Process Protocol for Prevention through Design (PTD) Implementation in Malaysian Construction Industry – A Concept Paper

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ABSTRACT

The construction industry is among the most hazardous sectors globally, with high rates of accidents, fatalities, and occupational illnesses often stemming from unsafe workplaces, flawed design decisions, and fragmented procurement practices during the pre-construction phase. To address these risks, Malaysia's Twelfth Malaysia Plan (2021–2025) introduced the Occupational Safety and Health (Construction Work) (Design and Management) Regulations 2024, emphasizing the integration of Prevention through Design (PtD) principles. The Regulations assign clear roles and responsibilities to stakeholders, including designers, contractors, and clients, to prioritize safety throughout the construction lifecycle. However, awareness and understanding of the PtD concept embedded in the Regulations remain limited due to the early stage of its enforcement, and research on PtD implementation under the CDM Regulations 2024 is scarce. This study explores current PtD practices in the construction industry, identifies legal requirements under the CDM Regulations 2024, and highlights issues arising from PtD implementation. A content analysis was conducted using a systematic literature review methodology guided by the PRISMA framework, analyzing 40 relevant articles. The findings reveal four main categories of PtD implementation issues: unresolved legal and contractual barriers, lack of awareness, procurement challenges, and industry culture. Subcategories include coordination, cost and time, liability, policy, lack of knowledge, fragmented procurement systems, and the inherent nature of the industry. By advancing understanding of PtD responsibilities and implementation strategies, this study contributes to improving occupational safety and health practices within Malaysia's construction industry, fostering sustainable and safe construction environments. The findings emphasize the need for a structured process protocol in future studies to clarify stakeholder duties, address contractual ambiguities, and cultivate a culture of safety-driven project management.

Keywords: Prevention through Design, issues, process protocol, construction industry, Malaysia

INTRODUCTION

The Twelfth Malaysia Plan (2021-2025) highlights the importance of embracing sustainable and technologically advanced methods in the construction industry to spur economic progress, generate employment, and draw both local and international investments. Nevertheless, despite its critical role in national development, the construction industry remains burdened with significant risk factors, leading to accidents, fatalities, and work-related illnesses. This makes it one of the most dangerous industries worldwide [1], [2], [3], [4], [5]. These risks stem from hazardous workplaces [6], specific design decisions [7], and procurement methods selected [8] during the pre-construction phase. In evidence, Malaysian construction industry cumulatively recorded 548 fatalities from 2017 to 2023, making it the sector with the highest fatality rates after manufacturing for five consecutive years [9]. In accordance to that, falls from heights are the leading

cause of fatal accidents, often resulting from inadequate or unsafe building designs [10], [11], such as insufficient fall protection or temporary structures [12]. Additionally, researchers also underscore that design-related issues were major contributors to construction fatalities, highlighting the need for thorough design considerations to prevent accidents [1], [3], [6], [10], [13], [14]. In short, these fatal incidents often stem from underlying management problems [15], including deficiencies in occupational safety and health management [16]. To address these issues, it is essential to focus on the root cause through external factors, namely policy and legislation [16]. Therefore, the Twelfth Malaysia Plan addresses this by advocating for stricter regulations, including the introduction of the Occupational Safety and Health (Construction Work) (Design and Management) Regulations 2024.

Following that, in conjunction to the Occupational Safety and Health Act 1994 (Act 514) under Section 66, the Occupational Safety and Health (Construction Work) (Design and Management) Regulations 2024 (CDM Regulations 2024) was enforced on 1st of June 2024 to improve occupational safety and health (OSH) standards in the Malaysian construction industry. Prior to the Regulations, the Guidelines on Occupational Safety and Health in Construction Industry (Management) (OSHCIM) had been in place since 2017 with a similar objective. These policies adopt a comprehensive approach, integrating Prevention through Design (PtD) principles, and outlining the responsibilities of construction stakeholders, including designers, contractors, and clients, to ensure safe construction practices from the design phase through to project completion [17]. In this context, under the CDM Regulations 2024, designers are required to conduct risk assessments and integrate safety measures into their designs. On the same hand, contractors must implement detailed safety plans and ensure worker adherence to protocols, while clients are responsible for prioritizing safety in projects and appointing competent professionals. In short, the CDM Regulations 2024 aims to prevent accidents, promote a safety culture, and ensure compliance through comprehensive guidelines and robust enforcement mechanisms. Nevertheless, despite the Malaysian government's efforts with the new enforcement of the Regulations, many construction stakeholders remain unaware of its existence and implementation procedures. This issue mirrors the introduction of OSHCIM, where stakeholders resisted implementation in their construction projects primarily due to the absence of enforcement. Even now, with enforcement in place, there is still a lack of adoption among construction stakeholders, due to a lack of clear understanding of how to properly implement the requirements.

Previous research has explored various aspects of integrating OSH into design practices, such as safety education for designers [4], [18], [19], [20], [21], [22], [23], their competency [2], [10], [14], [17], [24], [25], [26], legal considerations [3], technological advancements for building safety [27], [28], [29], [30], [31], and the connection between design issues and accidents [6], [12]. Despite progress in PtD concept in Malaysia, existing literature has mainly focused on safety education, designer competency, and the integration of Building Information Modeling (BIM) with PtD. Despite progress in the Prevention through Design (PtD) concept in Malaysia, existing literature has mainly focused on safety education, designer competency, and the integration of Building Information Modeling (BIM) with PtD. However, limited attention has been given to contractual issues concerning the implementation of CDM Regulations 2024, including regulatory requirements and collaborative efforts [10]. This lack of focus has hindered effective implementation. Therefore, this study aims to address these knowledge gaps.

The objective of this paper is to propose a conceptual framework for a process protocol to enhance the implementation of PtD in the Malaysian construction industry, in line with the CDM Regulations 2024. To achieve this aim, several objectives have been outlined: (1) To explore the current practice of PtD in the construction industry; (2) To determine PtD legal requirements, and finally; (3) To highlight the issues arising from PtD implementation. Therefore, the organization of this paper is outlined as follows: (1) Background section that offers a concise overview of prior research on PtD; (2) A review of the current PtD practices within the construction industry; (3) Literature review of the legal framework surrounding PtD; (4) Methodology section that outlines the systematic literature review approach used in this study; (5) Results highlight the key findings regarding the challenges of PtD implementation in construction industry; and (6) Discussion that proposes strategies to enhance PtD implementation by developing a process protocol.

