressing attitudinal barriers and promoting positive safety attitudes among workers can enhance safety behavior and reduce accidents (Xu *et al*., 2018). Addressing attitudinal barriers necessitates targeted awareness campaigns, training programs, and initiatives to cultivate a positive safety culture among designers. Again, changing attitudes through demonstrating benefits and providing motivators may help improve receptivity to design for safety principles.

6.0 Theoretical and Practical Implications

The four main Challenges in Integrating Design for Safety (viz. 1) Design Process and Communication Challenges; 2) Regulatory and Expertise Limitations; 3) Planning and Education Constraints; and 4) Attitudinal and Perception Barriers) have been identified, and they offer important novel information about the specific issues that are hindering the successful integration of DfS in the Ghanaian. These challenges have a widespread impact on diverse industries and sectors, thereby confirming their inherent universality. Also, complex challenges across multiple dimensions highlight the importance of implementing a multidisciplinary approach that incorporates stakeholders from various domains. The integration of insights and expertise from various disciplines, such as design, engineering, and technology, is imperative for the development of comprehensive strategies aimed at effectively addressing these challenges. The study also highlights the crucial importance of adhering to regulatory requirements and the impact of client involvement in fostering safety during the design phase. This finding supports the theoretical proposition that robust regulations and active client participation substantially affect the integration of safety measures. The study's findings should be considered by the government and relevant authorities in Ghana, as well as other developing nations, in formulating or revising construction safety policies. The findings suggest that it is crucial to enhance regulatory frameworks in order to enforce the inclusion of safety measures during the design phase. Once more, the results indicate that it would be beneficial to prioritize practical interventions aimed at improving education and training programs within the construction industry. It is recommended that institutions and organizations allocate resources towards the development of specialized education curricula, workshops, and certifications. These initiatives aim to provide professionals with the necessary knowledge and skills to effectively integrate safety measures. Promoting a culture of lifelong learning and fostering the acquisition of new skills will contribute to the mitigation of knowledge deficiencies. This approach's practical implementation should entail utilising sophisticated technologies such as Building Information Modeling (BIM) and risk assessment methodologies to facilitate improved collaboration and risk management. It is imperative for industry stakeholders to adopt collaborative platforms and tools in order to enhance communication and cooperation among all participants involved in a project. Promoting collaborative endeavors during the design phase can considerably augment safety measures on construction projects.

7.0 Conclusion and Recommendation

Incorporating Design for Safety (DfS) within the construction sector shows significant potential in improving safety outcomes and reducing risks. This research conducted a comprehensive analysis of the various challenges that hinder the incorporation of Design for Safety (DfS) practices within the construction industry in Ghana. The study aimed to provide insights into the key factors that impact this process. The data analysis revealed four primary clusters of challenges. The first cluster focuses on design processes and communication challenges. This highlights the importance of adopting a multidisciplinary approach to address knowledge gaps and promote successful collaboration among stakeholders. The second cluster focuses on the crucial role of regulations and expertise in facilitating safety during the design phase emphasizing the need for robust regulatory frameworks and enhanced expertise to overcome these barriers. In the third Component, the significance of proactive safety planning and education is emphasized, along with the advocacy for the early incorporation of Design for Safety (DfS) principles in project timelines and the establishment of industry-specific standards and educational initiatives. Lastly, Component 4 highlights the importance of tackling attitudinal barriers, placing emphasis on the necessity of fostering a favorable safety culture and reshaping perceptions within the construction sector.

Building on the findings and conclusions of this research, stakeholders should actively encourage communication and knowledge sharing among architects, engineers, contractors, and other construction project participants. This collaborative approach can bridge knowledge gaps and streamline design processes to encourage DfS principles. Policymakers and regulatory agencies should establish comprehensive and robust regulatory frameworks that accentuate safety during the design phase. These regulations should be clear, enforceable, and regularly updated to align with industry best practices. The Ghanaian construction sector should invest in safety education and training programs underscoring DfS tenets. This encompasses the early integration of safety considerations in curricula and industry-specific training initiatives. Construction companies and organizations should emphasize fostering a positive safety culture, achieved by promoting shared commitment to safety at all organizational levels and incentivizing safe practices. Companies could also better demonstrate the benefits of the concept and provide motivators to make personnel more receptive to the concept.

7.1 Limitations

It is essential to recognise some inherent limitations of the study that provide avenues for further research. The non-probability sampling techniques may restrict the generalizability of findings across the Ghanaian construction sector. The use of subjective self-reported data from industry professionals introduces possibilities of biases. Also, the cross-sectional nature of the research only provides a snapshot during a certain period in time especially in this rapidly changing digital age. However, it should be noted that many investigations undertaken in the construction industry context face such limitations in representativeness and variability across projects due to the nature of the industry.

