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Review

An Ontology to Represent the Prevention through Design (PtD) Concept in Integrated Project Delivery (IPD) in the Construction Industry from an Architectural Perspective

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Abstract: The Prevention through Design (PtD) concept has been widely used to mitigate potential safety and health hazards and minimize residual risks during the early design phase. Integrated Project Delivery (IPD) prioritizes project-wide collaboration and coordination; therefore, the importance of PtD has been widely recognized. There are still neglected issues pertaining to the implementation of the PtD concept from the architectural perspective. Hence, to fill this research gap, this review was motivated to highlight the ontological framework of PtD practices in the construction industry from the architectural perspective. The study is a thematic review aimed to synthesize the literature from 2011 to 2022 on the PtD concept from an architectural perspective. The study, using ATLAST.ti 8, a keyword search, followed by a filter using inclusion criteria from Scopus, Science Direct, Web of Science databases, and the snowball method, identified and analyzed 93 peer-reviewed journal articles. However, only 41 articles were used in the final review after the inclusion and exclusion process. A thematic review of these 41 articles identified five clusters representing the ontological framework findings, namely (1) designer competency, (2) planning and design decision making, (3) technologies related to building safety, (4) design features and workplace condition, and (5) laws and building legislation. The finding is expected to improve the understanding and implementation of the PtD concept to further develop an architectural safety design framework.

Keywords: ontological framework; Prevention through Design (PtD) concept; Integrated Project Delivery (IPD); architectural perspective

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1. Introduction

The construction industry is recognized as one of the riskiest sectors in Malaysia and worldwide. For instance, the industry reported the highest number of fatalities in developing countries [1]. This is also supported by Mazlina et al. [2] and Samsudin et al. [3] study, both of which determined that construction activities have also constituted many accidents, which has led to an increase in the proportion of illnesses and injuries suffered by construction workers and teams. Absence from one's place of employment, a fall in one's productivity, the development of a disability that is permanent, and even death are all results of these occurrences. The typical life cycle of a building or any structure involves the conceptual and design stage, construction stage, maintenance, and operation stage, and finally the demolition stage. Though the construction stage is considered the riskiest, it is the maintenance and operation stage of the building that is the longest.

On this account, the Prevention through Design (PtD) concept has been introduced in some countries as an initiative to improve safety performance for the whole life cycle of the structure. Different terms with a similar concept are used in other countries, such as "Construction Design and Management (CDM)" in the UK, "Safe Design" in Australia, "Design for Safety" in Singapore, "Occupational Safety and Health in Construction Industry (Management)" in Malaysia, and "Prevention through Design" in the US [4,5]. Other associated terms also include "Design for Occupational Safety and Health" (DfOSH), "Safety in Design" (SiD), "Construction Hazard Prevention through Design" (CHPtD), and "Design for Construction Safety" (DfCS) [6,7]. In this review, we focus on the PtD only, rather than searching for IPD as well. According to Toole et al. [8] interview's result and research by Somik et al. [9], IPD-enabled designer–constructor collaboration throughout design is essential for PtD.

PtD is a concept introduced to account for occupational safety and health matters right from the design stage of a building all the way to its overall lifecycle [10]. Hence, it is agreed upon 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. In the construction and building context, a designer is defined as anyone who prepares or instructs anyone to prepare a design of a structure or part of the structure, which includes drawings, design detailing, specifications, and bills of quantities [11]. Therefore, people in these positions should fulfill their ethical duty of ensuring the safety and health of human beings throughout the building's lifecycle by using PtD practice. Designers could be architects, engineers, town planners, contractors undertaking works of altering designs or materials, and even clients as they direct or constrain designs [12]. In [13], five PtD competency attributes were defined, which include the architect's responsibility to have a safety design feature skill to ensure smooth operation during the construction stage and the necessity of a building or structure after handover to be safe to operate and maintain. The researchers proposed a new perspective on architects' PtD competence in the construction industry.

In the context of Malaysia, the existing guidelines on implementing PtD concept are very minimal. However, the lack of rigorous enforcement of standard safety design guidelines remains a hurdle to practicing PtD. In addition, outdated safety laws and regulations lead to poor safety performance of the building [14]. While concerns about the maintenance safety of government housing projects are growing due to design issues, maintenance and design are often considered two independent processes, and not linked together [15]. Although design has been highlighted as one of the root causes of accidents in the Malaysian construction industry, there is still an absence of building safety design standard guidelines [16].

An important aspect to bear in mind is that the building should secure and protect its inhabitants from different environmental conditions which lead to injuries, especially the design elements and services in the building [17]. Thus, there is a significant relationship between collaborative safety design guidelines and the design of the building to prevent any accidents or injuries during the construction phase or during the occupancy of the residential building.

The purpose of this study research, an ontology, which is a collection of concepts and their respective interrelationships [18], offers an abstract representation for a specific field or area of study that is linked to the application of PtD. Hence, the objective of this paper is to conduct a thematic review of the literature from 2011 to 2022 on the ontological framework of the PtD practices in the construction industry from the architectural perspective based on the following question:

RQ: What is the ontological framework of PtD practices in the construction industry from an architectural perspective?

2. Methodology

A thematic review technique adopted by Maguiere and Brid Delahunt [19] is used to review the established literature for this study. Clarke and Braun [20] identified thematic analysis as a process for identifying the patterns and constructing themes through a thorough reading of the subject.

2.1. Literature Search

Electronic literature searching was conducted on Web of Science, Science Direct, and Scopus, and a snowball method was also used. Since some countries use different terms related to PtD, the key search phrases included a few variations of the concept. In addition, a technique adopted from the study of Che Ibrahim [21], the snowball method of identifying relevant articles that have not been captured by the three databases, has also been implemented. A selection of relevant keywords was used in all databases, which includes design safety, design causes or factor, design and accidents, prevention through design, architect, architectural design, architectural perspective, in architecture, in building, maintenance stage, or worker. These keywords were paired with each other accordingly to expand search results, as shown in Table 1. All searches were restricted to publications from the year 2011 to 2022 only.

Table 1. Keywords forming search strings for literature search and literature selection.

Database	Research	Search Strings	No. Results of Initial Search	No. after Preliminary Screening of Abstracts	No. Selected for Final Review
Scopus	Primary	TITLE-ABS-KEY (“design causes” OR “factor” OR “design” AND “accident” AND “prevention through design” AND “architect” OR “architectural design” OR “architectural perspective”) AND PUBYEAR > 2011	24	20	2
	Secondary	TITLE-ABS-KEY (“design safety”) AND (“architect” OR “architectural design” OR “architectural perspective”) AND PUBYEAR > 2011	20	2	3
Web of Science	Primary	TS = (“design safety” AND “causes” OR “factor” AND “accident” AND “in building” AND “maintenance stage” AND “maintenance worker”) AND SU = (“architecture”)	43	18	3
ScienceDirect	Primary	(“architect” AND “design causes” OR “factor” AND “accident” AND “prevention through design”)	44	38	21
Snowball	Primary	“prevention through design” AND “in architecture”	16	10	4
	Secondary	“design safety” AND “construction sites” AND “workplace conditions”	46	5	8
Total articles			**193**	**93**	**41**

2.2. Literature Selection

Although the search resulted in a great number of articles (193 articles), some articles were not relevant to the research subject. Duplicates were also expected due to overlapping databases and were eliminated. Thus, from each database, only articles that were deemed to be useful for the subject were selected. These papers were preliminarily screened by reviewing their titles and abstracts. Thus, from database searches, only 93 articles were considered acceptable for this study.

Subsequently, to determine eligibility, a further review was conducted on the selected papers by reading the full text. The main eligibility criteria were that the publication must clearly provide an insight into the current prospect of PtD in the field of architecture. After the review, unrelated papers were removed, and 41 papers were retained. The literature selection with its corresponding search strings is recorded in Table 1.

2.3. Data Extraction

Next, all 41 metadata were transferred to ATLAS.ti 8 and stored as primary documents, as adopted by Zairul [22] and Samsudin [5] analysis technique. From there, several groupings were created in the code group. ATLAS.ti 8 systematically sorted the documents in an orderly manner. A word cloud was also generated through the articles, as shown in Figure 1. Next, the codes were grouped into several themes. Themes were then finalized to formulate the answer for the research question, "What is the ontological framework of PtD practices in the construction industry from an architectural perspective?". The findings of this review are divided into Quantitative findings and Qualitative findings.

Figure 1. Word cloud generated from 41 articles.

