An overview of Prevention through Design (PtD): The architect's role in the lifecycle of building safety performance

Nor Syamimi Samsudin¹*, Khalil, N.¹, Mayamin Yuhaniz¹, Sayed Muhammad Aiman Sayed Abul Khair¹, and Azman Zainonabidin¹,²

¹Dept. of Built Environment Studies and Technology, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA, Perak Branch 32610 Seri Iskandar, Perak, Malaysia
²Arkitek Azman Zainonabidin,19A,Persiaran Dataran 2,Bandar Seri Iskandar,32610 Seri Iskandar,Perak Malaysia

¹*Email: norsya992@uitm.edu.my

Abstract. The notion of Prevention through Design (PtD) has been used extensively to mitigate any potential hazard and minimize residual risks during the early design phase. However, there are hurdles in implementing the PtD concept, such as lack of enforcement in terms of legislation and guideline, thus decreasing architects' responsibilities towards implementing PtD in the design and planning stage. Therefore, the review was motivated to highlight the PtD concept and the architect's responsibility to build safety performance throughout its entire lifecycle. The finding of this paper reveals the themes that influence the role of architects towards adopting the PtD concept, which in turn affects the safety of the whole building lifecycle. Since this paper focuses solely on the role of architects, further development of the topic can be aimed towards other roles of consultants.

1. Introduction

It is well-known that the construction industry makes a sizable contribution to the country's economic growth. However, construction activities have also constituted many accidents, causing the percentage of illnesses and injuries to workers and construction teams to escalate. The consequences of these occurrences include absence from the workplace, declining productivity, permanent disabilities, and deaths [1]. While most parties generally believe that building-related accidents are most frequent during construction, other phases included in the building lifecycle are also considered equally dangerous.

Additionally, previous studies have underlined that construction injuries are not adequately addressed during projects' construction and design phases. In response, some countries have been focusing on mitigating or minimize these issues through building or construction-specific policies or legislation, generally applied during upstream design phases [2]-[3]. It is agreeable that the role of designers is crucial, especially during the planning stage of projects, since they hold the most power in decision making during the upstream phase and can influence clients and other consultants. A designer is defined as someone directly in charge of planning or arranging for a person to prepare or plan a design related to a structure or part of the structure that includes drawings, design details, specifications, and bills of quantities [4]. Therefore, individuals with these positions should fulfil their ethical duties to place the utmost importance on the safety and health of human beings throughout buildings' lifecycle,
which is achievable through the practice of PtD. Those who are considered as designers include architects, engineers, town planners, contractors undertaking works of altering designs or materials, even clients as they direct and constrain designs [5]. Thus, this article explores the role of architects in fostering the practice of PtD for the lifecycle of building safety performance.

2. Definitions and terms

2.1. Variations of PtD
The main objective of PtD is to tackle the risks from its source by designing out serious hazards during the design phase to minimize the probability of accidents or injuries at construction (inclusive of demolition) and maintenance phases [6]. Accordingly, PtD emphasizes the significance of preventing any potential hazards by architectural design in the built environment context [7]. An architect can thus offer a solution for better and more effective safety prevention through architectural design.

Different countries use different terms that are similar to the PtD initiative. Other associated terms include 'Design for Occupational Safety and Health' (DfOSH), 'Design for Safety' (DfS), 'Safety in Design (SiD), 'Safe Design' (SD), 'Construction Hazard Prevention through Design' (CHPtD), Construction Design and Management (CDM), and Design for Construction Safety (DiCPS) [8]-[9]-[10]. It is noted that the terms 'safety management' and 'risk management' are both used in some literature to emphasize the importance of mitigating safety risks due to design aspects, construction work, and materials used in a building [11]-[13].

2.2. Building lifecycle
Few papers refer to the RIBA Plan of Work, which organizes the process: Strategic Definition, Preparation, and Brief, Concept Design, Developed Design, Technical Design, Construction, Handover and Close Out, to In Use stage. [14]. In comparison, New Zealand's Site Safe defines the stages of the project as conception, design, construction, use for the purpose, maintenance and repair, followed by decommissioning or repurposing, and finally demolition [5]-[15]-[16].