7.2 Future Research Directions

While this study focused chiefly on challenges, further research could examine the practical implementation of these suggestions to appraise their feasibility in the Ghanaian construction industry. Future work should investigate pilot testing proposed interventions and collecting data on critical implementation factors including required resources, timelines, and measurable indicators of success. Additional studies focused on empirical demonstration of solutions can provide evidence-based guidance for successful adoption of Design for Safety principles. Future research should also examine the potential benefits of adopting DfS practices in the Ghanaian construction industry. Investigating the tangible advantages of eliminating identified barriers can provide valuable insights driving industry transformation. Research should also explore integrating advanced technologies like artificial intelligence and machine learning to enhance DfS incorporation into architectural designs, paving the way for more sustainable construction practices.

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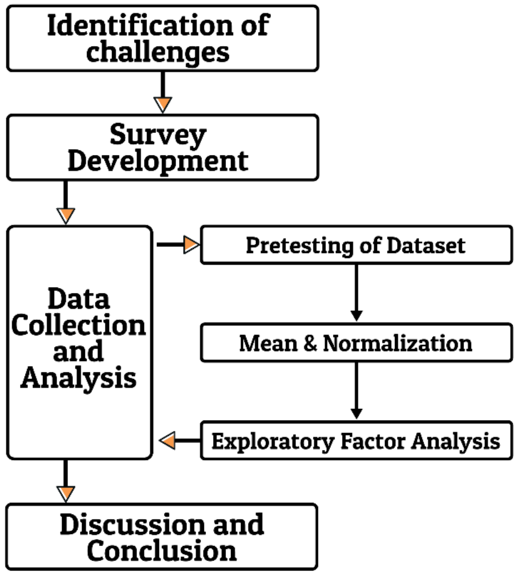

Figure 1 Research Methodology Workflow

(Source: Authors own work)

Table 1 Challenges in Integrating Design for Safety

Code	Challenge	Reference
CH1	Designer's attitude towards the concept	Abas et al (2020); Umeokafor et al (2023); Sharar et al (2022)
CH2	Limited or no construction experience among others	Umeokafor et al (2023); Gambatese et al (2017)
CH3	Absence of regulatory requirements	Umeokafor et al (2023); Karakhan et al (2017)
CH4	Narrow specialisation of construction in design	Gambatese et al (2005); Toole (2005)
CH5	Limited tools and guidelines	Umeokafor et al (2023); Gambatese et al (2017)
CH6	Limited preconstruction collaboration	Ndekugri et al (2023); Umeokafor et al (2023)
CH7	Limited education and training	Umeokafor et al (2023); Gambatese et al (2017)
CH8	Extensive upfront investment required	Nnaji and Karakhan (2020); Yap et al (2022)
CH9	Doubts regarding reliability of software for design for safety	Nnaji and Karakhan (2020)
CH10	Technologies/software for design for safety tend to be complex to use	Nnaji and Karakhan (2020)
CH11	Lack of information on the effectiveness of design for safety	Umeokafor et al (2023); Maliha et al (2021)
CH12	Lack of communication between designer and other stakeholders	Umeokafor et al (2023); Maliha et al (2021)
CH13	Insufficient motivation for designers to implement DfS	Poghosyan et al (2018); Christermaller et al (2022)
CH14	Insufficiency of designer knowledge and education	Umeokafor et al (2023); Gambatese et al (2017)
CH15	Lack of DFS legislation	Poghosyan et al (2018); Umeokafor et al (2023a)
CH16	Clients' influence	Poghosyan et al (2018)
CH17	Unavailability of related computer tools to help designers to include DfS in their designs	Ibrahim et al (2022); Poghosyan et al (2018)
CH18	Unavailability of industry standards, codes or guides on DfS	Asmone et al (2022)
CH19	Unclearness of safety responsibilities for designer	Umeokafor et al (2023)
CH20	Insufficiency of motivation for designers to implement DfS	Poghosyan et al (2018)
CH21	Increases duration of planning phase of projects	Ndekugri et al (2023)

(Source: Authors own work)

Table 2 Ranking the Challenges in Integrating Design for Safety

Code	Challenges in Integrating Design for Safety	Mean	Std. Deviation	NV	Rank
CH1	Designer's attitude towards the concept	3.70	1.26	1.00*	1st
CH21	Increases duration of planning phase of projects	3.66	1.20	0.91*	2nd
CH10	Technologies/software for design for safety tend to be complex to use	3.65	1.27	0.88*	3rd
CH12	Lack of communication between designer and other stakeholders	3.63	1.26	0.85*	4th
CH6	Limited preconstruction collaboration	3.61	1.15	0.79*	5th
CH8	Extensive upfront investment required	3.60	1.09	0.76*	6th
CH11	Lack of information on the effectiveness of design for safety	3.60	1.20	0.76*	7th
CH16	Clients' influence	3.59	1.19	0.73*	8th
CH18	Unavailability of industry standards, codes or guides on DfS	3.56	1.27	0.67*	9th
CH15	Lack of DfS legislation	3.50	1.14	0.52	10th
CH17	Unavailability of related computer tools to help designers to include DfS in their designs	3.50	1.26	0.52	11th
CH4	Narrow specialisation of construction in design	3.50	1.28	0.52	12th
CH3	Absence of regulatory requirements	3.46	1.39	0.42	13th
CH7	Limited education and training	3.46	1.30	0.42	14th
CH9	Doubts regarding reliability of software for design for safety	3.44	1.14	0.36	15th
CH5	Limited tools and guidelines	3.43	1.31	0.33	16th
CH14	Insufficiency of designer knowledge and education	3.41	1.26	0.30	17th
CH19	Unclearness of safety responsibilities for designer	3.38	1.25	0.21	18th
CH20	Insufficiency of motivation for designers to implement DfS	3.37	1.30	0.18	19th
CH2	Limited or no construction experience among others	3.33	1.37	0.09	20th
CH13	Insufficient motivation for designers to implement DfS	3.29	1.32	0.00	21st