LITERATURE REVIEW

The literature review aims to accomplish two key objectives, which to explore the current practice of PtD in the construction industry, examining how it is implemented in developed and developing countries, and provide a comprehensive overview of the established PtD legislation, detailing the associated legal requirements within the industry.

A. Prevention through Design (PtD) in the Construction Industry

Over the past decades, the construction industry has been exploring innovative methods to improve occupational safety and health (OSH) beyond conventional practices [4]. In response to this need, the National Institute for Occupational Safety and Health (NIOSH) launched the Prevention through Design (PtD) initiative in July 2007 in United States [32]. PtD is a comprehensive approach aimed at minimizing or eliminating the risk of accidents, injuries, and health issues by identifying and mitigating potential hazards at the early design phases of a construction project [10], [11], [33], [34]. Accordingly, PtD advocates for designers, such as architects and civil engineers, to address and mitigate risks and hazards from the outset, including architectural and structural design by considering various factors such as human behaviour, organizational aspects, and life cycle management, as well as the entire lifecycle of a building, from construction and operation to maintenance and demolition [10]. Therefore, by rigorously assessing risks and hazards during the planning and design phase, designers can provide more effective safety solutions and minimize project risks as much as possible [18], [26].

Concurrently, this initiative aligns with Szymberski's 1997 Time-Safety Influence Curve, which emphasizes that the best time to address construction safety is during the conceptual and early design stages [35]. Szymberski's model highlights that prioritizing safety during these initial phases is the most effective way to ensure safe working conditions for site workers. By considering safety early on, simple and cost-effective measures can be integrated, yielding substantial safety and health improvements and significantly reducing accidents compared to tackling safety issues later in the construction process [36]. For example, designers will incorporate safety considerations during design and reflect design decisions on how the project will impact the potential risks and hazards that await the construction workers [37]. Ultimately, the timing of safety interventions is closely linked to variations in incident rates [38]. Therefore, addressing risks and hazards as early as possible in the design phase is essential for enhancing occupational safety and health. Fig. 1 depicts the time-safety influence curve, demonstrating how the potential to improve safety diminishes rapidly as a project progresses from design to completion.

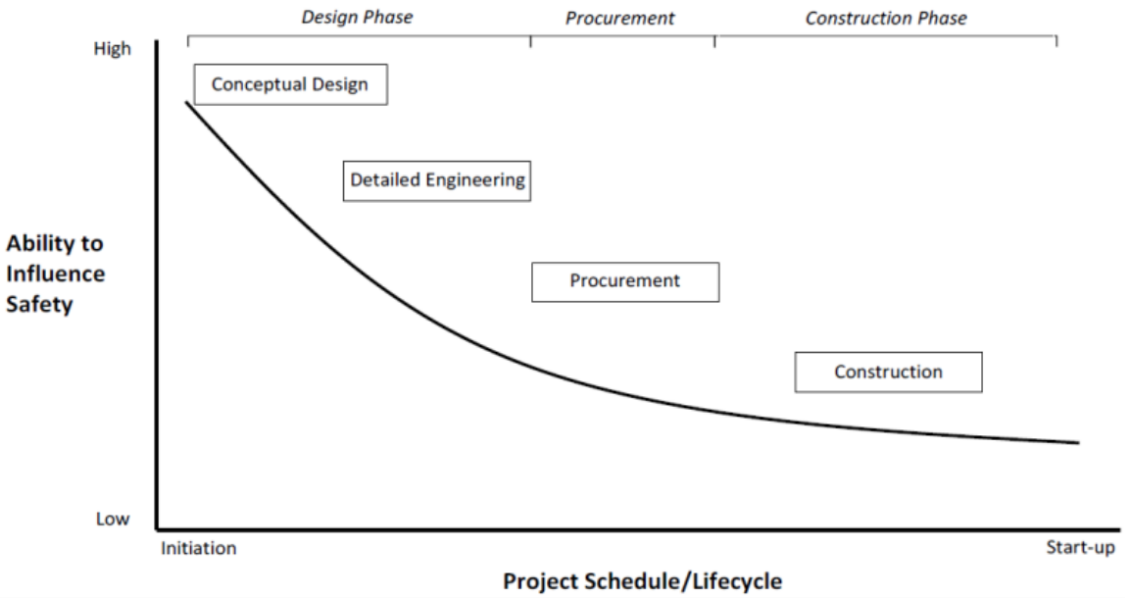

Fig. 1 Time-safety influence curve (Source: Karakhan et al., 2018) [38]

Globally, the PtD concept in the United States (US) is also known by different terms, such as Construction (Design and Management) (CDM) in the United Kingdom (UK), Design for Safety (DfS) in Singapore and South Korea, and Safe Design (SD) in Australia. In Malaysia, the PtD concept has been adopted by the Department of Occupational Safety and Health (DOSH) with the introduction of Guidelines on Occupational Safety and Health in the Construction Industry (Management) (OSHCIM) in 2017 [10], followed by the enforcement of CDM Regulations 2024. Nevertheless, these terms revolve around the core principle of PtD where designers have the responsibility to eliminate or minimize safety and health risks and hazards by incorporating safe design practices [11].

In conclusion, several countries, including UK, Singapore, Australia, South Korea, South Africa, and Malaysia have incorporated this concept into their OSH legislative frameworks, in contrast, other countries, such as the US, have introduced initiatives on a voluntary basis to promote the adoption of PtD. Table 1 demonstrates that the implementation of PtD is expanding in both developed and developing countries, driven by evolving legislative systems and industry practices. For example, in the US, the ANSI/ASSP Z590.3-2021 provides a framework to integrate safety into the design phase of projects [39]. Additionally, in the UK, the Construction (Design and Management) Regulations 2015 mandate that designers have a legal duty to plan, manage, and oversee, as well as coordinate OSH matters during the preconstruction phase of projects [40]. Meanwhile, in Singapore, Ministry of Manpower (MOM) enacted Workplace Safety and Health (Design for Safety) Regulations 2015 which outline the legal responsibilities of developers, designers, and contractors to identify and manage any potential design-related risks. There has been similar movement in Australia to place safety responsibilities on designer through the "Code of Practice: Safe design of structures", which is part of the Work Health and Safety Act and Work Health and Safety Regulation [41]. Furthermore, in South Korea, the Ministry of Land, Infrastructure, and Transport (MLIT) introduced PtD process in 2016 [42], and it is currently in operation through the Design Safety and Health Ledger System, while South Africa mandate the Construction Regulations 2014 which require designers to consider ergonomic design principles to reduce ergonomic-related hazards throughout all phases of a structure's life cycle [43]. Finally, in Malaysia, DOSH introduced OSHCIM in 2017 as a voluntary initiative [44]. However, due to a steady increase in fatal injuries over the past few years, the Occupational Safety and Health (Construction Work) (Design and Management) Regulations came into effect on the 1st June of 2024. Table 1 summarizes the previous PtD-related studies that describes the current practice of PtD and its associated terms within the developed countries, including US, UK, Singapore, Australia, and South Korea, as well as in developing countries like South Africa and Malaysia.