3. Results

Although this paper was targeting prevention through design from the architectural perspective, the journals recorded that the articles varied in publishing. Figure 2 indicates the key source journals of articles. The research strings used are either directly or indirectly referred to in the identified 41 articles through several periodicals. The prospects of PtD were subsequently carried out by a critical review of the findings from the selected articles.

From Figure 2, the trend of publishing is seen to be consistent from year to year. In 2011, very few publications highlighted the idea of PtD from an architectural perspective, whereas 2022 recorded only two, possibly due to some articles still being in progress. As the sample literature was spread across 22 journals, it is noted that considerable research on PtD is published in journals outside the architecture domain, particularly in the engineering domain. The most papers were published in 2016, which shows the implementation on PtD started to become broad in construction industry.

In descending order, most articles recorded are from Safety Science, followed by Automation in Construction, Accident Analysis and Prevention, Procedia Engineering, and World Multidisciplinary Civil Engineering-Architecture-Urban Planning Symposium (WMCAUS). Other journals resulted at the same frequency.

The 41 research articles have been reviewed in an iterative process in which comparisons for similarities and differences have been made to achieve consistency in the resulting subcategories. A list of publications and their allocation into the subcategories can be found in the pie chart below. Furthermore, the different perspectives from which PtD in the architecture scene has been researched so far were identified. The initial coding was further categorized into five main themes: designer's competency, planning and design decisions, technology for safety, design features and workplace conditions, laws, and legislation (Figure 3).

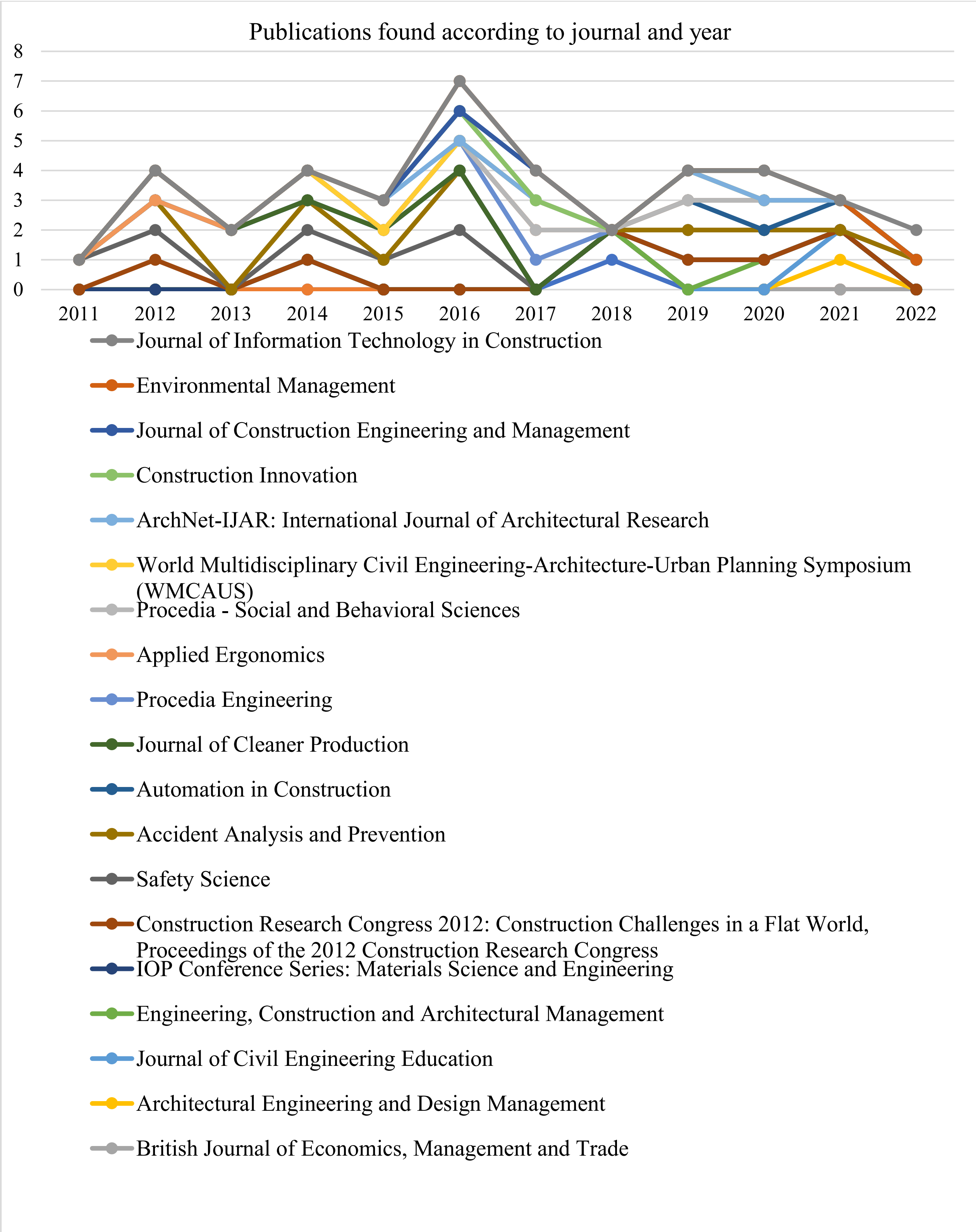

Figure 2. Articles reviewed based on journals.

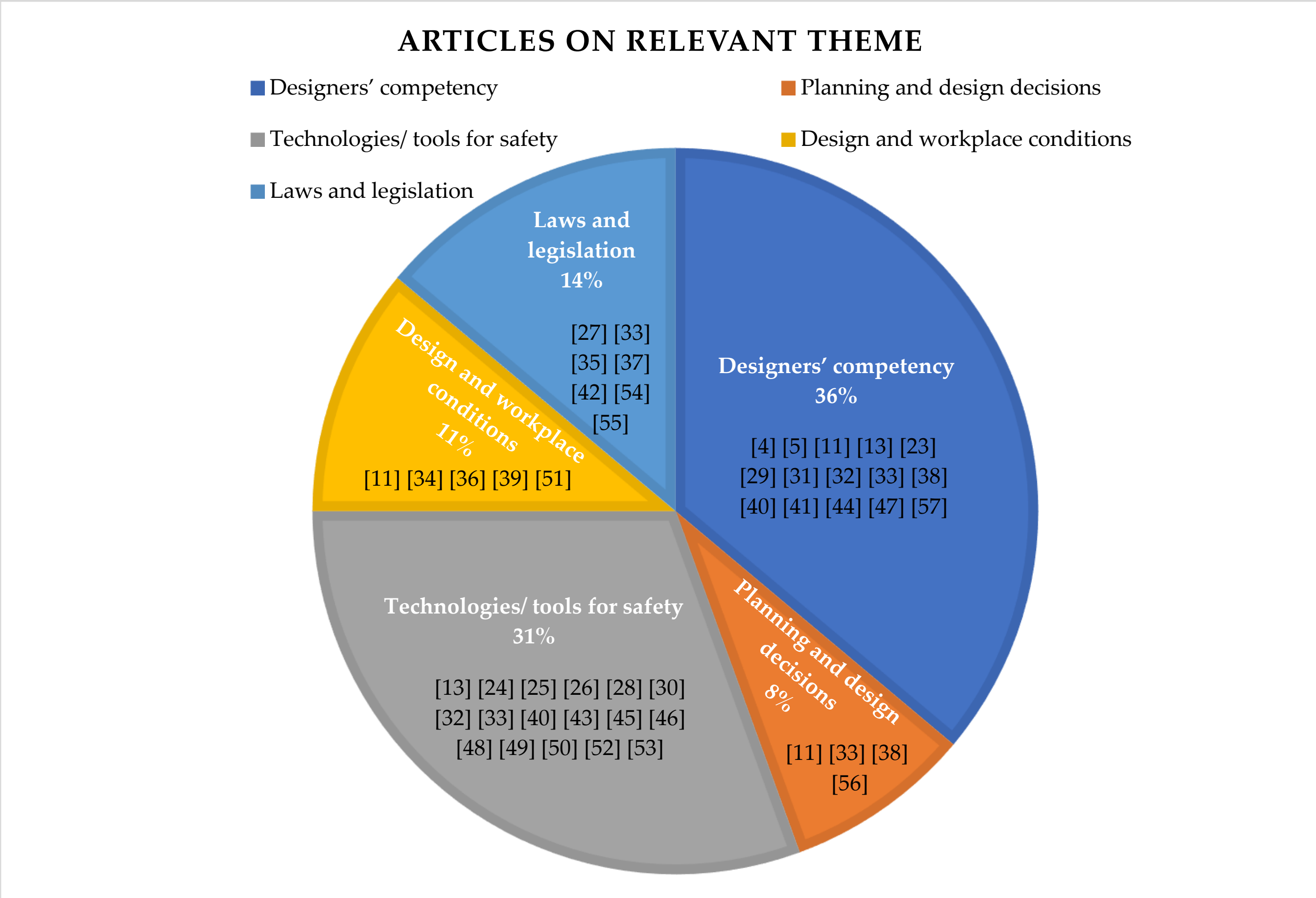

Figure 3. Articles on relevant theme pie chart [4,5,11,13,23–57].