However, many precedent research highlighted Symberszki's definition of building lifecycle [17], which encompasses concept, preliminary design, design detail, construction stage, operation and maintenance, and lastly, demolition. According to his time-safety influence curve [17] illustrated in Figure 1(a), in decreasing effectiveness, safety input may be exercised in the phase of conceptual design, detailed engineering, procurement, and construction. Additionally, Site Safe further expands this notion by including the expense of incorporating safety strategies [4], as seen in Figure 1(b).

![Figure 1](image)

Figure 1. Safety influence throughout lifecycle; (a) time-safety influence curve, (b) time-safety-cost influence curve (adopted from [17])

As the lifecycle of a design project progresses, the potential to influence safety and health decreases (as shown in Figure 1(a)). Adding input to the theory, Site Safe by New Zealand (Figure 1(b)) stated that the cost to manage health and safety risks increases as the building lifecycle advances towards the end-stage. Thus, PtD should be implemented to avoid the rise in accident occurrences and cost in the future. Hence, this analysis discusses the architect's responsibility in PtD for lifecycle building safety performance.
3. Methodology
A comprehensive literature review was undertaken to evaluate architects' roles in building safety performance at all phases of its lifecycle. Information was obtained from several sources such as journal articles, conference papers, review articles, and relevant safety guidelines for the review. Journals were extracted from two (2) leading databases: Scopus and Web of Science (WoS). The main keywords used in searching the articles were "prevention through design," "architect," "responsibility," "safety performance," and "building lifecycle." The keywords were then expanded accordingly to facilitate further searches. The analysis of the architect's role in the lifecycle of building safety performance was subsequently carried out by a critical review of the findings from the selected articles.

4. Result and Discussion
The review results show that the researchers have analyzed the selected papers listing PtD practices directly impacting the different building life cycle stages. Besides that, the researcher analyzed the articles that discuss architect's responsibilities and mindsets regarding PtD. Gambatese et al. [18] suggested that designers' understanding and acceptance of the concept, designers' training and education, designers' commitment to apply the PtD concept, the ease of implementation, access to resources and tools affect the execution of PTD. Therefore, when it comes to the subject of architects' roles and implementation of PtD for building lifecycle, five main themes were discovered, which are: (1) design decisions, (2) knowledge or awareness, (3) skills, (4) technologies or tools for safety, and lastly, (5) attitude.

4.1. Design decisions
In the construction industry, the term design describes a product that follows construction requirements specified by a brief, while a brief defines a set of specifications and restrictions as mandated by the client[19]. As a result, the design phase's output should include detailed solutions to the owner's issues or concerns.

Design decisions were made during the stages of conception, preliminary design, and design details. However, these decisions heavily influence building safety at later stages, namely construction and operational and maintenance stage. In a study conducted by Gambatese & Alomari [20], the results revealed that particular design features could moderately or significantly affect worker's safety during construction. Additionally, most of the respondents also believed there is a link between one worker and another in terms of workplace [20]. Thus, the architects need to assess possible risks and hazards during the upstream phase.

Additionally, Brioso et al. [21] argued that building design rules and regulations might be imprecise, resulting in a loss of design quality or value. Consequently, designers, contractors, even local governments could adhere to the bare minimum of design requirements and declare that they have not violated the law [21].

Although there is no definite law for the practice of PtD, architects should base their design decisions regarding the safety of the buildings' occupants. Therefore, architects should acknowledge the benefits of PtD and implement it in every project's design phase. Also, since it has been proven repeatedly that design decisions directly impact occupational building safety and health, it is established that architects require adequate and appropriate knowledge of PtD to execute the right decisions during the design phase.

