



# Enhancing Safety in the Construction Industry: A Review of Design for Safety Concept

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## Abstract

The construction industry is well-known for its high-risk environment, where accidents and injuries have long been a pressing concern. The design aspect of projects is identified as being a significant contributing factor to construction site accidents. This paper presents a review of the Design for Safety (DfS) concept as a potent intervention to enhance safety within the construction industry. DfS involves the early integration of safety measures, site-specific design, hazard elimination, and the incorporation of safety features into the project's design. The review shows that, contrary to common misconceptions, DfS does not necessarily lead to higher construction costs; it often results in cost savings by preventing accidents and reducing insurance premiums. Also, the professionals associated with construction projects are ready to implement the DfS concept. However, the review uncovers barriers limiting the adoption of DfS, such as the lack of guidelines and client cost concerns, are not insurmountable. Recommendations for future research were proffered including longitudinal studies, investigating barriers and solutions, conducting economic analyses, exploring client involvement, and drawing insights from other industries with mature safety cultures.

**Keywords:** Construction Sites, Accidents, Design for Safety, Design Implementation, Review.

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## Introduction

The global construction industry has long been plagued by its reputation as a dangerous sector, notorious for its high rates of fatalities and injuries (Zhang et al., 2013; Williams et al., 2020). Each year, an alarming 2.3 million individuals experience accidents, ranging from injuries to disease exposure, during their work. This translates to over 600 fatalities every single day, as reported by the International Labour Organization in 2022. These sobering statistics underscore that, despite the heightened awareness and emphasis on safety and health within numerous construction firms, there remains a pressing need for substantial improvements. Safety, not only during project completion but also prior to and during construction, is of paramount importance. Construction companies worldwide have made safety their number one priority, implementing zero-injury programs, and exploring the use of information technology-based systems, such as online training and smartphone safety applications, to enhance safety and health within their organizations. These companies often convey this commitment through slogans such as 'Safety First' and 'Safety is our top priority.'

While safety standards in the construction industry have improved over the past five decades, they still lag behind many other industries (BLS, 2015). Despite the industry's significant contributions to a country's development, it remains a major contributor to occupational accidents, posing a continuous threat to the welfare and safety of the workforce (Awwad et al., 2016; Kim and Chi, 2019; Dogan et al., 2021). One effective avenue to significantly mitigate accidents on construction sites is through the integration of safety considerations into the design phase. Several studies have shown a clear link between

design decisions and accident rates on construction sites (Manu et al., 2014). This correlation has led to the emergence of the concept of Design for Safety (DfS). A substantial body of literature has explored DfS in various countries, including the UK, other European countries (e.g., Spain), the USA, Australia, and Singapore (Manu et al., 2018; Manu et al., 2019). These findings are in line with the claims made by Awodele and Ayoola (2005) and Smallwood and Haupt (2005), highlighting that hundreds of construction workers lose their lives each year, with many more enduring permanent disabilities as a result of accidents on construction sites.

Despite the evident impact of design on construction safety and the potential benefits of its implementation, the widespread adoption of this intervention is currently lacking in the Nigerian construction industry (Okeola, 2009). This situation raises questions about the feasibility of implementing DfS in the construction industry. Can the concept of designing for safety be readily embraced by the construction industry, and if so, would the resulting improvements in safety justify the effort involved? Should the industry choose to adopt this concept, what adjustments would be required in practice to facilitate its implementation? There is a paucity of research focused on DfS awareness and its implementation among design professionals in the construction industry. This study seeks to investigate the level of DfS awareness and its implementation among design professionals within the construction sector in Gombe Local Government Area. By gaining insights into the extent of awareness and implementation, the study aims to guide the efforts of designers and other industry stakeholders, including educators, professional bodies, and occupational safety and health regulatory agencies, towards raising the profile of DfS and



enhancing its practical application. Notably, despite advancements in safety measures, the number of safety lapses on construction sites in these countries remains significantly higher than in other sectors (Umar et al., 2019).