Notes: NV = (mean–mini mean value)/ (maxi mean value–mini mean value); * represents NVs $\geq$ 0.60 is critical.
(Source: Authors own work)

Table 3 Summary of Exploratory Factor Analysis

Code	Challenges in Integrating Design for Safety	Rotated Component Matrix				
		Component				Extracted Communalities
		1	2	3	4	
CH1	Designer's attitude towards the concept				.874	.845
CH2	Limited or no construction experience		.591			.649
CH3	Absence of regulatory requirements		.557			.592
CH4	Narrow specialisation of construction in design		.676			.614
CH8	Extensive upfront investment required		.690			.590
CH9	Doubts regarding reliability of software for design for safety		.548			.590
CH16	Clients' influence		.661			.532
CH10	Technologies/software for design for safety tend to be complex to use	.616				.720
CH11	Lack of information on the effectiveness of design for safety	.536				.488
CH12	Lack of communication between designer and other stakeholders	.649				.483
CH13	Insufficient motivation for designers to implement DfS	.754				.751
CH14	Insufficiency of designer knowledge and education	.751				.769
CH15	Lack of DfS legislation	.686				.566
CH17	Unavailability of related computer tools to help designers to include DfS in their designs	.504				.538
CH19	Unclearness of safety responsibilities for designer	.661				.552
CH20	Insufficiency of motivation for designers to implement DfS	.681				.689
CH6	Limited preconstruction collaboration	.570				.463
CH21	Increases duration of planning phase of projects			.600		.616
CH18	Unavailability of industry standards, codes or guides on DfS			.793		.776
CH7	Limited education and training			.575		.580
	Total	9.175	1.538	1.203	1.010	
	% of Variance	43.689	7.322	5.729	4.808	
	Cumulative %	43.689	51.011	56.740	61.548	
	KMO	.847				
	Bartlett's Test of Sphericity					
	Approx. Chi-Square	2062.22				
	df	210				
	Sig.	0.000				

Extraction Method: *Principal Component Analysis.*
Rotation Method: *Varimax with Kaiser Normalization.*
a. Rotation converged in 10 iterations.

(Source: Authors own work)

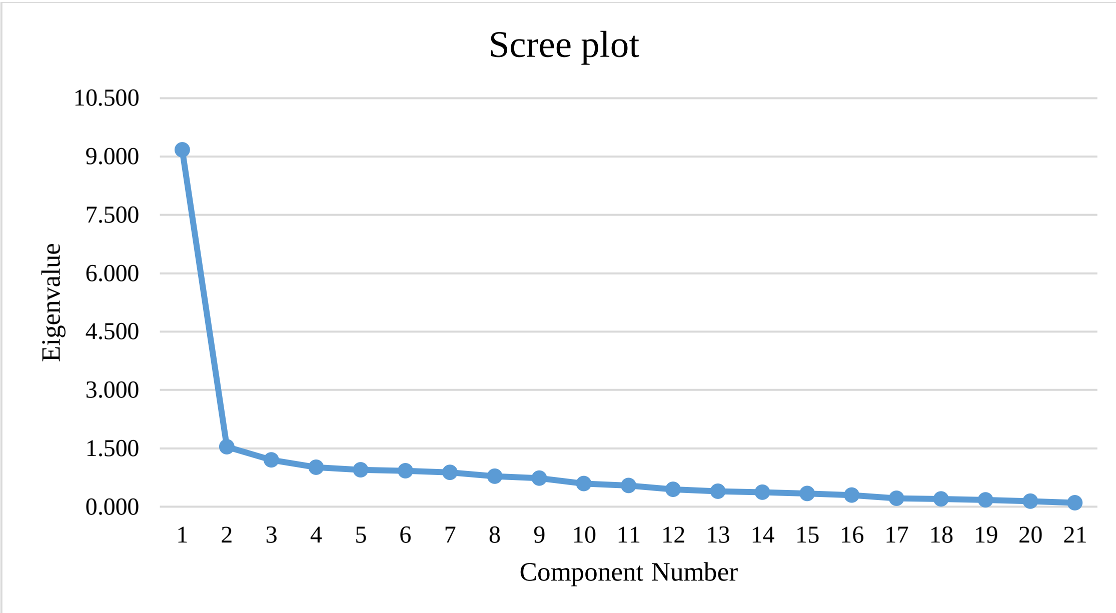

Figure 2 Scree plot

(Source: Authors own work)