4.2. Knowledge or awareness
The need for PtD knowledge is essential, especially among architects, to ensure the proper application of PtD. According to research, it is undeniable that among construction design professionals, the inadequate knowledge to adopt PtD is overwhelming [22]. Apart from that, it's been reported that comprehension of PtD has been linked to the lifecycle construction process for a long time [10]. Table 1 shows the summary of findings on the retrievable reviewed articles for this study since most papers...
included other consultants as their sample of study due to the nature of them covering 'designers,' only those that include architects are reviewed.

Table 1. Decisions influencing safety at different aspects of design.

| Category                      | Statement/general finding | Source & details based on a respective sample study |
|-------------------------------|---------------------------|---------------------------------------------------|
| Awareness of PtD concept      | Majority are aware        | [23]-[24]-[25]-[12]-[26]                         |
| Source of PtD knowledge       | Acquired from many sources such as work, formal education, and others | [23] • formal education [25] • formal education • working experience • others (publications, emails, website) [12] • formal education [26] • formal education |
| Engagement in PtD training    | Very few attended the training course | [23] • attained training [25] • attained training [12] • attained training [26] • attained training |
| Implementation of PtD in projects | Mostly low               | [23]-[25] [12]-[26] • Low [27] [24] • High from C&S engineers, low from architects |

*Categories of respondents: [23]: 60 respondents (architects, C&S engineer, building engineer); [24]: 40 respondents (architects, C&S engineers, and quantity surveyors); [25]: 257 respondents (architect, CS engineer, ME engineer, developer/client, project manager, safety professional, and others); [12]: 161 respondents (architects); [26]: 130 respondents (architects); [27]: 108 respondents (consultants - architects and engineers, contractors, workers, owner).

The statistics presented by numerous studies make it clear that adequate and proper knowledge of PtD is vital to ensure its adoption in the industry. Even when most studies show that most of their study samples have awareness about PtD, the implementation in construction projects is still low. Thus, the inclusion of PtD education in construction or building-related courses such as architecture is crucially important. Even though PtD is gradually paving its way into the building industry of various countries, the inclusion of PtD in tertiary education remains elusive [10]. This is supported by a study by Lopez-Arquillos et al. [28]; insufficient attention was placed on the importance of PtD during design and construction courses in Spain. Furthermore, it was outlined that occupational safety and health (OSH) education is only covered moderately [16].

Other than depending on the change of formal education syllabus, architects could also take the initiative to participate in training or workshops that will expose them more to the subject of PtD.

4.3. Skills

Knowledge acquisition can then be applied in practical works, which will evolve into skill, as designers learn to do it effectively due to experience from the practice they have had. A review by Che Ibrahim et al. [10] noted two crucial talents or skills regarding PtD, markedly technical and soft skills, as shown in Figure 3 below.
Figure 2. Category of skills (Source: adapted from Che Ibrahim et al. [10]).

A professional's capabilities or proficiencies are developed by education, training, or hands-on experience. When it concerns PtD, the designer must have experience undertaking safety design-related are very minimal. In terms of technical skills, it is vital to have hazard recognition and analysis skills, which most architects lack. This is proven in a study conducted by Zhao et al. [29], claiming that builder's risk assessment seems remarkably accurate, assuming that they have a complete understanding of construction methods. Subsequently, this finding is followed by a statement that suggested engineers' risk assessment is relatively high, while architects have a low-risk assessment.

Therefore, architects need to team up with builders, engineers, and project management teams during the design phase as they have more skills and experience regarding construction injuries and risk handling. In this instance, it is apparent that good soft skills are a vital trait for architects. As lead consultants, architects need to encourage cooperation and trust within their teams in line with this.

4.4. Technologies or tools for safety

The usage of technology-enabled tools was included in the list of technical skills [10], as based on Figure 3. The construction industry has seen the advancement and application of technologies in the last decade. Many technological innovations were implemented to either enhance the quality of the end product or increase the construction process's productivity, ultimately resulting in lower costs and higher profitability [30]. A few examples of these tools include Building Information Modelling (BIM), Augmented Reality (AR) to perform activities, virtual design, and construction.