The pattern was analyzed using the year of the study conducted (Table 2). The pattern on designer's competency is widely discussed, beginning in 2012. This is further divided into subcategories: knowledge and skills and experience. Next, planning and design decision was one of the first aspects to be discussed in 2011. Though not many papers were solely focused on the theme, it remains one of the important themes, as PtD helps in decision making. The trend on technologies for safety is the most frequently discussed and contributes to more recent publications since more software or tools are developed with safety and health at their core. In addition, design features and workplace conditions are also one of the earliest aspects to attract attention, having already been discussed since 2011. Other than that, the paper also reported the trends on laws and legislation were focused on, as the subject has already started being discussed in 2012. This implies the lawmakers' role in imposing laws to encourage PtD in projects.

In descending order, most articles recorded contribute to the theme of technologies or tools for safety, followed by designer's competency, laws and legislations, design features and workplace conditions, and finally planning and design decisions.

The articles reviewed were published in many different countries (Figure 4). The trends of PtD were popular in the United States. There are also PtD publications reported from other countries such as Portugal, Egypt, Poland, Brazil, Netherlands, Spain, United Kingdom, Singapore, China, Malaysia, South Africa, and Nigeria. Other than that, many articles were published as a collaborative effort between different universities from different countries (Table 3).

Table 2. Themes of articles according to year published (after screening process).

Source	Keyword Search Strings	Number
Scopus	TITLE-ABS-KEY(“design causes” OR “factor” AND “accident” AND “prevention through design” AND “architect” OR “architectural design” OR “architectural perspective”) AND PUBYEAR > 2011	2
	TITLE-ABS-KEY (“design safety”) AND (“architect” OR “architectural design” OR “architectural perspective”) AND PUBYEAR > 2011	3
Web of science	TS = (“design safety” AND “causes” OR “factor” AND “accident” AND “in building” AND “maintenance stage” AND “maintenance worker”) AND SU = (“architecture”)	3
Science Direct	(“architect” AND “design causes” OR “factor” AND “accident” AND “prevention through design”)	21
Snowball method	“prevention through design” AND “in architecture”, year: [2011 to 2022]	4
	“design safety” AND “construction sites” AND “workplace conditions”, year: [2011 to 2022]	8
	Total	41

Themes | Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Designer’s Competency	-	1	-	1	1	3	-	2	3	1	2	1
Planning and design decisions	1	1	-	-	-	1	-	2	-	-	-	-
Technologies for safety	-	-	2	3	2	2	-	1	2	2	2	2
Design features and Workplace environment/ condition	1	-	-	1	-	1	2	1	-	-	-	-
Laws and legislation	-	1	1	-	-	1	2	1	-	1	-	-

Note: Research sources covering journals and conferences published from 2011 to January 2022.

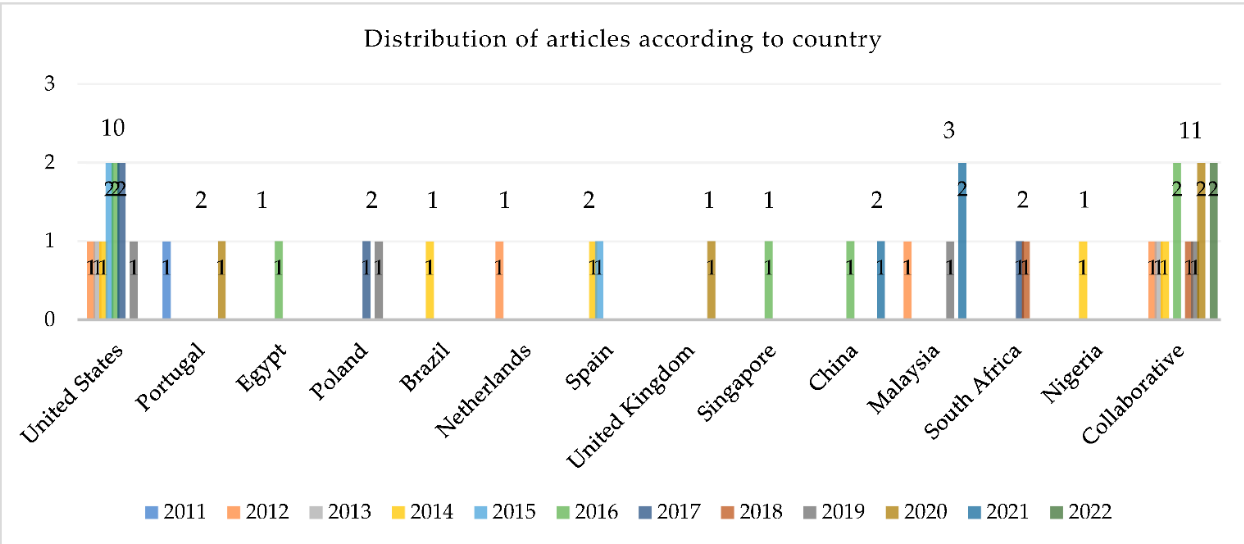

Figure 4. The distribution of articles according to country.

Table 3. Articles of collaborative effort according to year published.

Year	Nos. of Articles	Countries
2011	n.a	n.a
2012	1	Australia, United Kingdom, Singapore
2013	1	United States, South Korea
2014	1	Pakistan, Germany
2015	n.a	n.a
2016	2	United States, Australia and United States, Iraq
2017	n.a	n.a
2018	1	United Kingdom, United States
2019	2	China, United States, Malaysia
2020	2	Cyprus, Germany, Lithuania, Malaysia and Malaysia, United Kingdom
2021	2	Malaysia
2022	2	Malaysia, United Kingdom

Note: n.a is not available.

4. Discussion and Findings

This section summarizes data from the reviewed publications. In cases of the selected papers reviewing or using other journals as references, the article is cited along with the original authors. The findings were categorized into five primary categories: (1) designer's competency, (2) planning and design decision making, (3) technologies related to building safety, (4) design features and workplace condition, and (5) laws and building legislation (as illustrated in Figure 5).

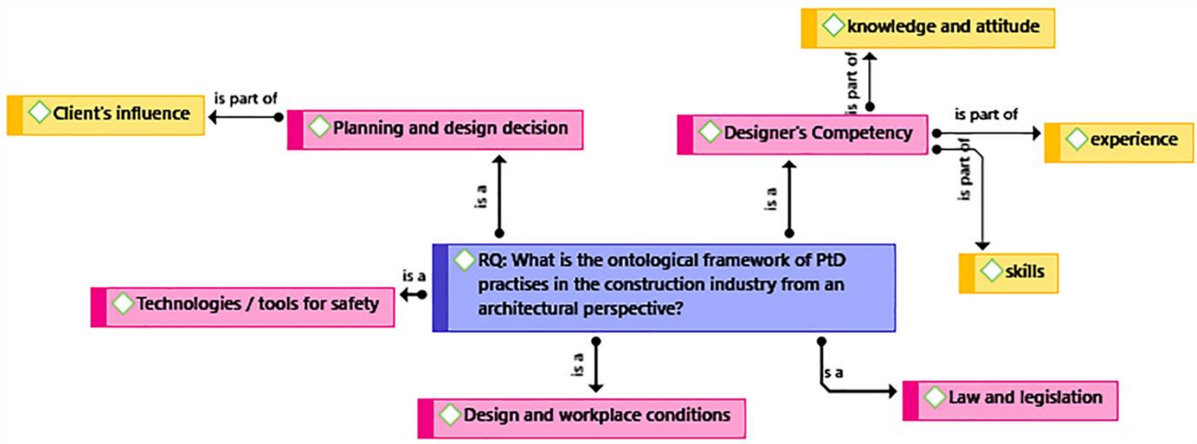

Figure 5. The ontological framework developed by utilizing an ATLAS.ti 8 software to address the research questions.