Despite the annual loss of lives in the global construction industry due to accidents, issues related to occupational health and safety continue to be relegated to a secondary position due to the presence of competing social, economic, and political barriers (Maliha et al., 2021). The primary goal of this study is to evaluate Design for Safety in the construction industry. The research is specifically tailored to the building design team, which comprises architects, civil/structural engineers, mechanical engineers, and electrical engineers. Recognizing that the majority of construction activities necessitate the identification and resolution of the root causes of hazards, this study is geared towards ensuring the safety of all aspects of the project's life cycle (Samsudin et al., 2022).

## Conceptual Background

The application of DfS in the construction industry encompasses a multifaceted approach that places safety considerations at the forefront of project development. As highlighted by Adaku (2021) and the theoretical underpinnings of Lorent's 1987 report and Szymberski's (1997) Time-Safety Influence Curve theory, DfS begins with the early integration of safety measures during the project's design phase. Architects, engineers, and designers collaborate closely to identify potential hazards and risks, aiming to eliminate or mitigate these risks through design modifications (Tymviov and Gambatese, 2020). This proactive approach ensures that safety considerations become an intrinsic part of the project's core. Contrary to common misconceptions, DfS does not necessarily lead to higher construction costs. On the contrary, integrating safety into the design phase can often lead to cost savings by preventing accidents, reducing insurance premiums, and minimizing project delays. This not only aligns with regulatory requirements but also enhances the overall efficiency and safety culture within the construction industry (Manu et al., 2019).

DfS is not a static process but an ongoing commitment to safety. Designers and project managers continually assess the safety performance of the construction project and make necessary adjustments and refinements to address emerging safety concerns (Tymviov and Gambatese, 2020). DfS also ensures regulatory compliance, making certain that construction projects adhere to safety regulations and standards. Staying updated on evolving safety regulations and making design modifications accordingly is essential to maintain compliance (Tymviov and Gambatese, 2020). Moreover, DfS emphasises the involvement of workers in the design process. Workers' insights and feedback, stemming from their practical experiences on the construction site, provide valuable input into the design. This engagement enhances their commitment to safety and fosters a culture of safety within the workforce (Tymviov and Gambatese, 2020).

Recognizing the unique challenges posed by each construction site, DfS advocates for site-specific design. This acknowledges that factors such as topography, climate, and the presence of existing structures play a crucial role in shaping the safety concerns associated with a specific location. The design team must meticulously consider these factors when developing plans to address safety concerns (Manu et al., 2018). Firstly, hazard elimination and reduction are fundamental aspects of DfS. The design team diligently seeks to identify and remove potential hazards. For example, fall prevention measures, such as the inclusion of guardrails or safety nets, are designed to reduce the risk of accidents involving workers falling from heights (Manu et al., 2019).

Secondly, incorporating safety features into the construction project is another key element of DfS. Designers aim to create structures and equipment with built-in safety mechanisms, such as fail-safes or emergency shut-off systems, to prevent accidents and injuries (Manu et al., 2018). Also, material selection is a crucial consideration within DfS (Sapuan, 2022). Designers not only evaluate the functionality of materials but also assess their safety implications. For instance, the choice of fire-resistant materials or materials that do not emit harmful fumes during construction can significantly enhance safety.

Another set of important safety factors in DfS is accessibility and ergonomics. Ensuring that buildings are accessible to all, including individuals with disabilities, is a paramount safety and ethical concern. Designers incorporate features like ramps, handrails, and wider doorways to enhance accessibility. Also, ergonomics in construction design aim to reduce physical strain on workers, thus decreasing the risk of musculoskeletal injuries (Ibrahim et al., 2022).

## Accidents Types and Causes on Construction Sites

The construction industry frequently experiences a high incidence of accidents (Zhang et al., 2007). These accidents have been attributed to various factors, including job pressures, extended construction periods, hazardous machine operations, complex processes, and hazardous work environments. Behm's (2005) report identified the major causes of these accidents, which encompass poor management practices, such as inadequate supervision, the pressure to meet production targets, and inadequate safety management systems. Additionally, accidents are often exacerbated by the failure to learn from previous incidents, communication issues between shifts and personnel and management, inadequate reporting systems, complacency, violations of safety standards, inadequate training, especially in areas like emergency responses, fire safety, and general safety procedures, lack of competency, excessive working hours leading to mental fatigue, inadequate procedures, modifications or updates to equipment made without operator knowledge or revised risk assessments, and inadequate maintenance of tools and equipment.