Most research focuses on the topic of BIM since Panteli et al. [31] stated that BIM extends beyond producing architectural drawings to incorporate the entire lifecycle of a project, including design, construction, and post-construction. From the perspective of safety management during design, the automated identification procedure of safety problems that use the suggested method can save designers' time and effort, reducing the number of accidents during construction and other related project stages [9].

In developing countries, the adoption of BIM faces few limitations, namely less investment in relevant training and technologies, not forgetting the hesitation to quit traditional practices or tools that have become habitual [32]. For example, in Pakistan, Girginkaya et al. noted in their study that the majority of architects have never used BIM in their projects [33]. With regards to the subject BIM in Seychelles, respondents from Adam et al.'s study [34] minimal BIM education and training resulted in 60% of the participants being knowledgeable about BIM, verifying the fact that even when the advantages of BIM for the built environment are known, professional participation in BIM education and training has not resulted in increased preparedness for incorporating BIM into practice.

4.5. Attitude

Unfortunately, knowledge and available tools for design safety alone do not guarantee PtD application. Other probable causes limit PtD adoption. Firstly, it would be the misconceptions and mindsets of designers, especially the belief that safety concerns in construction are complex—next, the thoughtlessness of designers towards worker’s vulnerability to safety hazards. Finally is the inadequate understanding or knowledge of the responsibilities of designers in tackling OSH concerns during upstream phases [10]. In line with this, Azmi [4] stated in a study that while most architects support
PtD, few of them do not think of themselves as responsible for providing and preserving safety on-site, also further insisting that they are not likely to influence the safety of construction workers. Additionally, Abas et al. [24] noted that the designers that are the least confident in practising PtD concept were the architects.

On the contrary, in Palestine, based on a study by Abueisheh et al. [23], design professionals generally agreed that PtD holds high significance in the industry and indicated that they would adopt PtD in their projects if given a choice. Therefore, this displayed positive attitudes of the designers towards the implementation of PtD. Nevertheless, more than half of respondents disagreed on whether Palestinian construction is willing to take responsibility for integrating PtD into real-life projects.

Meanwhile, in Singapore, based on a survey carried out by Toh et al. [25], most stakeholders view PtD adoption as critical and significant, with all architect respondents expressing either positive or neutral views on the concept's seriousness. Furthermore, most of the groups believe that their construction industries are willing to employ the responsibilities of PtD in projects. Nevertheless, the majority only represents 54.4% in this case, which means almost half of the respondents disagreed with the notion. Hence, while several research demonstrated that most design professionals have positive attitudes towards PtD, there is also evidence that not every designer or firm is convinced of their commitment to PtD [13]. Generally, architects should be flexible to adapt to the changes, especially when it involves the health and safety of occupants of their designed buildings. Architects should consider other benefits such as saving cost and time to encourage positive acceptance towards the execution of PtD. It is also essential to stay ahead and be in the trend of new construction needs to compete and remain relevant within the industry.

5. Conclusions
Recently, much research has underlined the responsibilities held by designers towards PtD practices in the construction industry. This research focused specifically on the architects' role in implementing PtD. Findings of this study have identified the main themes commonly associated with PtD and architects' roles towards building safety performance: design decisions, knowledge or awareness, skills, technologies, or tools for safety, and finally, attitude. Although generally it is suggested that designers support PtD and possess an awareness of the notion, a continuous improvement of the level of understanding, education, and provision of tools is required, as current technologies keep leapfrogging past designs.

However, this paper possesses a few limitations. First, this study was limited mainly to the role of architects in PtD. Secondly, as several articles were reviewed, the study occasionally needed to provide a broad overview of the subject instead of a detailed account of extremely detailed findings. Still, the outcomes could serve as a reference point for designers, particularly architects and their respective firms or organizations, to self-assess their PTD proficiencies, which will then spark a movement to enhance the abilities of designers regarding the concept continuously. Consequently, with adequate knowledge, capabilities, and experience, designers can work cohesively and efficiently in line with established PtD related legislations, policies, and even guidelines.