4.1. Planning and Design Decisions

The planning stage is important, as it influences the rest of the project's life cycle. Consistent with the statement of Pinto [58], safety should be addressed in the planning phase to be effectively implemented on site. The researcher also suggested the involvement of an OSH practitioner during preconstruction and operational maintenance phases. This corroborated Samsudin [5], namely the assertion that to avoid more accidents and higher costs in the future, PtD must be put into place earlier in the design phase.

Acknowledging safety in components of project construction can significantly improve safety on site. For example, some construction project characteristics (e.g., pre-assembly method of construction) can mitigate the proximal accident causal factors induced by other project characteristics (e.g., a restricted site, which induces site congestion) [23,59]. On different perspectives, Rybak et al. [60] stressed the necessity of taking into consideration the requirements of environmental safety at the design stage and at the operational and maintenance stage, which corroborated Kemajl [61], namely the assertion that operational and maintenance tasks are disproportionately responsible for workplace accidents. In addition, De Silve et al. [62] emphasized the need of prioritizing safe design for maintenance and operation activities at the early stages of the design process. Many practitioners are determining maintenance priority based on biased experience, subjective or personal appraisal, and conservative decisions, and some even adopt a specific building maintenance handbook by default without making a deliberate choice.

Client's Influence

A client, sometimes referred to as an owner, is a person or entity whom a construction project is carried out for, and who also funds the construction works, thus playing a vital role in encouraging the application of PtD [8,11,33].

A survey investigating practices of PtD by Goh and Chua [38] demonstrated that client motivation for PtD in Singapore could be the key to developing designers' PtD knowledge, attitude, and, most importantly, practices as referred to in Figure 6. Therefore, to include PtD in planning and design decisions, Azmi and Misnan [11] outlined a few roles that clients must undertake, such as motivating designers to acknowledge occupational safety and health during the design stage of projects, instructing tenderer to make provision for the cost of safety and health measures during the process, and ensuring that construction works are held back until the safety and health plan is fully developed.

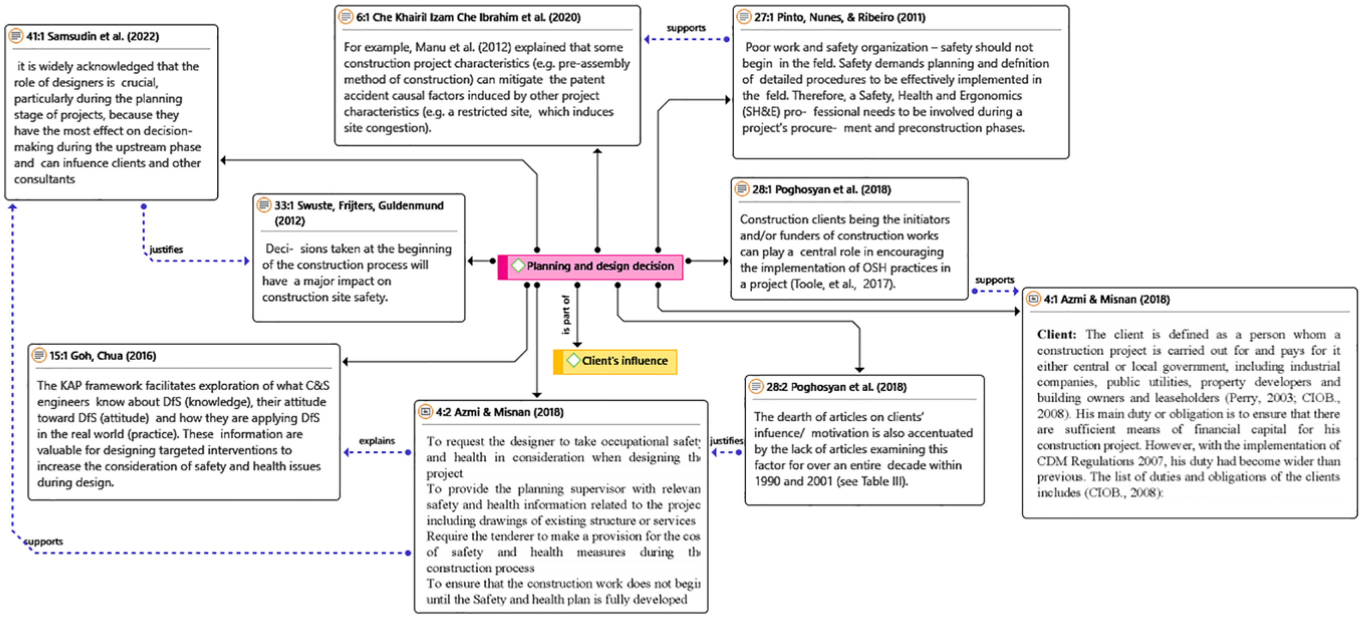

Figure 6. Client influence network diagram. Notes: ⟶ Solid line denotes to the primary attribute. - - - ➤ Dotted line denotes the presence of supporting literature reviews from various authors (i.e., supports, justifies, explains, continued by).

In summary, client encouragement toward occupational safety and health influences designers to plan and make design decisions that reflect the ideals of PtD. However, despite the evidence from different studies that propose client's influence is probably the most important aspect of PtD practice, according to Poghosyan [33], only a small number of articles cover the subject. Hence, more research would be helpful in this regard. Client influence relies on the project delivery method as well. Design-bid-build projects do not allow this collaboration because construction firms are not chosen until after design. Design-build and IPD, which enable collaboration, are the best project delivery techniques for PtD [8].

4.2. *Designer's Competency*

Prior study by Che Ibrahim and Belayutham [23] noted that "competency" is defined as the possession of knowledge, skills, and experience by the designer to perform PtD practices. Designer's competency is divided into three subcategories: (1) knowledge and attitude, (2) skills, and (3) experience. This will be further discussed in the following section.

4.2.1. Knowledge and Attitude

Based on Figure 7, the need for PtD knowledge, sometimes referred to as PtD awareness, is important especially among architects to ensure proper application of PtD, particularly because the designer's lack of understanding of construction processes is a significant hurdle that would prevent designers from contributing to worker safety [33,63]. PtD knowledge can be categorized into tacit knowledge and explicit knowledge [21,32]. Tacit knowledge is personal know-how (practicality) that is largely gained through education, training, and experience, while explicit knowledge is personal know-how (theoretical) based on guidelines, procedures, and best practices [23,64]. Hence, PtD knowledge is often obtained through tertiary education, training programs, experience, and guidelines.

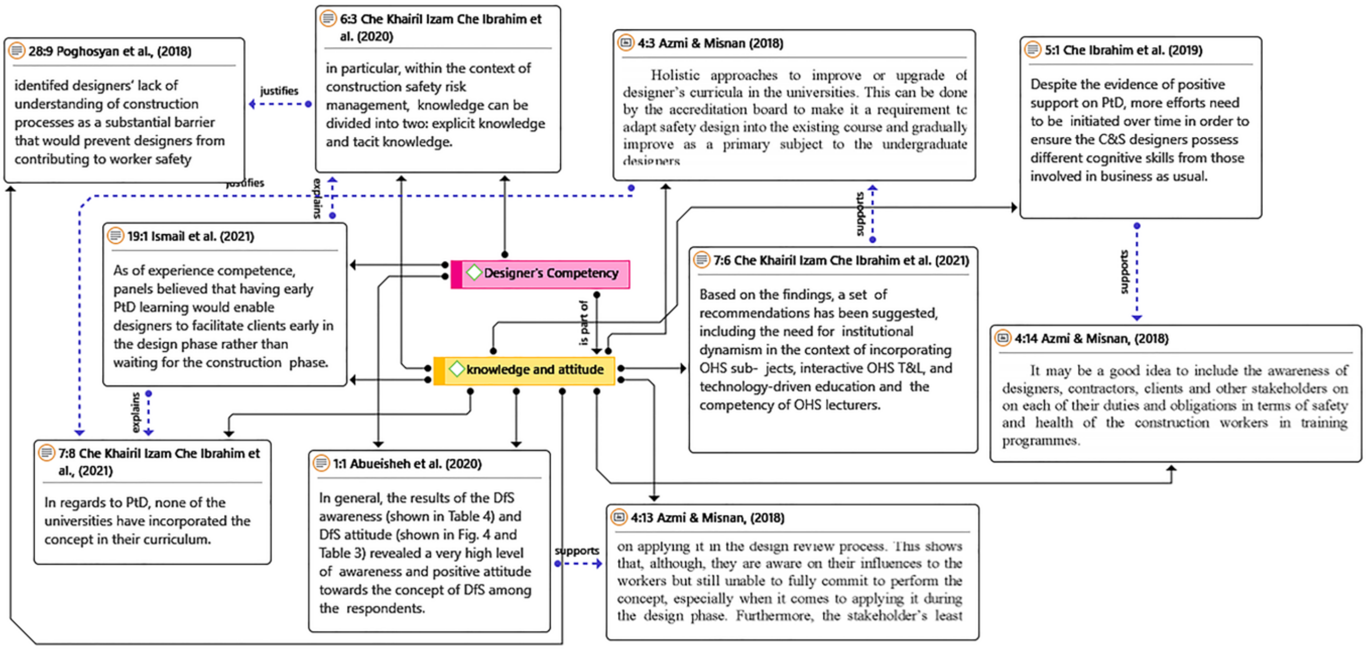

Figure 7. Knowledge and attitude network diagram. Notes: ⟶ Solid line denotes to the primary attribute. - - -➤ Dotted line denotes the presence of supporting literature reviews from various authors (i.e., supports, justifies, explains, continued by).