Table I Previous PtD-related studies

Author(s) and year	**Country**	**Legislation**	**Types of PtD-related legislation framework**	**Enforcement**	**Summary of research output**
(Al-Bayati et al., 2024) [45]	United States	Guideline	ANSI/ASSP Z590.3-2021 Prevention through Design Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes	Voluntarily	Incorporating PtD as small modules within existing design courses into engineering programs.
(Ndekugri et al., 2023) [40]	United Kingdom	Regulation	Construction (Design and Management) Regulations 2015	Mandatory	Barriers to PtD practices are client approach issues, supply chain fragmentation, and limitations in designer skills.
(Toh et al., 2016) [41]	Singapore	Regulation	Workplace Safety and Health (Design for Safety) Regulations 2015	Mandatory	PtD practices can be improved through enhancing training programs, establishing a DfS Community of Practice, and developing DfS courses in universities

(Creaser, 2008) [46]	Australia	Code of Practice	Code of Practice: Safe design of structures	Mandatory	National-level strategies are key to improve PtD practices.
(Shin et al., 2023) [47]	South Korea	Regulation	Design Safety and Health Ledger System	Mandatory	Safety knowledge, resistance to design changes, and lack of client support hinders the implementation of PtD.
(Goldswain & Smallwood, 2015) [43]	South Africa	Regulation	Construction Regulation 2014	Mandatory	The PtD approach depends on the knowledge of architectural designers in developing designs that prioritize construction OSH.
(Che Ibrahim, Belayutham, Manu, et al., 2022) [4]	Malaysia	Guideline	Guidelines on Occupational Safety and Health in Construction Industry (Management) 2017 (*now enacted as Occupational Safety and Health (Construction Work) (Design and Management) Regulations 2024*)	Voluntarily (*now enforced*)	PtD requires improvement through shared learning, continuous education, and organizational training.

B. PtD Legal Requirements

Table 1 provides a summary of the global PtD legislative frameworks currently in place. These documents primarily serve to guide PtD stakeholders, particularly contracting parties such as clients, designers, and contractors, in meeting their legal responsibilities while overseeing PtD-driven projects. Fig. 2 illustrates some of the provisions in the Construction (Design and Management) Regulations 2015 form UK and Occupational Safety and Health (Construction Work) (Design and Management) Regulations 2024 from Malaysia.

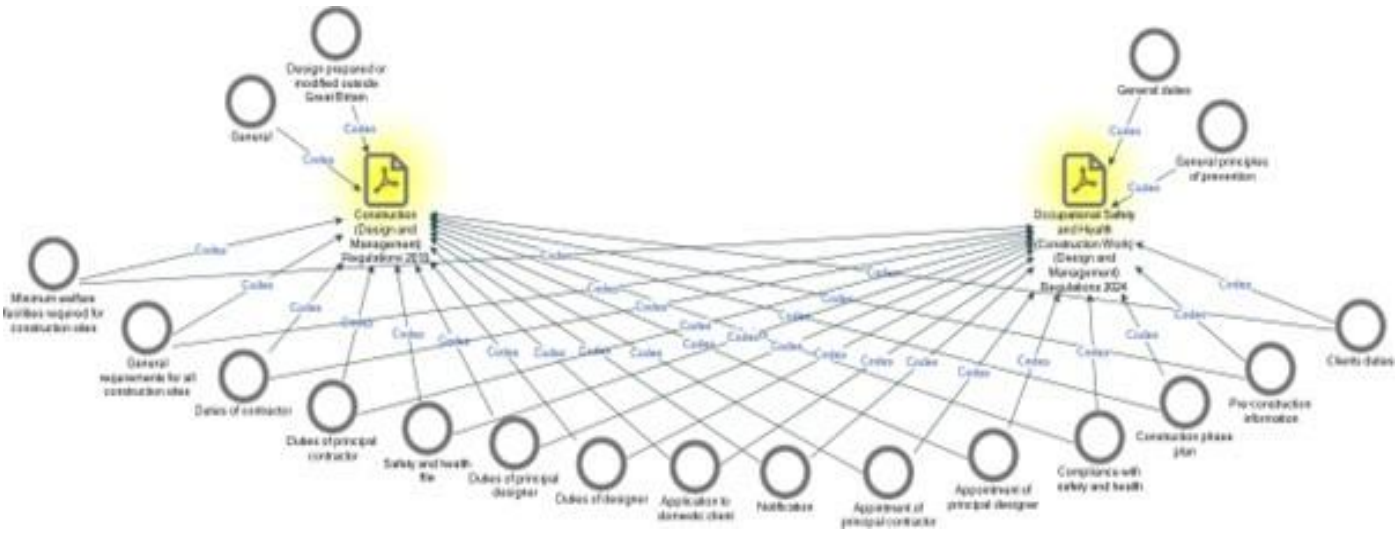

Fig. 2 PtD provisions in the CDM Regulations 2015 and the CDM Regulations 2024

Accordingly, Fig. 2 was utilized to analyze these two references using NVivo, by highlighting the similarities and differences in the legal requirements for PtD implementation. In this regard, the shared elements between these two regulations are outlined as follows:

i. Client duties
ii. Pre-construction information
iii. Construction phase plan

iv. Compliance with safety and health
v. Appointment of principal designer
vi. Appointment of principal contractor
vii. Notification
viii. Application of domestic client
ix. Duties of designer
x. Duties of principal designer
xi. Safety and health file
xii. Duties of principal contractor
xiii. Duties of contractor
xiv. General requirements for all construction sites
xv. Minimum welfare facilities required for construction sites

SYSTEMATIC LITERATURE REVIEW METHODOLOGY

This research utilized a Systematic Literature Review (SLR) combined with deductive content analysis to examine and organize articles from reputable journals focusing on the application of PtD in the construction industry. The methodology followed the PRISMA guidelines established by Moher et al. (2010) [48], aiming to develop a thorough understanding of emerging challenges in PtD implementation while developing a conceptual framework for improving PtD compliance through a process protocols. The structured process aligns with the approach outlined by Maali et al. (2024) [49], comprising four key stages: (1) Background, (2) Systematic Literature Review Methodology, (3) Results, and (4) Discussion.