However, it is important to note that accidents on construction sites are not solely a result of external factors. Workers' attitudes and behaviours also play a significant role in accident occurrence. Many fatalities have been attributed to negligence, unsafe worksite conditions, the absence of protective safeguards, and the mishandling of tools and equipment. Similarly, Williams et al. (2019) identified the most common types of accidents, including contact with working tools, vehicle-related incidents, and slip and falls. They also reported that major causes of accidents include the failure of edge protection, violations of safety standards, overloading of scaffold and crane equipment, improper ladder placement, loss of control over body movement, design flaws, the absence of warning signs, vehicle speeding, improper tool selection, failure to use personal protective equipment, improper equipment installation, horseplay, and poor housekeeping.

## Safety in the Construction Industry

Safety in the construction industry is an issue of paramount concern, with enduring challenges despite notable strides in various areas. One of the primary issues highlighted by Abdul Hamid and Singh (2008) is the industry's tendency to prioritize other factors, such as time, cost, and quality, over safety performance. This imbalance in priorities has contributed to the persistence of safety-related problems within the construction sector. Trinh and Feng (2020) add to the discourse by emphasizing the complexities of ensuring safety in the construction



industry. With its diverse range of projects, complex processes, and extensive scope of work, the industry faces unique challenges in maintaining high safety standards. The multifaceted nature of construction projects requires rigorous attention to detail and proactive safety measures.

The gravity of the safety situation in the construction industry is further underscored by data collected by the Centre to Protect Worker's Rights (CPWR) in 2005, revealing that the construction sector experiences a disproportionately high rate of occupational injuries and fatalities compared to many other industries worldwide. This alarming statistic serves as a stark reminder of the urgent need to address safety concerns in the construction field (CPWR, 2005). In response to these challenges, experts like Ayomoh and Oke (2006) advocate for the establishment of effective safety systems. These systems aim to prevent or minimize accidents and hazards that jeopardize work operations. The idea is to proactively address safety concerns and create a robust framework that safeguards the well-being of construction workers.

Building upon this foundational notion, extensive research has consistently shown that the implementation of basic safety practices can lead to significant improvements in safety outcomes within the construction industry. Studies by Abubakar et al. (2020), Albert et al. (2017), Hallowell et al. (2013), and Sawacha et al. (1999) collectively support the assertion that safety hazards can be controlled, and accidents can be averted through these proactive measures. By integrating safety into the core of construction practices and emphasizing preventive strategies, the industry can enhance its overall safety performance (Abubakar et al., 2020; Albert et al., 2017; Hallowell et al., 2013; Sawacha et al., 1999).

To recap, the construction industry's safety challenges persist, but they are not insurmountable. The key lies in a shift in priorities towards the integration of safety as a fundamental aspect of construction operations. With proper safety systems and the proactive implementation of safety practices, the industry can take significant steps towards improving the well-being of its workers and reducing the incidence of accidents and hazards. This comprehensive approach, as supported by various research studies, is a crucial step in enhancing safety within the construction sector.

## Design for Safety (DfS)

DfS, also known as prevention through design (PtD), is a total approach that revolves around the consideration of construction site safety from the project's inception. This entails making modifications to the permanent features of the construction project to ensure that construction site safety is a core consideration. It also extends to the preparatory phase when plans and specifications are developed, ensuring that safety is integral to the project's design. DfS is not just about theoretical considerations; it involves the practical implementation of safety suggestions in the design, with a focus on communicating potential risks related to the design in the context of the construction site and the tasks to be performed (Behm, 2005).

Engineers and architects play a pivotal role in DfS, as they explicitly factor in the safety of construction workers during the design process, aiming to eliminate or reduce hazards that may pose risks to those working on the construction site (Manu et al., 2018). The history of integrating worker health and safety into design dates back to the 1800s, with efforts to make machinery safer and later progressing to ergonomic workplace design (Schulte et al., 2008).

DfS is not just a theoretical concept; it is a practical intervention in the construction industry aimed at improving safety performance. It recognizes that the most effective opportunities to mitigate Work Health and Safety risks exist during the pre-construction phase of projects, and as projects

progress, these opportunities diminish, a concept known as the time-safety influence curve (Lingard et al., 2015).