A study by Ismail [13] demonstrated that having early access to knowledge of PtD would enable designers to facilitate clients better at the design phase, rather than waiting for the construction phase to make amendments. This stems from the statement that when designers are exposed to the concept, guidelines, and legislations of PtD in tertiary education, it could enhance design thinking as well as change the design approach. This statement supports the survey carried out by Behm [65] which showed that educational intervention changed student perceptions of accident causality and prevention to favor safe design thinking. However, the integration of PtD in the curricula remains elusive, as identified in research by Che Ibrahim [4] in a study in Malaysia out of seven universities that participated in the study; none of them incorporated the concept in their curriculum. The researchers also acknowledged four major challenges for PtD education, which include current curriculum being too crowded with designated courses, lack of OSH-related content in the curriculum, traditional methods of teaching and learning, and lack of availability of well-equipped lecturers regarding PtD.

Thus, holistic approaches need to be implemented to upgrade or enhance designer's curricula in universities [11]. This can be made possible by accreditation boards establishing a requirement to adopt safety design into existing courses and design programs, which will then evolve gradually into a primary or core subject for undergraduate designers. Moreover, Che Ibrahim [4] suggested introducing OSH subjects, adopting an interactive and technology-driven approach to teaching and learning, and including competent OSH lecturers to improve existing curricula.

Moreover, Azmi and Misnan [11] suggested that effective training programs on design for safety should be made regular and lifelong. Professional bodies can make it a requirement for designers to attend training or seminars to register or renew their professional license. Finally, organizations also need to have an effective safety knowledge management (KM) process in place [33].

Accordingly, the topic of designer knowledge and awareness is often paired with designer attitude [33]. Unfortunately, knowledge and available tools for design safety alone do not guarantee PtD application. As per Che Ibrahim [66], first, it would be the misconceptions and mindset of designers, particularly the view that safety issues are complex in construction. Next, designers tend to be insensitive to worker safety, and finally, they lack knowledge and understanding of their roles and responsibilities in addressing the OSH issues.

In this regard, a finding by Azmi and Misnan [11] revealed that although stakeholders are aware of their influences on OSH, they still feel unable to fully commit to performing the concept, especially regarding applying it during the design phase. This is also supported by Abueisheh [27], who identified that in Palestine, design professionals generally consider the importance of PtD to be high and indicated that they would include the practice of PtD in their work if given a choice, therefore showing positive attitude toward the implementation of PtD.

However, in the same study, when asked about whether the Palestinian construction industry is ready to take on the responsibility of including PtD in projects, the majority expresses the idea that it is not. Nonetheless, this mindset may change once designers fully understand the ways in which their design can influence safety and health [11]. Even if designers know about construction safety and PtD, Toole et al. [8] research showed that designers, the lead contractor, construction stakeholders, and construction safety professionals must collaborate during design through IPD project delivery to create an effective PtD concept implementation. Overall, attitude and knowledge go hand in hand. Knowledge is considered crucial for PtD concept implementation, and the openness of architects to adapt to it makes it possible.

4.2.2. Skills

Skills are developed through the exercise of knowledge. According to Figure 8, Che Ibrahim [21] stated that skills are divided into technical skills and soft skills. Technical skills are categorized into the ability to forecast wide-ranging hazards during the design, ability to conduct the process of hazard recognition and its severity, ability to navigate information-technology-enabled tools, and ability to perform cost–benefit analysis to justify PtD design expenditures. Meanwhile, the key attribute of soft skills is the ability to work collaboratively with other consultants.

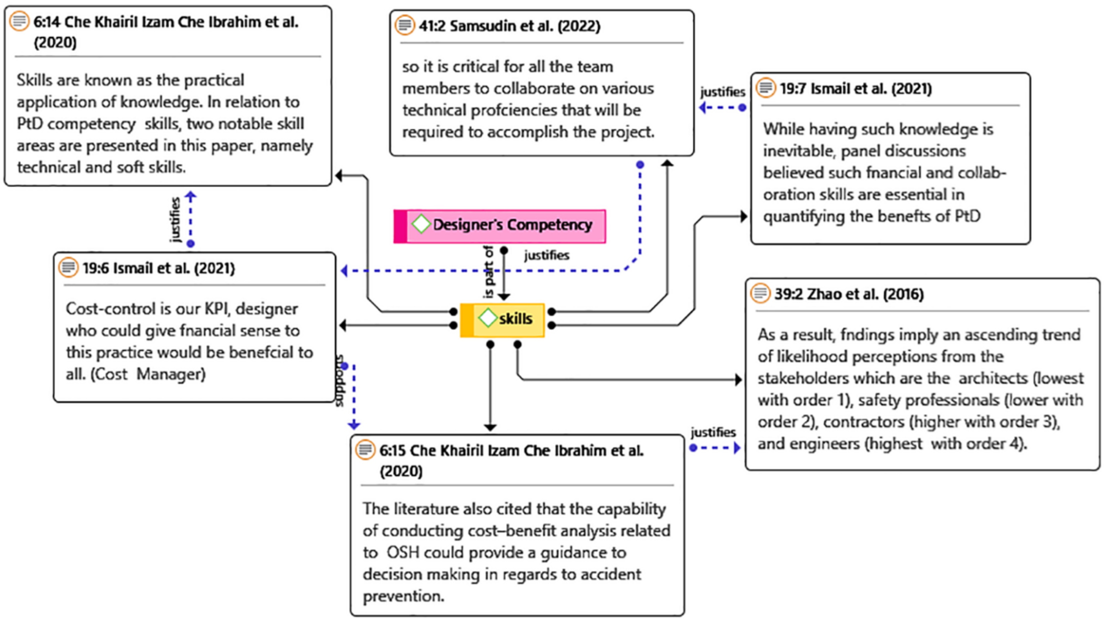

Figure 8. Skills network diagram. Notes: ⟶ Solid line denotes the primary attribute. - - -► Dotted line denotes the presence of supporting literature reviews from various authors (i.e., supports, justifies, explains, continued by).

One of the most important technical skills is hazard recognition skill, which unfortunately most architects are lacking. A study by Zhao [41] revealed that architects have low risk assessment. However, in the same study, the builders' risk assessment seems comparatively accurate assuming they thoroughly understand construction means and methods, while the engineers' risk assessment is comparatively high. Another skill that is preferred in encouraging PtD implementation is the capability of conducting cost–benefit analysis related to OSH because it could provide guidance to decision making regarding accident prevention [21]. Studies have also highlighted that the ability to use technology-enabled tools could further add value and maximize the potential benefits of PtD implementation.

For this reason, architects need to cultivate their soft skills, which enable them to work collaboratively with other professionals toward PtD practices [5]. Furthermore, panel discussions from the study of Ismail [13] revealed that such financial and collaboration skills are essential in quantifying the benefits of PtD as well as enhancing existing fragmented relationships toward a more collaborative culture. Nonetheless, the researcher also added that in Malaysia, although collaborative project delivery is said to be effective in improving the practice of PtD, such an approach has not been practiced yet.