Firstly, the background section provides an overview of the current PtD practices in the construction industry. Secondly, the literature review was conducted in three phases: (1) Identifying relevant PtD publications through electronic databases, (2) Screening the literature to remove duplicates and irrelevant studies, and selecting appropriate ones for further analysis, and (3) Extracting data using deductive content analysis to categorize the collected articles into relevant groups addressing PtD implementation issues in the construction industry. Finally, the study proposes a conceptual framework designed to improve PtD implementation in the construction industry. Fig. 3 illustrates the SLR process as aligned with the approach outlined by Maali et al. (2024) [49].

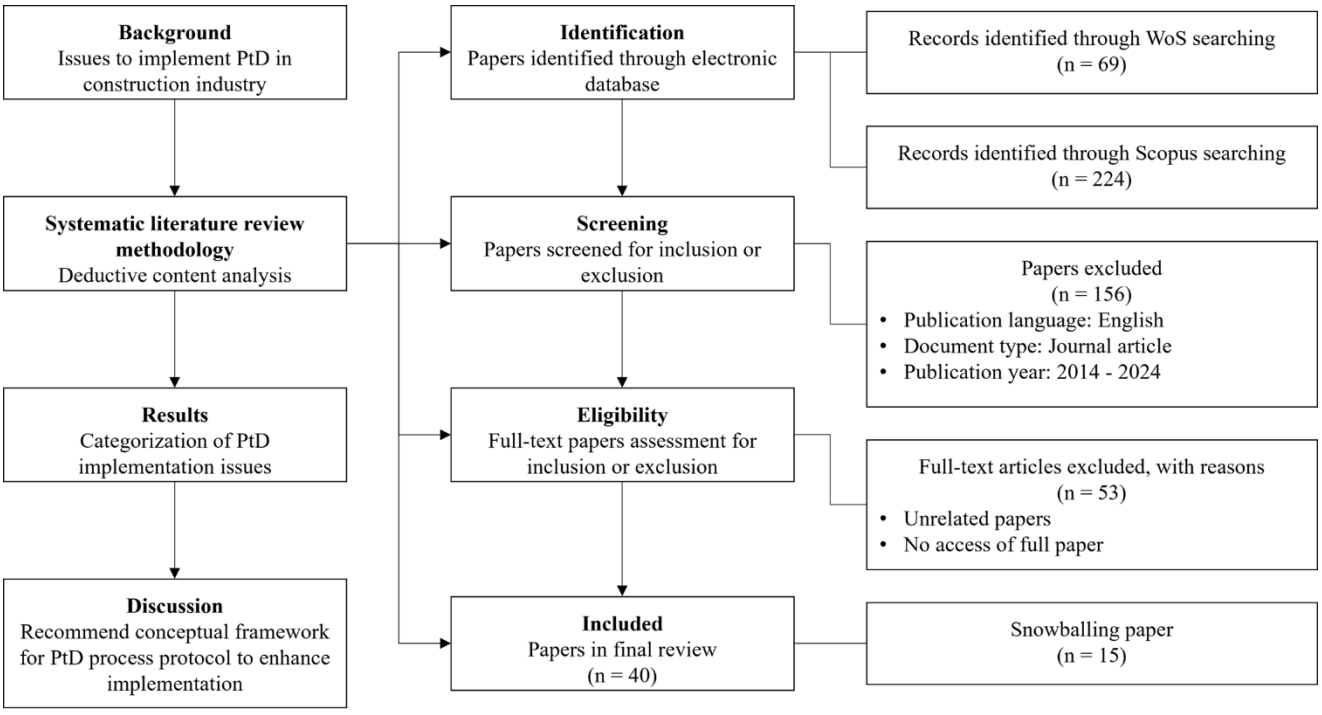

Fig. 3 Systematic literature review methodology (Source: Maali et al., 2024) [49]

A. Selection of Articles

Firstly, in the identification phase, PtD-related articles were searched based on their title, abstract, and keywords within two electronic databases: Web of Science (WoS) and Scopus. The inclusion criteria for these articles were: (1) the presence of relevant keywords, (2) publications in English with full-text access from 2014 to 2024, and (3) being journal articles. In addition, this comprehensive search aimed to cover topics related to PtD implementation issues in the construction industry. Precisely, the selected articles were required to include at least one relevant term in their title, abstract, or keyword categories: (1) PtD, (2) implementation, (3) issues, and (4) construction industry. As a result, a total of 293 articles were identified, with 69 articles from WoS and 224 articles from Scopus.

Secondly, during the screening of identified articles, duplicates were removed first. Since the literature search was conducted across two different databases, duplicate articles were expected due to the overlap. After removing duplicates, 234 articles remained. The next step involved reviewing the titles and abstracts of the selected articles to evaluate their relevance for inclusion in the review. The inclusion criteria required that the articles be complete journal articles, mention PtD, and address implementation issues in the construction industry. Only 78 articles met these criteria, as some were published before 2014, lacked abstracts, or were not in English. Subsequently, a full-text screening of the remaining articles was conducted. Two articles were excluded due to the lack of full-text access, leaving 76 articles for detailed review. The primary criterion for qualification was that the article must provide insights into PtD implementation issues in the construction industry. Articles that only discussed PtD in a general context without explicitly addressing implementation issues were excluded. Ultimately, 40 articles were shortlisted, including 15 identified through snowballing, as the basis for reviewing PtD implementation issues in the construction industry. Table 2 presents the criteria used to determine which PtD-related publications were included or excluded, resulting in the final selection of articles for review and deductive content analysis.