To promote awareness and understanding of DfS, educational initiatives have been introduced, including integrating DfS lessons into the engineering curriculum. These lessons serve as a foundational source of knowledge about safe design, the tools available for implementing safety in design, and the resources that guide designers in this process. Various tools have been developed to facilitate DfS, such as automated safety rule checking tools integrated into Building Information Models (BIM) (Martínez et al., 2010). Digital solutions like web-based tools have been created to assess design firms' capabilities in implementing DfS, enhancing its practical application (Poghosyan et al., 2020). The field of DfS continues to evolve, with the development of additional digital tools and resources (Farghaly et al., 2021).

The role of clients in promoting DfS is significant, as they are often the primary funders and initiators of construction projects. Client involvement and influence play a crucial role in shaping the adoption of DfS (Tymvios and Gambatese, 2016).

Recognizing the critical link between the design phase and accidents that occur during construction, several countries have introduced legislation to encourage or require designers to actively engage in ensuring construction workers' safety (Martínez et al., 2010). An example of such legislation is the UK's Construction Design and Management Regulations 2015, which highlights the legal obligations of designers in promoting safety. However, despite the construction industry's well-known safety risks, there remains a notable lack of comprehensive data on accidents and injuries within the sector (Umar et al., 2019). Research indicates that many construction accidents can be attributed to inadequately safe design practices (Ismail et al., 2021).

Ensuring health and safety during the pre-construction phase is a fundamental aspect of enhancing safety in the construction industry. DfS, underpinned by legislative support, has the potential to significantly improve safety outcomes and mitigate risks throughout the construction project's lifecycle.

## Discussion

Designing for safety is an intervention that is gaining interest in the construction community, but which has not become part of standard design practice. The reviewed literature indicates, among other, that DfS is a viable intervention in construction, that it allows for safe design modifications, that its implementation aligns with safety concerns of the construction industry, that designers are eager and ready to implement the concept.

### Success Potentials of DfS

Successful implementation of DfS holds the promise of substantial positive outcomes for the construction industry. This aligns with the idea that embedding safety considerations into the design of a construction project can lead to improved safety performance and reduced incidents of accidents and hazards.

DfS is a comprehensive approach that offers substantial benefits in enhancing safety within the construction industry. DfS places a strong emphasis on identifying and eliminating potential hazards during the early stages of a project's design. This process is crucial as it contributes to making the construction site significantly safer and reduces the risk of accidents. Research conducted by Manu et al. (2018) highlights the importance of hazard elimination in DfS, emphasising its role in minimising risks and enhancing safety for construction workers. Furthermore, DfS doesn't stop at hazard elimination alone; it also involves the incorporation of safety measures into the design of a construction project. This includes designing structures and equipment with built-in safety features, such as emergency shut-off systems or fail-safes. These safety measures



are strategically integrated to prevent accidents and injuries during construction activities. Manu et al. (2019) supported this aspect of DfS, illustrating that safety measures designed within the project can lead to a safer working environment for construction workers.

The positive impact of DfS on construction safety cannot be overstated. Research findings indicate that when DfS principles are effectively applied, there is a direct correlation with improved safety outcomes in the construction industry. This translates to a reduced number of accidents, fewer injuries, and an overall safer working environment for those involved in construction projects. The studies conducted by Manu et al. (2018) and Manu et al. (2019) further substantiate this point, underlining the significant influence of DfS on enhancing safety within the industry. However, it is essential to dispel the misconception that implementing DfS leads to higher construction costs. On the contrary, DfS often results in cost savings by preventing accidents, reducing insurance premiums, and minimizing project delays. These economic benefits demonstrate the practicality and cost-effectiveness of DfS as a safety concept (Manu et al., 2018; Manu et al., 2019).

### Challenges to DfS Viability

One primary challenge hindering the adoption of DfS is the lack of comprehensive guidelines and standards. Designers often rely on established regulations and standards in their decision-making processes. Without clear and universally accepted guidelines for incorporating safety into design, it becomes more difficult to integrate safety considerations seamlessly. However, this barrier is not insurmountable. As more research is conducted and best practices emerge, there is potential for the development of industry-specific guidelines that can guide designers in implementing safety features during the design phase (Poghosyan et al., 2020).