4.2.3. Experience

The proficiencies of a professional are developed through learning, training, or hands-on experience. In addition, as pointed out by Durdyev et al. [67], frequent disputes, goal inconsistency, change orders, rework, adversarial relationships, arbitrations, and litigations are some of the problems that have been reported to be caused by traditional construction procurement methods. These problems require enhanced performance to be achieved through IPD, but this has not been realized in actual practice. In the case of PtD, the need for the designer to have experience in conducting design-related construction works is critical. Figure 9 shows that such experiences could provide different aspects of design information that facilitate hazard recognition activities [21,24]. The experience of working on different types of projects could also enhance the understanding of ways in which different approaches of PtD could come into play within respective projects [24].

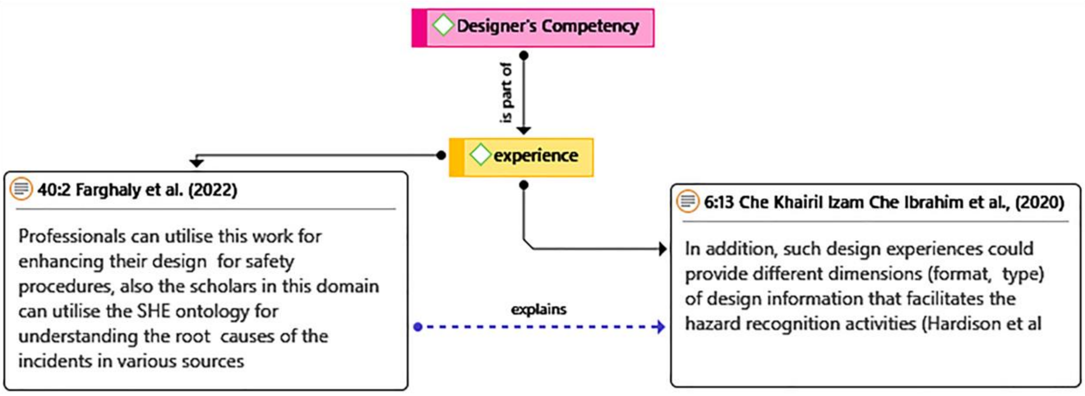

Figure 9. Experience network diagram. Notes: ⟶ Solid line denotes the primary attribute. - - -► Dotted line denotes the presence of supporting literature reviews from various authors (i.e., supports, justifies, explains, continued by).

Adapted from Che Ismail [23] and Addis [64], the categories and attributes that form designer's competency are summarized in Figure 10. Hence, the acquisition of knowledge in turn develops needed skills. With the two combined, designers can seek experience by applying them to real projects, therefore resulting in designer's competency. Evidently, it is important to note that knowledge and awareness of PtD is the starting point for the concept implementation. As outlined by Ismail [13], the knowledge of PtD is necessary to initiate collaboration between professionals. Furthermore, collective decision making through IPD implementation can be aided through a proper understanding of ways in which this practice could affect project performance and safety.

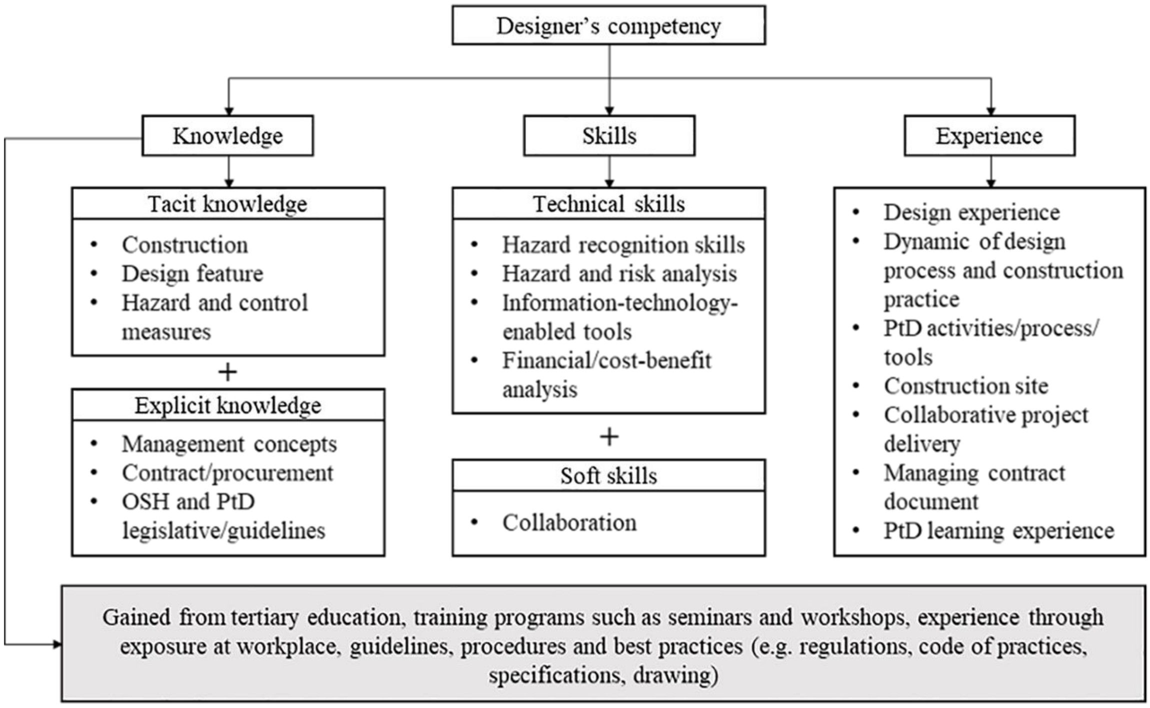

Figure 10. Designer's competency and its components (adapted from Che Ismail [23] and Addis [64]).

4.3. Technologies/Tools for Safety

Technologies are becoming more advanced, and recent developments enabled the identification of all potentially possible threats to health and safety at work using 3D modelling. This is made possible through countless research on PtD tools, with articles that started to emerge as early as 1996 [33]. It is believed that, in recent years, IPD has been widely advocated for because of its potential to facilitate the use of BIM on construction projects [67]. This is the standpoint from which IPD-PtD application can be seen. It has been demonstrated that combining IPD-PtD with BIM can increase project efficiency, cut down on errors, make it possible to investigate alternative methods, and broaden the scope of market potential.

With reference to Figure 11, Poghosyan [33] stated that one of the first computer-based IPD-PtD application tools was "Design for Construction Safety Toolbox". It was noted that by linking the design and construction phase, the tool helps designers to recognize project-specific hazards, and afterwards adopting the tool's suggestions into a project.

Apart from this, in most of the articles reviewed for this paper, the usage of BIM software has been frequently mentioned as one of the methods of implementing PtD. Panteli [26] stated that the BIM method progresses beyond the architectural drawing design to include all the project life cycles. From the perspective of safety management during design, designers' efforts and time can be saved by the automated detection process of safety risks using the proposed method, thus minimizing accidents during construction work [7,32].

In a study, Ismail [13] noted that consultants acknowledged that the use of BIM and associated tools is vital for information exchange and efficient communication within IPD-PtD implementation, as it can enhance visualization.