Table II Search criteria for selected articles

Criteria for inclusive articles	**Criteria for exclusive articles**
Articles including “Prevention through Design” OR “Design for Safety” OR “Safe by Design” OR “Safe Design” OR “Design for Construction Safety” OR “Construction Design and Management” OR “Construction Work Design and Management” OR “Occupational Safety and Health in Construction Industry (Management)” in their TITLE-ABS-KEY category	Articles that do not indicate to PtD or any associated terms
Articles including “Implementation” OR “Application” OR “Practice” OR “Employment” OR “Operation” OR “Usage” OR “Use” OR “Utilization” and “Issue” OR “Concern” OR “Problem” OR “Barrier” OR “Challenge*” in their TITLE-ABS-KEY category	Articles unrelated to the implementation issues of PtD
Articles including “Construction” OR “Construction industry” OR “Construction sector” OR “Construction safety” OR “Construction safety and health” OR “Built environment” OR “Architecture*” in their TITLE-ABS-KEY category	Articles that fail to address the challenges associated with implementing PtD in the construction industry
Articles written in English language with full-text access from 2014 to 2024	Articles lack of access and accurate comprehension (e.g., non-English, only including abstract, outdated)
Articles focused exclusively on journal articles to ensure a consistent and high-quality source of information	All other document types (e.g., review, conference paper, letter)

B. Content Analysis

Once the final set of 40 articles was selected, a formal deductive content analysis using Nvivo was carried out to investigate the current state of PtD in construction research. This analysis focused on implementation

patterns, categorization of issues, and identifying potential solutions for improving PtD practices. The deductive approach helped structure and assess the core elements of the articles by identifying significant concepts and organizing the data into relevant categories to gain a deeper understanding of the topic [50]. Key details extracted from the selected articles included: (1) the country where PtD was implemented, (2) the research problem addressed, (3) the study's objectives, (4) challenges in PtD implementation, (5) motivations for applying PtD in the construction field, and (6) possible solutions to enhance PtD. The major issues affecting PtD implementation were then classified, analyzed, and discussed in terms of their influence and recommendations for improvement. In this study, the issues were grouped into key areas affecting construction, including (1) legal and contractual challenges, (2) awareness, (3) procurement processes, and (4) cultural factors.

Accordingly, legal and contractual barriers to implement PtD include regulatory compliance, liability concerns, narrowly defined scopes of work, cost constraints, and performance metrics that prioritize cost and time over safety. Next, the awareness category highlights a lack of knowledge among designers to implement PtD in construction industry. Furthermore, in the procurement category, fragmented procurement methods commonly used in the construction industry may hinder collaboration among construction stakeholders. Finally, the industry culture category reflects a tendency to stick with traditional practices, focusing on cost and time savings rather than investing in PtD, which is often seen as an unnecessary expense with unclear immediate benefits. All in all, these interconnected issues impede the implementation of PtD in the construction industry. For example, increased liability, and additional costs and time associated with addressing risks during the design phase can lead to negative attitudes towards PtD among construction stakeholders. Therefore, addressing these issues may help improve PtD implementation. Fig. 4 shows the PtD implementation issues in construction industry identified from the SLR.

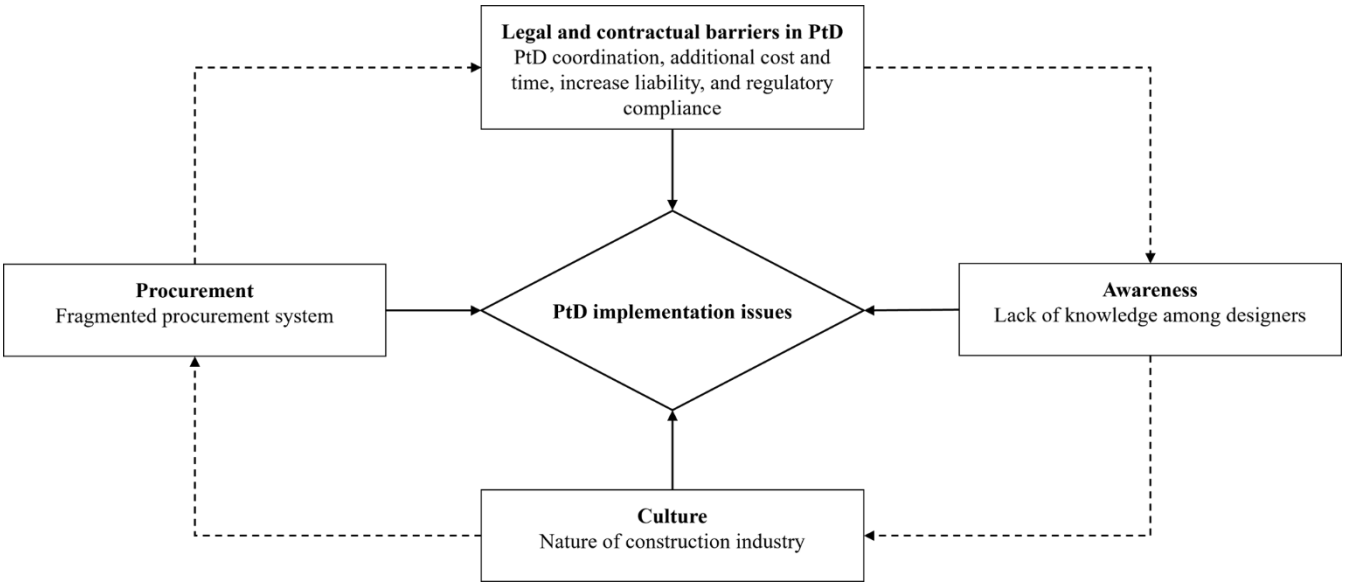

Fig. 4 PtD implementation issues

RESULTS

The deductive content analysis of 40 selected articles identified four main categories of PtD implementation issues: legal and contractual barriers, awareness, procurement, and culture. Among these, legal and contractual barriers emerged as the most significant challenge, with issues related to coordination (10 articles), cost and time constraints (12 articles), liability (11 articles), and policy (17 articles). Next, awareness was the second major barrier, primarily linked to a lack of knowledge among designers (33 articles). Furthermore, procurement challenges, particularly the fragmented procurement system, were the third major barrier (22 articles). Finally, cultural factors related to the nature of the industry (8 articles) were identified as the least significant barrier affecting PtD implementation. Table 3 presents a summary of the main categories and

subcategories of PtD implementation issues identified in the publications. The publications are elaborated in greater detail in Table 4.