A second barrier is the concern of clients regarding the potential increase in construction costs associated with DfS. Clients typically have financial considerations and may perceive DfS as an additional expense. While it is essential to address these concerns, it is crucial to emphasize that DfS does not necessarily lead to higher costs. In fact, research has shown that integrating safety into the design phase can often lead to cost savings by preventing accidents, reducing insurance premiums, and minimizing project delays (Behm, 2005). Effective communication of these cost-saving benefits to clients is essential to overcome this barrier.

Motivation to implement the concept of DfS is another obstacle. Some designers may be resistant to change and hesitant to adopt new approaches that may disrupt their established design practices. To address this barrier, continuous efforts should be made to increase designer knowledge of the DfS concept. This can be achieved through educational initiatives, such as integrating DfS lessons into the engineering curriculum (Behm et al., 2014). Also, the dissemination of information about the benefits of DfS and real-world success stories can inspire and motivate designers to embrace this approach (Tymvios and Gambatese, 2016).

Furthermore, to facilitate DfS implementation, new design tools and resources can be created to assist designers in addressing safety during the design phase. As mentioned earlier, automated safety rule checking tools integrated into Building Information Models (BIM) are one example of digital resources that can guide designers in implementing safety features (Martinez et al., 2010). The continued development of such tools, along with the adaptation of emerging technologies, can significantly enhance the feasibility and ease of DfS adoption (Farghaly et al., 2021).

Overall, while barriers to the implementation of DfS in the construction industry do exist, they are not insurmountable. With a concerted effort to develop guidelines, address cost

concerns, motivate designers, and provide them with the necessary tools and resources, the adoption of DfS can be promoted. The key lies in a combination of research, education, and the effective communication of the benefits of this approach to all stakeholders, ultimately enhancing safety in the construction industry.

### Design Modifications

Design modifications play a pivotal role in ensuring safety in the construction industry. As mentioned earlier, the design phase is a critical point in a construction project where safety considerations can be integrated to prevent accidents and hazards. Owners of construction projects can significantly influence the extent to which designers prioritize safety in their designs. One way to motivate designers is through contractual requirements. Owners can stipulate in project contracts that safety considerations must be incorporated into the design process. This contractual obligation can make designers more accountable for ensuring that safety is an integral part of the project from the outset (Behm, 2005).

Monetary incentives can also be a powerful motivator for designers. Owners can offer financial bonuses or rewards to designers who excel in incorporating safety features into their designs. This approach not only encourages designers to prioritize safety but also recognizes and rewards their efforts. Financial incentives can be a practical means of aligning the interests of designers with the goal of enhancing safety (Behm, 2005).

Owner acknowledgment of the importance of designing for safety is a crucial element in overcoming barriers to its implementation. Owners have a central role in setting project parameters and priorities. When owners acknowledge that safety is of paramount importance, it can significantly influence the project's overall direction. This acknowledgment places designing for safety as a higher priority compared to other project parameters, such as time and cost (Tymvios and Gambatese, 2016).

Several strategies and means to overcome these barriers have been identified and successfully implemented in various construction projects. The integration of safety requirements into project contracts, along with the offer of monetary incentives, has been shown to motivate designers to incorporate safety features into their designs. Additionally, owners' acknowledgment of the importance of safety and their active commitment to it can be instrumental in ensuring that safety is a central focus in the design phase (Poghosyan et al., 2020; Farghaly et al., 2021).

### Designers' Readiness for the DfS Concept

The outcome of our review on the DfS concept indicates that designers within the construction industry are increasingly prepared and willing to implement the DfS concept. Several key factors and pieces of evidence support this assertion. Firstly, DfS has gained substantial interest among both scholars and practitioners in various geographical contexts. Studies by Manu et al. (2018, 2019) have explored DfS concepts and their implementation in different countries, including the UK, the USA, Australia, and Singapore. This research shows that DfS is a topic of interest and study in multiple regions, suggesting a global readiness to explore and implement DfS practices.