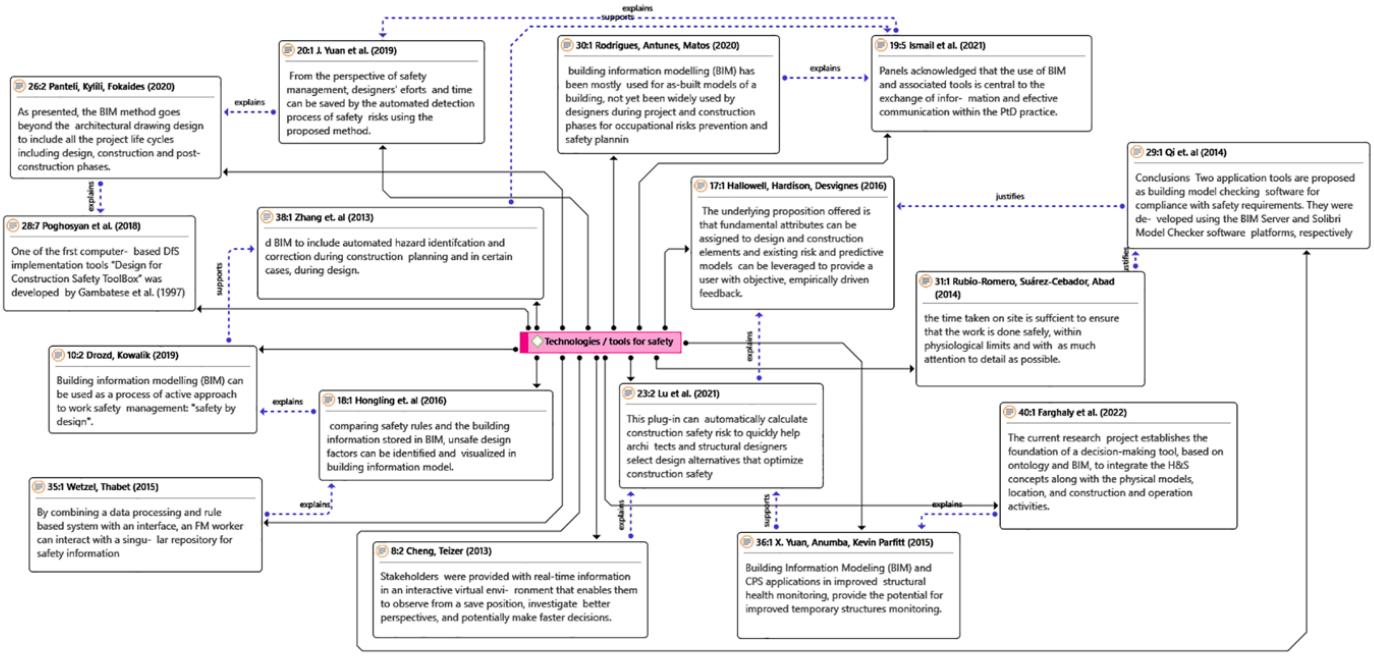

Figure 11. Technologies/tools for safety network diagram. Notes: ⟶ Solid line denotes the primary attribute. - - -► Dotted line denotes the presence of supporting literature reviews from various authors (i.e., supports, justifies, explains, continued by).

4.4. Design Features and Workplace Conditions

The construction industry is plagued by occupational risky situations and poor working conditions. Although it is said that workers are much more responsible for their own protection [58], this should not be the case. Various parties including clients, consultants, contractors, and facility management should collaborate to ensure that safe design is implemented.

Lack of worker skills, training and experience, poor use of safety gear, poor risk perception, and deviation from safety standards dominate among the principal causes of accidents on construction sites. A study by Agwu and Olele [51] highlighted a significant relationship between poor safety culture and an increased rate of unsafe acts in the Nigerian construction industry. The researchers also added that safety consideration in construction project delivery is not assigned a priority and is considered a burden in most developing countries. Developing countries, on the other hand, are not well prepared to meet these standards, which highlights the fact that the application of IPD is impeded by constraints, particularly in the context of developing countries [67].

As a result, based on Figure 12, because workplace accident causation is multifaceted and complex, design has been identified as one of the major contributors to accidents and injuries [27]. Design has long been identified as a leading cause of workplace accidents that result in deaths, injuries, and illnesses in the construction industry [6,7]. Despite the fact that workplace safety design concerns have grown in popularity among industry leaders, the PtD concept has been overlooked in their industrial development policies and strategies [8].

Regardless of one's feelings about increased responsibility for design professionals, it is undeniable that design-related issues have emerged as the leading cause of construction injuries and fatalities, which must be addressed during the initial design stage. Recent research, on the other hand, has detected a link between occupational safety and architectural design [9–13]. Goldswain and Smallwood [14] also drew attention to critical workplace safety challenges in the context of architectural designs that must be addressed to reduce workplace accidents and injuries.

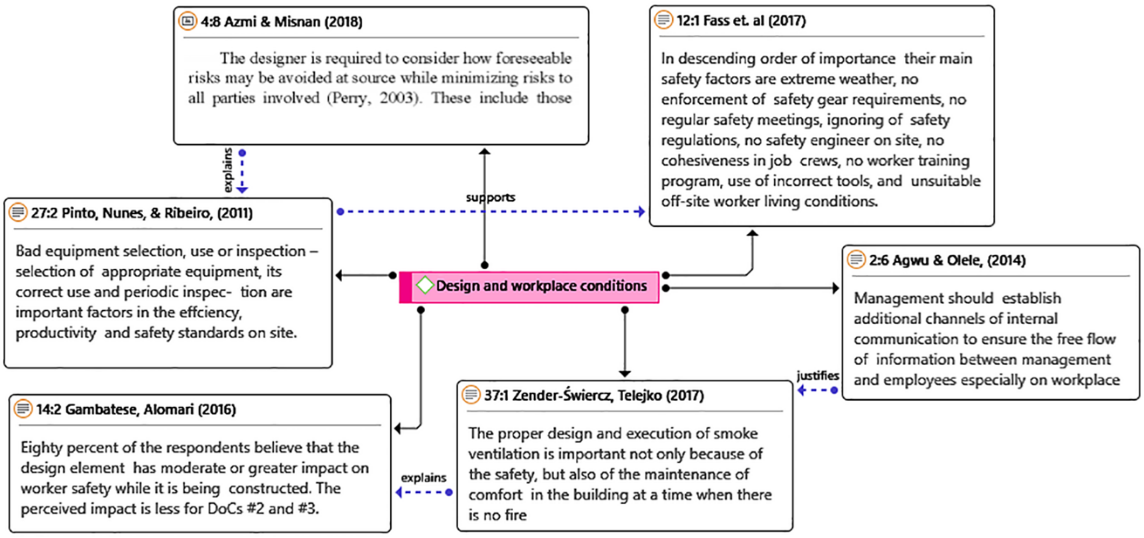

Figure 12. Design and workplace conditions. Notes: ⟶ Solid line denotes the primary attribute. - - - ► Dotted line denotes the presence of supporting literature reviews from various authors (i.e., supports, justifies, explains, continued by).

In addition, in study [68], most respondents believe that the design element has a moderate or greater impact on worker safety during construction. Additionally, most of the respondents also felt that there is a connection between one worker and another worker in terms of safety in the workplace. This is an indicator that the responsibility to provide a safe environment for workers in construction sites relies not only on contractors and project management alone but also on designers. Designers supposedly consider ways in which foreseeable risk may be avoided or minimized for all parties involved [11].

As an approach to improving safety culture in construction, Tymvious and Gambatese [51] proposed a few suggestions: (1) top management needs to show a clear commitment to organizational safety issues, (2) implementation of regular staff training on safe work procedures is needed, (3) establishment of safety committees and regular safety audits or site inspections is required, (4) it is suggested to abolish productivity bonus schemes that act as incentives for employees to work faster. This is supported by Pinto [58], who asserts that economic and time pressure lead to relaxing rules and procedures, causing reckless operations and practice.

4.5. Laws and Legislation

The proven connection between design and construction or occupational accidents prompted various countries to establish legislations to encourage designer involvement in PtD.

A survey of design engineers in Australia concluded that the regulations and codes of practice have a positive impact on construction worker safety [65]. Nevertheless, available studies regarding the topic of PtD in construction of developing countries have been very limited [27], therefore indicating a possible lack of PtD legislation reviews or enforcement in said countries. Similarly, in 2012, Saifullah and Ismail [55] mentioned that there are no specific legal obligations imposed on clients, designers, and other "upstream stage" personnel to ensure that construction projects in Malaysia run safely. It is worth mentioning, however, that although many articles regarding PtD were published in the context of the U.S, the country currently has no PtD legislation in place.

Meanwhile, the implementation of PtD in construction has been prominent in some countries for several years, particularly those in the European Union (EU) as well as in the United Kingdom. In contrast, research from Canada indicates that failing to incorporate stakeholders early limits the use of IPD by public authorities, while poor risk/reward sharing mechanisms and state legislation limit IPD use by public authorities [67]. In a review by Poghosyan [33] as referred to in Figure 13, it was indicated that there is only a small amount of research exploring the topic of legislation or laws regarding PtD adoption, and the studies cover mostly legislation in developed countries. In view of this, there is the opportunity of drawing lessons from PtD implementation and its evolution over the years in those countries and then consider the possibility of appropriately contextualizing some of those lessons [27]. Although some countries do not have direct legislation regarding PtD, some possess a more general OSH or construction safety legislation instead, as reported in Table 4.