Table III Summary of PtD implementation issues based on past research

Category	**Subcategory**	**Details**	**No. of selected articles**
Legal and contractual barriers in PtD	Coordination *(L1)*	· Lack of good practice/ lack of information of effectiveness of PtD · Unclear scope of PtD among stakeholders · Opaque PtD process · Contract documentation did not encourage PtD	10
	Cost and time *(L2)*	· Increase project cost · Insufficient time · Additional fees to the designers	12
	Liability *(L3)*	· Increased legal responsibilities · Insurance challenges	11
	Policy *(L4)*	· Lack of standardization · Outdated safety laws and regulations · Lack of enforcement of safety design principles · Absence of regulatory requirements	17
Awareness	Lack of knowledge *(A1)*	· Designer's competency (i.e., skills, experience, knowledge) · Insufficient training · Lack of education · Lack of resources (e.g., tools, technologies)	33
Procurement	Fragmented procurement system *(P1)*	· Lack of client's support · Lack of collaboration among project stakeholders	22
Culture	Nature of industry *(C1)*	· Design features and workplace condition · Designers are usually not responsible for OSH	8

Additionally, the subsequent sections provide detailed analysis of each barrier category, discussing relevant articles to illustrate how and why these barriers hinder effective PtD implementation in the construction industry. Articles presented in Table 4 were selected for in-depth discussion based on their thorough examination of the PtD implementation issues in construction industry and their provision of recommendations or solutions.

Table IV Summary of publications on PtD implementation issues

Publications	Legal and Contractual barriers				Awareness	Procurement	Culture
	L1	L2	L3	L4	A1	P1	C1
(Che Ibrahim & Belayutham, 2020)					/		
(Guo et al., 2021)	/	/				/	
(Yaşar & Tulubas Gokuc, 2020)	/	/	/		/		
(Babalola et al., 2023)		/					
(Samsudin et al., 2022)			/	/	/	/	
(Samsudin et al., 2023)				/	/	/	/
(Samsudin, Khalil, et al., 2021)				/	/		/
(Ismail et al., 2022)					/	/	
(Che Ibrahim, Belayutham, Awuzie, et al., 2022)				/	/	/	
(Machfudiyanto et al., 2023)	/	/		/	/	/	
(Labadan et al., 2022)		/	/				
(Lu et al., 2021)					/		
(Manu et al., 2019)				/	/	/	
(Abueisheh et al., 2020)				/	/	/	
(Abas et al., 2020)							/
(Che Ibrahim et al., 2019)					/		
(Acheampong et al., 2024)	/	/		/	/	/	
(Johansen et al., 2023)		/		/			
(Christermaller et al., 2022)				/	/	/	
(Edirisinghe et al., 2016)	/			/	/	/	
(Karakhan & Gambatese, 2017)		/	/	/	/	/	/
(Che Ibrahim, Belayutham, Manu, et al., 2021)	/			/	/	/	/
(Goh & Chua, 2016)			/		/		/
(Che Ibrahim, Belayutham, Manu, et al., 2022)			/		/		
(Toh et al., 2016)	/	/	/			/	
(Yahya & Rohani, 2021)					/		
(Martínez-Aires et al., 2024)					/	/	
(Tajul Ariffin et al., 2020)							/
(Tajul Ariffin et al., 2020)					/		
(J. Gambatese et al., 2017)		/	/	/	/	/	/
(Toole et al., 2016)	/	/		/	/	/	
(Ndekugri et al., 2023)			/		/	/	
(Che Ibrahim, Belayutham, & Mohammad, 2021)					/		
(Samsudin, Abidin, et al., 2021)				/	/		
(Asmone et al., 2022)				/	/	/	
(Dharmapalan et al., 2015)					/		
(Hoeft & Trask, 2022)					/		

Publications	Legal and Contractual barriers				Awareness	Procurement	Culture
	L1	L2	L3	L4	A1	P1	C1
(Belayutham et al., 2019)	/		/		/	/	
(Ndekugri et al., 2022)						/	
(Bong et al., 2015)	/	/	/	/		/	
Total	10	12	11	17	33	22	8

FINDINGS

The following section provides an in-depth analysis of the PtD implementation issues identified in the selected articles.

A. Legal and Contractual Barriers in PtD

The primary challenge to implementing PtD in the construction industry lies in legal and contractual barriers. As PtD maturity increases, more complex issues are expected to arise due to the intricate requirements that stakeholders must address in the initial project phase. These barriers, such as difficulties in coordination, added costs and time, liability concerns, and weak regulatory enforcement, will significantly hinder PtD adoption. In Malaysia, despite the introduction of the OSHCIM 2017 Guidelines and the establishment of the CDM Regulations 2024 to enforce PtD, adoption remains low due to a lack of awareness and best practices among stakeholders. Therefore, to overcome these challenges, it is crucial to establish clear guidelines, strengthen regulations, and align incentives to support effective PtD implementation. One potential strategy is to pilot PtD in government projects, demonstrating its benefits and encouraging broader adoption across the industry.

1. Coordination

Coordination is a significant contractual barrier to implement PtD in the construction industry, largely due to an unclear scope, opaque processes, a lack of best practices, and insufficient contract documentation. These interconnected issues compound the challenge of effectively coordinating PtD. Firstly, the unclear scope of PtD involves vague safety responsibilities [41], [51] and a narrow focus within construction design [51] among designers, leading to misunderstandings about the complexities of PtD, leading to misunderstandings about the complexities of PtD, such as addressing safe construction, use, and maintenance [52]. These complexities are further complicated by varying perspectives on what defines a safety risk that can be mitigated through design, and obstacles in obtaining approval for or acceptance of residual risks that are not cost-effective to address during the design stage [11]. Secondly, the opaque PtD process refers to the lack of a clear procedure to guide stakeholders in effective problem-solving, especially when design challenges are complex [5], [52], [53]. This results in ineffective PtD implementation, as stakeholders often do not understand how to properly execute it [11]. Thirdly, the lack of best practices stems from the absence of evidence on the effectiveness of PtD [51]. Although many construction projects already incorporate PtD, it often goes unrecognized [11], leading stakeholders to question its necessity [54]. Finally, inadequate contract documentation poses a barrier, as current contracting systems often fail to encourage PtD [55]. This includes the need for better coverage of designers' scopes of work, responsibilities, fees, and obligations to facilitate PtD implementation [56], as well as addressing the potential cost-plus scenarios that may arise from the unfamiliarity with the PtD process [53]. In summary, the unclear scope leads to an opaque process, which in turn prevents the establishment of best practices. The lack of best practices is then compounded by insufficient contract documentation, which does not adequately support PtD implementation. Therefore, to overcome these barriers, establishing a robust PtD framework with clearly defined tools, guidelines, and techniques could significantly enhance the adoption of PtD among construction stakeholders. Developing standardized PtD contracts or standards that address critical issues such as safety costs, designers' liability insurance, remuneration, and professional fees will help clarify roles and responsibilities, thereby strengthening PtD implementation across the industry [1]. Additionally,

establishing process protocols to structure the roles and responsibilities of project stakeholders in the PtD process will further enhance its effectiveness.