Acknowledgment
The authors wish to acknowledge and express gratitude towards Special Incentive for Supervision in Perak-Industry (GKIPPI) by Universiti Teknologi MARA, Perak Branch, Malaysia [Ref.no: ArAZ2020/GKIPPI/11-02] for their support of this study.

References
[1] N. De Silva, U. Rathnayake, and K. M. U. B. Kulasekera 2018 Under-reporting of construction accidents in Sri Lanka J. Eng. Des. Technol. vol 16 no 6 pp 850–868.
[2] I. Okpala, C. Nnaji, and A. A. Karakhan 2020 Utilizing emerging technologies for construction safety risk mitigation Pract. Period. Struct. Des. Constr. vol 25 no 2 pp 1–13.
[3] C. K. I. Che Ibrahim, S. Belayutham, E. A. Azmi, and A. Hussain 2019 Exploring the knowledge of prevention through design (PtD) among Malaysian civil & structural designers Exploring the knowledge of Prevention through Design (PtD) among Malaysian civil & structural designers IOP Conf. Ser. Mater. Sci. Eng.

[4] W. F. W. Azmi and M. S. Misnan 2018 Stakeholder's attitude towards construction worker's safety and health Journal of Engineering and Applied Sciences vol 13 no Special issue pp 6950–6953.

[5] P. P. Ron Wakefield, Helen Lingard, James Harley 2019 Safety in design in construction: An introduction no June pp 1–23

[6] P. A. Schulte, R. Rinehart, A. Okun, C. L. Geraci, and D. S. Heidel 2008 National prevention through design (PtD) initiative J. Safety Res. vol 39 no 2 pp 115–121.

[7] N. S. Samsudin, M. N. Z. Abidin, M. Z. Mohammad, A. F. Yusof, and M. H. M. Salehan 2021 Prevention through design: Architecture student cognizance IOP Conf. Ser. Earth Environ. Sci. vol 738 no 1.

[8] E. Adaku, N. A. Ankrah, and I. E. Ndekugri 2021 Design for occupational safety and health: A theoretical framework for organisational capability Saf. Sci. vol 133 no August 2020 p 105005 2021.

[9] J. Yuan, X. Li, X. Xiahou, N. Tymvios, Z. Zhou, and Q. Li 2019 Accident prevention through design (PtD): Integration of building information modeling and PtD knowledge base Autom.Constr. vol 102 no February pp 86–104.

[10] C. K. I. Che Ibrahim, S. Belayutham, P. Manu, and A. M. Mahamadu 2020 Key attributes of designers' competency for prevention through design (PtD) practices in construction: a review Eng. Constr. Archit. Manag. no 03.

[11] H. Lingard 2013 Occupational health and safety in the construction industry Constr. Manag. Econ. vol 31 no 6 pp 505–514.

[12] P. Manu, A. Poghosyan, I. M. Mshelia, S. T. Iwo, A. M. Mahamadu, and K. Dziekonski 2019 Design for occupational safety and health of workers in construction in developing countries: a study of architects in Nigeria Int. J. Occup. Saf. Ergon. vol 25 no 1 pp 99–109.

[13] A. Poghosyan, P. Manu, L. Mahdjoubi, A. G. F. Gibb, M. Behm, and A. M. Mahamadu 2018 Design for safety implementation factors: A literature review J. Eng. Des. Technol. vol 16 no 5 pp 783–797.

[14] N. M. Pilanawithana and Y. G. Sandanayake 2017 Positioning the facilities manager's role throughout the building lifecycle J. Facil. Manag. vol 15 no 4 pp 376–392

[15] C. K. I. Che Ibrahim, S. Belayutham, and M. Z. Mohammad 2021 Prevention through design (PtD) education for future civil engineers in Malaysia: Current state, challenges, and way forward J. Civ. Eng. Educ. vol 147 no 1 Jan.