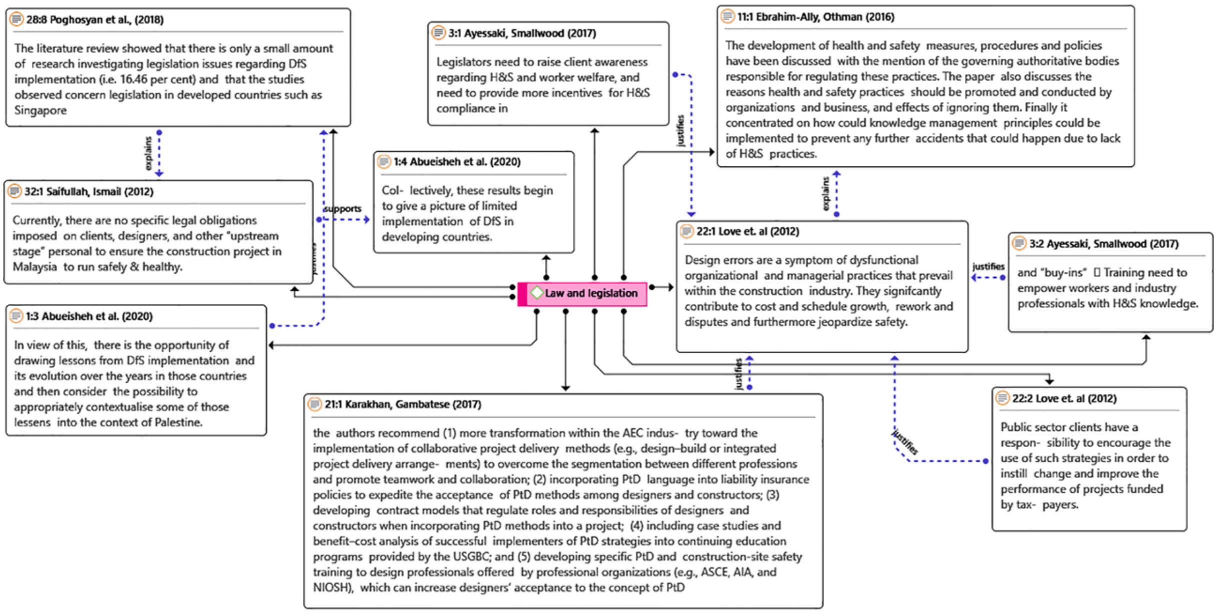

Figure 13. Law and legislation network diagram. Notes: ⟶ Solid line denotes the primary attribute. - - -▸ Dotted line denotes the presence of supporting literature reviews from various authors (i.e., supports, justifies, explains, continued by).

Table 4. PtD or OSH-related legislation or guidelines in countries.

Countries	Legislations Regarding PtD Implementation	Source
Singapore	Workplace Safety and Health (Design for Safety) Regulations 2015	[33]
Australia	Work Health and Safety Acts and Regulations	
United Kingdom	Construction Design and Management Regulations 2015	
EU countries	Adaptations of European Framework Directive 92/57/EEC	
Ireland	Safety, Health and Welfare at Work (Construction) 2013	[13]
New Zealand	Health and Safety at Work Act (HSWA) 2015	
Malaysia	Occupational Safety and Health in Construction Industry (Management) (OSHCI(M)) 2017	
Korea	Enforcement Decree of the Construction Technology Promotion 2016	
Palestine	The Palestinian Labor Act no. 7	[27]

As legislation can be considered a powerful stimulus for change, the absence of construction PtD legislation in countries, especially ones of developing economies, could potentially have implications for the awareness, knowledge, and practice of PtD [69]. Thus, the roles of governments or lawmakers are vital in the pursuit of the implementation of PtD concept among design professionals.

Existing OSH laws can be refined to include the call for practice of PtD explicitly. New regulatory frameworks and laws could also be established to convince firms to undertake PtD, for example, setting financial "penalties" for failing to comply with PtD standards or providing "incentives" that will then encourage the use of PtD in the architecture industry.

4.6. The Ontological Worldviews Findings

This paper addressed a multitude of ontologies using thematic literature review findings to propose interpretations for the pattern that can be subject to hypothesis contrast and lead to the practical applicability of its architectural overview in the integrated project delivery (IPD) knowledge metrics for future use. The thematic review technique, which is a part of the content analysis method, was used as a comparison since it is the only accessible assessment mechanism that can be generated comprehensively without the need for an expert's assessment of the ontologies. It is important to emphasize that this form of established pattern cannot replace expert logical assessments such as those that have already been documented in the literature; instead, it assists in improving existing kinds of evaluations to the present.

The key resource for integrating and managing research on previous ideologies on PtD concept based on architectural view has emerged as ontological results from this review study. Moreover, a new set of standards to formally express these results was developed and saw extensive use. The planning and design decision is the first pattern that emerged from the findings. As per research, the client has an impact on planning and design decisions. A client can play an important role in encouraging designers to employ PtD.

The second pattern is designer's competency, which consists of knowledge and attitude, skills, and experience. PtD knowledge is essential among architects to enable the correct implementation of PtD, particularly since designers' lack of understanding of building processes is a substantial barrier in their role in worker safety. Four major challenges were identified by the researchers for PtD Implementation at the tertiary education level: the current curriculum being too crowded with designated courses, the lack of OSH-related content in the curriculum, traditional methods of teaching and learning, and the lack of availability of well-equipped lecturers on the PtD topic. Therefore, students must strive diligently to acquire new PtD information via tertiary education. In the project's conceptual and planning stages, the goal of PtD is to identify and reduce potential hazards to OSH. Anticipation, detection, and mitigation of danger in the design phase will become simpler, cheaper, and more effective with an adequate understanding of design safety instead of redesigning a project that has been put into production.

The third pattern is the technology tools for safety implementation. The use of BIM software is widely suggested as one approach to adopting IPD-PtD. The design model may be validated using PtD rules as the BIM advances. This means that safety issues will be automatically recognized, and the identification result will also be shown in the model.

In addition, one of the recurring themes is both design and workplace condition. Based on the findings, all work-related safety and health aspects should be properly reviewed by all stakeholders of the project to minimize future safety issues. This will help to avoid any potential risks or dangers that may arise during the later stages of the project. Employers should take steps to guarantee and promote workplace safety to prevent injuries and accidents.

In contrast, in law and regulation pattern finding, there is a paucity of research on the issue of legislation or laws pertaining to PtD adoption, with most studies focusing on legislation in developed nations. Although some nations do not have PtD-specific laws, others have OSH or construction safety regulations. Existing OSHA regulations may be modified to reflect the express demand for PtD practice. Additionally, new regulatory frameworks and rules might be enacted to persuade businesses to engage in PtD, for instance, establishing monetary "penalties" for non-compliance with PtD standards or to creating "incentives" to promote the adoption of PtD in the architectural sector. PtD's effective incorporation into the architectural scene may require a long time without the necessary impetus provided by the implementation of law.

5. Conclusions

Prevention through Design (PtD) has been extensively used to prevent any possible hazards throughout the early design stages. Although the significance of PtD has been generally acknowledged, there are still unaddressed concerns about its architectural overview in the integrated project delivery (IPD) knowledge. To address this research gap, this study thoroughly explained the ontological framework of PtD processes in the integrated project delivery (IPD) in the construction industry from an architectural perspective. The use of IPD has seen a tremendous uptick in the architectural, engineering, and construction (AEC) industry as a direct result of the high rate of success it has achieved, in particular regarding issues of cost and time. The IPD method is different from other approaches because it implements changes in the contract, process, information and modelling, team, and communication. The beneficial outcomes include cost control, time management, quality improvement, and the handling of unforeseen safety design issues through integration with the PtD concept implementation. This systematic review attempts to summarize PtD-related architectural perspectives published between 2011 and 2022.

A code-to-document analysis of ATLAS.ti 8 findings showed that five clusters answered the research question. The five clusters are patterned as follows: (1) designer's competency, (2) planning and design decision making, (3) technologies related to building safety, (4) design features and workplace conditions, and (5) laws and building legislation.

Nevertheless, based on the findings of this study, it can be concluded that there is a significant lack of research into the planning and design decision-making among stakeholders as well as designers' capability to implement PtD, and this is an issue that needs to be addressed. The limitations of the research must be addressed, and some of them are given as follows. This research focused mostly on the applicability of the PtD idea in developing countries. As the number of papers retrieved during the last 11 years is small (41), the information gathered is restricted. Moreover, since several articles were analyzed, the researchers sometimes felt the need to provide a wide summary of the topic. Future studies should investigate the specific problems, possibilities, and practicality of the PtD idea in connection with the stakeholders' planning and design choices. It is prudent to investigate the ontological structure of PtD from an architectural standpoint. Thus, it is advisable to mention the following: further study is required to widen the scope of this work, and verification of the results' generalizability is necessary. In order to evaluate the future influence of developing designer roles, the architectural design for safety and planning and design decisions made by stakeholders, it is also suggested that more studies be conducted in the field of architectural safety design.

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