2. Cost and time

Additional costs and time are significant barriers to PtD implementation, driven by increased fees, project expenses, and time management challenges. Firstly, the integration of PtD in the construction industry imposes extra design fees and charges on designers, who are responsible for identifying and mitigating risks during the design phase [53], [57], [58]. The allocation of these fees plays a critical role in designer participation, as they are unlikely to voluntarily implement PtD [37] without reasonable compensation aligned with their qualifications, such as skills, knowledge, and experiences [56]. Additionally, the willingness to implement PtD depends on client acceptance of these costs as part of the overall life cycle expense [55]. Secondly, PtD implementation can significantly increase overall project costs [54], [55], [57], [59], [60], driven by higher fees for designers and substantial upfront investments in training, tools, and technologies needed to support effective PtD practices [11], [51]. Lastly, the requirement for additional time during the early project phases also hampers PtD adoption [11], as it demands extra time for risk and hazard mitigation in the design stage [51]. This can cause delays in the project schedule [54], [60], especially when designers are already burdened with other critical design considerations, such as regulatory requirements and building codes [59]. In summary, the added costs and time required for PtD implementation hinder its adoption in the construction industry. Higher fees, increased project costs, and extended design timelines discourage stakeholders, thus, highlighting the need for strategies that align incentives and streamline processes to support PtD integration.

3. Liability

Liability is a significant legal barrier to the implementation of PtD in the construction industry because it imposes additional legal responsibilities on designers. These responsibilities extend beyond their traditional roles, requiring them to address and mitigate potential safety hazards during the design phase, which can increase their vulnerability to legal consequences. In this context, designers often hesitate to engage in PtD due to fears of being held accountable for safety-related issues [3], [33], [37], [41], [54], [57]. They are concerned that their involvement in safety efforts could expose them to legal consequences, especially if accidents or injuries occur on-site [7], [59]. This concern is exacerbated by difficulties in securing adequate professional indemnity insurance, which leaves designers feeling unprotected from potential lawsuits [40]. Furthermore, the fear of liability can discourage designers from pursuing innovative design solutions, as they may worry about the legal risks associated with such actions [4]. As a result, this liability concern can undermine the effectiveness of PtD by limiting designers' willingness to fully participate in the process. In summary, while designers recognize the importance of addressing safety risks, their fear of increased liability exposure acts as a significant obstacle to PtD implementation. Therefore, to overcome this, legal frameworks need to be established that protect designers from excessive liability while encouraging their active involvement in safety-focused design [55].

4. Policy

The construction industry encounters significant legal and contractual barriers to the implementation of PtD, mainly due to inadequate policy enforcement, insufficient regulatory requirements, and outdated safety legislation [3], [14], [26], [61]. Consequently, the established correlation between design choices and construction or occupational accidents has prompted various countries to enact laws that encourage designer participation in PtD [1]. In this case, in Malaysia, current legislation, including OSHA 1994, inadequately addresses the governance of OSH in construction, particularly failing to clarify the specific duties of stakeholders beyond contractors. This regulatory gap negatively impacts safety performance in construction projects and inhibits the adoption of PtD. To address these issues, the CDM Regulations 2024 have been introduced, aiming to enhance OSHA 1994 by distributing safety responsibilities more equitably among all key participants in the construction process [3]. However, the lack of standardization within regulatory frameworks, absence of specific regulations mandating safety considerations in design, and the lack of

structure and clear instructions for compliance continue to pose challenges [52], [53], [57], [62], [63]. Without defined regulatory requirements, recognized responsibilities, or immediate financial incentives, many designers may hesitate to embrace the responsibility of ensuring construction safety in their designs [5], [51], [60], [64]. Therefore, it is essential for professional bodies, government entities, and regulatory agencies to enforce legislative frameworks that promote and standardize the PtD concept within the industry [22], [55], [56].

B. Awareness

The lack of knowledge and awareness among designers is a major barrier to PtD implementation in the construction industry. In Malaysia, despite the introduction of OSHCIM in 2017 and the enforcement of CDM Regulations in 2024, designers' understanding of PtD remains inadequate. This gap, due to insufficient education, training, and exposure to technologies like BIM, limits hazard recognition and occupational safety considerations during design. Therefore, to improve PtD adoption, raising awareness, integrating PtD into education, and enhancing professional development are essential.

1. Lack of knowledge

The effective application of PtD in the construction industry encounters major obstacles stemming from insufficient knowledge among designers, including architects and civil engineers. This issue arises from limited education, training opportunities, and access to essential tools and technologies necessary for incorporating safety into the design workflow [14], [52], [54], [59], [62], [65]. Many designers lack the necessary hazard recognition skills and an understanding of OSH, which hampers their ability to contribute effectively to worker safety [1], [4], [5], [10], [12], [22], [40], [57], [63], [66]. The absence of PtD education in architecture and engineering courses further exacerbates this issue, leaving designers unaware of their critical roles and responsibilities in addressing safety during the design phase [20], [23], [26], [33], [64]. Moreover, the limited adoption of innovative technologies like Building Information Modelling (BIM) is hindered by a shortage of skilled professionals, restricting PtD implementation [3]. Despite the potential of BIM to alter the construction landscape by improving productivity and safety at early stages, its full potential remains untapped due to insufficient expertise [17], [60]. The diffusion of PtD remains slow even in regions with established guidelines and regulations (e.g., UK, Singapore, Australia), as designers' insufficient knowledge, experience, and motivation continue to be major barriers [19], [51]. Therefore, integrating PtD principles into higher education is essential for establishing a solid base of safety knowledge among upcoming designers. This can be achieved by updating curricula to improve students' grasp of OSH skills, fostering a safety-oriented culture from the outset, and ensuring that all designers have the necessary knowledge and tools to prioritize safety in all their work [41], [56]. Additionally, this education should be complemented by ongoing professional development for experienced designers, ensuring they fully understand their expanded roles in PtD [10], [17], [61], [67]. Furthermore, it is essential to create PtD checklists tailored to specific disciplines. These checklists can either be developed internally or obtained from external sources to assist design professionals in incorporating safety measures effectively [53]. The inclusion of these tools in the design process, alongside advanced technologies, is essential assist designers to safe design and improving overall safety outcomes [7], [68]. Ultimately, a comprehensive approach that integrates education, training, and technology adoption is vital for advancing PtD practices in the construction industry.