Secondly, educational institutions have recognised the importance of DfS in the construction industry. Behm et al. (2014) suggested that incorporating DfS lessons into engineering curricula is a primary method to influence the knowledge of safe design and tools used in design. This approach implies that educational institutions acknowledge the significance of preparing future designers with the skills and knowledge necessary to implement DfS concepts effectively. Furthermore, the development of digital tools and resources to support DfS implementation, such as automated safety rule checking tools



and web-based assessment tools, indicates a proactive approach to provide designers with the means to address safety during the design phase (Martínez et al., 2010; Poghosyan et al., 2020). The existence and continued development of such tools suggest that the design community is ready to embrace DfS.

Legislation, such as the UK's *Construction Design and Management Regulations 2015*, has introduced requirements that encourage or mandate designers to participate in ensuring the safety of construction workers (Martínez et al., 2010). Compliance with such regulations indicates that designers are prepared to fulfil their roles in enhancing safety during the design phase. Overall, the growing interest in DfS, the integration of DfS into educational curricula, the development of digital tools, and adherence to relevant legislation all indicate that designers are indeed ready to implement the DfS concept. These factors collectively contribute to a positive outlook for the implementation of DfS within the construction industry, with designers playing a pivotal role in enhancing safety throughout the project lifecycle.

## Conclusion

This review on DfS concept in the construction industry highlights its significant potential to enhance safety. DfS emphasises hazard elimination, safety measures incorporation, and has demonstrated a direct correlation with improved construction safety outcomes, including fewer accidents and injuries. Contrary to misconceptions, it can be cost-effective, offering savings by preventing accidents, reducing insurance premiums, and minimizing project delays. Designers' readiness to implement DfS is evident, with growing recognition through educational integration and the development of digital tools. While challenges and barriers exist, their solutions are within reach. This underscores the significance of DfS in creating a safer construction industry and the increasing readiness of designers to embrace it.

## Recommendations for Future Research

The following recommendations stem from the findings and discussions in the review, and they address key areas for further research that can significantly contribute to enhancing safety in the construction industry through the adoption of the DfS concept.

1. **Longitudinal Studies:** Longitudinal studies are crucial to assess the sustained impact of DfS implementation on construction safety. This recommendation is closely related to the findings that successful DfS implementation correlates with improved safety outcomes in the construction industry. By conducting long-term studies, researchers can track whether these improvements are maintained over time and identify any areas that might require continuous attention. Understanding the long-term effects of DfS is essential for validating its effectiveness and encouraging its adoption in the industry.
2. **Barriers and Solutions:** The review highlighted various barriers that currently limit the widespread adoption of DfS, including the lack of guidelines and standards, cost concerns, and motivation to implement the concept. Research focusing on these barriers and potential solutions is directly related to the review's findings. By delving deeper into the specific challenges faced by designers and exploring ways to overcome them, this research can provide valuable insights for improving DfS adoption rates. Addressing these barriers is essential for enhancing construction safety through design.
3. **Economic Analysis:** The review emphasised that DfS does not necessarily lead to higher construction costs and can, in fact, result in cost savings by preventing accidents and reducing insurance premiums. Research into the economic aspects of DfS aligns with this finding. Conducting detailed cost-benefit analyses can provide concrete evidence of the financial advantages of DfS, potentially influencing industry stakeholders and decision-makers. This research can further validate the economic viability of DfS and its positive impact on construction safety.
4. **Client Involvement:** The review highlighted the role of clients in motivating designers to prioritize safety in their designs. Understanding how client requirements and expectations influence DfS implementation is a logical continuation of this finding. Research in this area can provide insights into effective ways for clients to incentivise designers to consider safety. As clients are often the funders and initiators of construction projects, their engagement in DfS is crucial for its successful implementation.
5. **Cross-Industry Insights:** While not directly discussed in the review, the concept of drawing insights from other industries with mature safety cultures is a valuable recommendation. Learning from other sectors can provide fresh perspectives and best practices for integrating safety into the design process. This research can offer comparative analyses and case studies that shed light on effective strategies for DfS implementation. Cross-industry insights may provide innovative solutions and approaches that the construction sector can adapt to enhance safety.