[16] S. Ismail, C. K. I. Che Ibrahim, S. Belayutham, and M. Z. Mohammad 2021 Analysis of attributes critical to the designer's prevention through design competence in construction: The case of Malaysia Archit. Eng. Des. Manag. pp 1–19 Apr.

[17] R. T. Szymberski 1997 Construction project safety planning Tappi J. vol 80 no 11 pp 69–74.

[18] J. A. Gambatese, M. Behm, and J. W. Hinze 2005 Viability of designing for construction worker safety J. Constr. Eng. Manag. vol 131 no 9 pp 1029–1036 Sep..

[19] A. L. Olanrewaju and S. Y. Tan 2018 An exploration into design criteria for affordable housing in Malaysia J. Eng. Des. Technol. vol 16 no 3 pp 360–384.

[20] J. Gambatese and K. Alomari 2016 Degrees of connectivity: Systems model for upstream risk assessment and mitigation Accid. Anal. Prev. vol 93 pp 251–259.

[21] X. Brioso, A. Humero, D. Murguia, J. Corrales, and J. Aranda 2018 Using post-occupancy evaluation of housing projects to generate value for municipal governments Alexandria Eng. J., vol. 57 no 2 pp 885–896.

[22] J. A. Gambatese, A. G. Gibb, C. Brace, and N. Tymvios 2017 Motivation for prevention through design: Experiential perspectives and practice Pract. Period. Struct. Des. Constr..
[23] Q. Abueisheh, P. Manu, A. M. Mahamadu, and C. Cheung 2020 Design for safety implementation among design professionals in construction: The context of Palestine Saf. Sci. vol 128 no March p 104742.
[24] N. H. Abas, R. Abd Rahman, H. Mohammad, and M. H. Rahmat 2020 Designer's confidence and attitude towards designing-for-construction-safety (DiCS) implementation IOP Conf. Ser. Mater. Sci. Eng. vol 713 no 1
[25] Y. Z. Toh, Y. M. Goh, and B. H. W. Guo 2017 Knowledge, attitude, and practice of design for safety: Multiple stakeholders in the Singapore construction industry, J. Constr. Eng. Manag. vol 143 no 5 p 04016131
[26] P. Manu, A. Poghosyan, G. Agyei, A. M. Mahamadu, and K. Dziekonski 2021 Design for safety in construction in sub-Saharan Africa: A study of architects in Ghana Int. J. Constr. Manag. vol 21 no 4 pp 382–394
[27] S. Ahmed 2019 Causes of Accident at construction sites in Bangladesh Organ. Technol. Manag. Constr. an Int. J. vol 11 no 1 pp 1933–1951
[28] A. López-arquillos, J. C. Rubio-Romero, and M. D. Martinez-aires 2015 Prevention through design (PtD). The importance of the concept in engineering and architecture university courses Saf. Sci. vol 73 pp 8–14
[29] D. Zhao, A. P. McCoy, B. M. Kleiner, T. H. Mills, and H. Lingard 2016 Stakeholder perceptions of risk in construction Saf. Sci. vol 82 pp 111–119
[30] C. Nnaji and A. A. Karakhan 2020 Technologies for safety and health management in construction: Current use, implementation benefits and limitations, and adoption barriers J. Build. Eng. vol 29 no January p 101212
[31] C. Panteli, A. Kyliili, and P. A. Fokaides 2020 Building information modelling applications in smart buildings: From design to commissioning and beyond a critical review J. Clean. Prod. vol 265 p 121766
[32] N. Bui, C. Merschbrock, and B. E. Munkvold 2016 A Review of building information modelling for construction in developing countries Procedia Eng. vol 164 no 1877 pp 487–494
[33] S. Girginkaya Akdag and U. Maqsood 2020 A roadmap for BIM adoption and implementation in developing countries: The Pakistan case Archnet-IJAR vol 14 no 1 pp 112–132
[34] V. Adam et al. 2021 Building information modelling (BIM) readiness of construction professionals: the context of the Seychelles construction industry J. Eng. Des. Technol.