## References

- Abdul Hamid, A., Abd Majid, M. Z., and Singh, B. (2008). Causes of Accidents at Construction Sites. *Malaysian Journal of Civil Engineering*, 20(2), 242-259
- Abubakar, M., Ibrahim, Y. M., Bala, K., and Ibrahim, A. D. (2020). Identifying the Factors Influencing Hazard Recognition Capability of Construction Workers. *Construction Research Congress 2020*, 268-278.
- Adaku, E., Ankrah, N. A. and Ndekugri, I. E. (2021). Design for Occupational Safety and Health: A Theoretical Framework for Organisational Capability. *Safety Science*, 133, 105-119.
- Albert, A., Hallowell, M. R., Skaggs, M., and Kleiner, B. (2017). Empirical Measurement and Improvement of Hazard Recognition Skill. *Safety Science*, 93, 1-8
- Awodele, O. A., and Ayoola, M. C. (2005). An Assessment of Safety Programmes on Construction Sites. *Journal of Land Use and Development Studies*, 1(1).
- Awwad, R., El Souki, O., and Jabbour, M. (2016). Construction Safety Practices and Challenges in a Middle Eastern Developing Country. *Safety Science*, 83, 1-11.
- Ayomoh, M., and Oke, S. (2006). A Framework for Measuring Safety Level for Production Environments. *Safety Science*, 44(3), 221-239
- Behm, M. (2005). *Linking construction fatalities to the design for construction safety concept* (Vol. 43).
- Behm, M., Culvenor, J. and Dixon, G. (2014). Development of safe design thinking among engineering students. *Safety Science*, 63, 1-7.
- BLS, (2015). Census of fatal occupational injuries summary.
- Dogan, E., Yurdusev, M.A., Yildizel, S.A. and Calis, G. (2021). Investigation of scaffolding accident in a construction site: A case study analysis. *Engineering Failure Analysis*, 120, 105108
- Farghaly, K., Collinge, W., Hadi Mosleh, M., Manu, P., and Cheung, C. (2021). Digital information technologies for prevention through design (PtD): A literature review and directions for future research", *Construction Innovation: Information Process Management*. doi: 10.1108/CI-02-2021-0027
- Hallowell, M. R., Hinze, J. W., Baud, K. C., and Wehle, A. (2013). Proactive Construction Safety Control: Measuring, Monitoring, and Responding to Safety Leading Indicators. *Journal of Construction Engineering and Management*. 139(10), 04013010.
- Ibrahim, C. K. I. C., Manu, P., Belayutham, S., Mahamadu, A.-M. and Antwi-Afari, M. F. (2022). Design for Safety (DfS) Practice in Construction Engineering and Management Research: A Review of



- Current Trends and Future Directions. *Journal of Building Engineering*, **52**, 104352.
- ILO. (2022). Facts on Safety at Work. [www.ilo.org/safework](http://www.ilo.org/safework)
- Ismail, S., Che Ibrahim, K. I., and Belayutham, S. and Mohammad, M. Z. (2021). Analysis of attributes critical to the designer's prevention through design competence in construction: the case of Malaysia. *Architectural Engineering and Design Management*. doi: 10.1080/17452007.2021.1910926
- Kim, T. and Chi, S. (2019), "Accident Case Retrieval and Analyses: Using Natural Language Processing in the Construction Industry", *Journal of Construction Engineering and Management*, **145**(3), 04019004.
- Lingard, H., Saunders, L., Pirzadeh, P., Blismas, N., Kleiner, B. and Wakefield, R. (2015). The relationship between pre-construction decision-making and effectiveness of risk control", *Engineering, Construction and Architectural Management*, Vol. **22**(1), 108-124.
- Maliha, M.N., Aisheh, Y.I.A., Tayeh, B.A. and Almalki, A. (2021). Safety barriers identification, classification, and ways to improve safety performance in the Architecture, Engineering and Construction (AEC) industry: Review study. *Sustainability*, **13**(3), 3316.
- Manu, P., Ankrah, N., Proverbs, D., and Suresh, S. (2014). The health and safety impact of construction project features. *Engineering, Construction and Architectural Management*, **21**(1), 65-93.
- Manu, P., Poghosyan, A., Ageyi, G., Mahamadu, A.-M. and Dziekonski, K. (2018). Design for safety in construction in sub-Saharan Africa: a study of architects in Ghana. *International Journal of Construction Management*, pp.1-13.
- Manu, P., Poghosyan, A., Mshelia, I.M., Iwo, S.T., Mahamadu, A.-M. and Dziekonski, K. (2019). Design for occupational safety and health of workers in construction in developing countries: a study of architects in Nigeria", *International Journal of Occupational Safety and Ergonomics*, **25**(1), 99-109.
- Martínez Aires, M.D., Rubio Gámez, M.C. and Gibb, A. (2010). Prevention through design: The effect of European Directives on construction workplace accidents. *Safety Science*, **48**(2), 248-258.
- Okeola, O. G. (2009). Occupational Health and Safety (OHS) Assessment in the Construction Industry. Paper presented at the 1st Annual Civil Engineering Conference University of Ilorin, Nigeria, 26-28 August 2009.
- Poghosyan, A., Manu, P., Mahamadu, A.-M., Akinade, O., Mahdjoubi, L., Gibb, A., and Behm, M. (2020). A Web-based Design for Occupational Safety and Health Capability Maturity Indicator. *Safety Science*, **122**.
- Samsudin, N.S., Mohammed, M.Z., Khalil, N., Nadzri, N.D. and Ibrahima, C.K.I.C. (2022). A thematic review on prevention through design (PtD) concept application in the construction industry of developing countries. *Safety Science*, **148**, 105640.
- Sapuan, S., Ilyas, R. and Asyraf, M. (2022). *Safety and Health in Composite Industry*. Singapore: Springer Nature Singapore Pte Ltd.
- Sawacha, E., Naoum, S., and Fong, D. (1999). Factors Affecting Safety Performance on Construction Sites. *International Journal of Project Management*, **17**(5), 309-315.
- Schulte, P.A., Rinehart, R., Okun, A., Geraci, C.L. and Heidel, D.S. (2008). National Prevention through Design (PtD) Initiative. *Journal of Safety Research*, **39**(2), 115
- Smallwood, J., and Haupt, T. (2005). The need for construction health and safety (Hands) and the Construction Regulations: Engineers' perceptions. *Journal of the South African Institution of Civil Engineering*, **47**(2), 2-8.
- Szymberski, R. (1997). Construction Project Safety Planning. *TAPPI Journal*, **80**(11), 69-74.
- Trinh, M. T., and Feng, Y. (2020). Impact of Project Complexity on Construction Safety Performance : Moderating Role of Resilient Safety Culture. *Journal of Construction Engineering and Management*, **146**(2).
- Tymvios, N. and Gambatese, J.A. (2016). Perceptions about Design for Construction Worker Safety: Viewpoints from Contractors, Designers, and University Facility Owners. *Journal of Construction Engineering and Management*, **142**(2), 04015078.
- Tymvios, D. Hardison, M. Behm, M. Hallowell, J.A. Gambatese (2020). Revisiting Lorent and Szymberski: Evaluating how research in prevention through design is interpreted and cited. *Safety Science*, **131**.
- Umar, T., Egbu, C., Honnurvali, M.S., Saidani, M. and Al-Bayati, A.J. (2019). Briefing: Status of occupational safety and health in GCC construction. *Proceedings of the Institution of Civil Engineers - Management, Procurement and Law*, Vol. **172** No. 4, pp.137-141.
- Williams, J., Fugar, F., and Adinyira, E. (2020). Assessment of Health and Safety Culture Maturity in the Construction Industry in Developing Economies A case of Ghanaian Construction Industry. *Journal Engineering Design and Technology*, January.
- Williams, O. S., Hamid, R. A., and Misnan, M. S. (2019). Causes of building construction related accident in the south-western states of Nigeria. *International Journal of Built Environment and Sustainability*, **6**(1), 14-22. <https://doi.org/10.11113/ijbes.v6.n1.313>
- Yuan, J., Li, X., Xiahou, X., Tymvios, N., Zhou, Z., Li, Q. (2019). Accident prevention through design (PtD): Integration of building information modeling and PtD knowledge base. *Automation in Construction*, **102**(February), 86-104. <https://doi.org/10.1016/j.autcon.2019.02.015>.
- Zou, P. X. W., Zhang, G., and Wang, J. (2007). Understanding the key risks in construction projects in China. *International Journal of Project Management*, **25**(6), 601-614. <https://doi.org/10.1016/j.ijproman.2007.03.001>