A. Procurement

It is widely recognized that the existing contractual and procurement frameworks in the construction industry are inadequate for supporting the collaborative and collective efforts required for effective PtD implementation. This shortcoming significantly hinders the adoption of PtD practices. In Malaysia, for example, the absence of collaborative procurement approaches exacerbates these challenges. Designers often find themselves working in isolation, deprived of the benefits that a unified team approach could provide, making it difficult to fully integrate safety considerations into their designs, with the opinion of contractor or

OSH practitioners. Therefore, promoting the use of collaborative procurement could support the successful implementation of PtD in construction industry.

1. Fragmented procurement system

The fragmented procurement system within the construction industry poses a significant challenge to effectively implementing PtD, largely due to a lack of support from clients and limited cooperation among involved parties [11], [14], [17], [41]. Clients, who hold significant influence as project funders, play a critical role in promoting PtD by encouraging designers to prioritize OSH during the design stage [56], ensuring that safety measures are considered in project processes [57], and ensuring that collaboration is established early in the design process [1], [40], [53], [61], [62], [64]. Unfortunately, conventional procurement system, like the design-bid-build approach, often segregate design and construction phases, leading to minimal interaction between designers, contractors, and other key players, including OSH practitioners, limiting the ability of stakeholders to work together on safety from the start [1], [3], [55], [56]. Limited collaboration not only hampers effective safety planning during the pre-construction, but also creates adversarial relationships that further impede PtD adoption [51], [69]. Furthermore, the current procurement and contracting frameworks do not adequately support the collective efforts required for PtD, limiting the ability to establish shared safety responsibilities across all levels of the project [5], [7], [52]. Moreover, the lack of contractor involvement during the design phase undermines the potential for innovative safety solutions, which could otherwise be developed through early and sustained collaboration [59], [67]. Therefore, to address these barriers, the construction industry must pivot towards more collaborative procurement methods, such as Integrated Project Delivery (IPD), partnering, and early contractor involvement. These approaches enable a more cohesive working environment where safety can be a central focus from the outset [63]. Additionally, leveraging advanced technologies like BIM in conjunction with IPD can enhance project efficiency, reduce errors, and expand market opportunities by fostering a culture of safety and collaboration [1]. Implementing these changes is crucial for transforming the fragmented procurement landscape into one that fully supports the principles of PtD, ensuring that safety is embedded in every aspect of the construction process.

B. Culture

The successful integration of PtD in the construction industry is significantly impeded by cultural attitudes, where designers often prioritize factors such as quality, time, and cost over safety, viewing it as complex and burdensome. To address these challenges, it is essential to cultivate a robust safety culture among designers and bridge the gap between design and construction practices. By fostering awareness and shifting cultural attitudes towards safety, the construction industry can enhance the adoption of PtD and ultimately improve safety outcomes across projects.

1. Nature of industry

The final barrier to PtD implementation in the construction industry stems from the nature of design features, workplace conditions on-site [1], and misconceptions among designers who often see safety as overly complex and secondary to priorities like quality, time, and cost [5], [26], [33]. In many developing countries, safety considerations in construction projects are often viewed as a burden rather than a priority. This mindset, coupled with poor safety culture, has been linked to higher rates of unsafe acts [1]. Additionally, designers often lack adequate understanding of how to identify, assess, and control OHS risks in their designs, largely due to a historical disengagement from workplace safety [2]. This traditional separation of design and site safety, where architects and engineers are distanced from safety responsibilities that are typically assigned to contractors, further perpetuates these challenges [44], [59]. The fear of liability and misconceptions about the complexity of safety issues contribute to the reluctance of designers to fully engage in safety practices, hindering the effective diffusion of PtD in the industry [57]. Therefore, to overcome this, it goes back to the needs of integrating PtD principles into education and promoting a safety culture to create awareness, and addressing misconceptions about safety complexity among stakeholders, especially designers, to facilitate more effective PtD adoption.

DISCUSSION

The successful implementation of PtD in the construction industry faces several significant barriers, including (1) coordination issues, (2) additional cost and time, (3) liability concerns, (4) regulatory gaps, (5) knowledge deficits, (6) procurement challenges, and (7) deeply ingrained cultural misconceptions. Coordination is hampered by unclear scopes, opaque processes, a lack of best practices, and insufficient contract documentation, all of which make it difficult to effectively implement PtD [11], [41], [51], [52], [53]. The financial and time demands of PtD add to the challenge, as stakeholders are often reluctant to bear the increased costs and extended timelines [37], [54], [55], [57], [59], [60]. Additionally, liability concerns further deter designers from engaging fully in safety practices due to the fear of legal consequences [3], [7], [33], [37], [41], [54]. Inadequate regulatory frameworks fail to enforce PtD, and the lack of education and training among designers limits their ability to incorporate safety into their work [1], [14], [40], [52], [54], [59], [62], [63]. The fragmented procurement system discourages collaboration, while cultural attitudes in the industry, especially in developing countries, downplay the importance of safety, viewing it as complex and secondary to other priorities like cost and quality [1], [5], [26], [33], [57].

Therefore, to address these challenges, the construction industry must establish a robust PtD framework with clearly defined tools, guidelines, and techniques. Standardized contracts that address critical issues such as safety costs, designers' liability, insurance, remuneration, and professional fees are essential to clarify roles and responsibilities [1], [22], [55], [56]. Furthermore, integrating PtD principles into education and promoting a safety culture will create awareness and shift mindsets, helping to overcome misconceptions about the complexity of safety [41], [56]. Collaborative procurement methods, such as Integrated Project Delivery (IPD), along with the adoption of advanced technologies like BIM, can foster a more cohesive and safety-focused environment [1], [64]. By addressing these barriers, the construction industry can more effectively implement PtD, ultimately enhancing safety outcomes across projects.

PROPOSED SOLUTION

The discussions above have explored various theoretical aspects related to PtD and its contractual implications. The current challenges with PtD stem from a fragmented procurement system, legal and contractual barriers, poor understanding among project players, and the absence of standardized contractual frameworks to guide PtD contracts. Notably, until the recent introduction of the CDM Regulations 2024, no standard forms in Malaysian construction contracts incorporated PtD provisions. Therefore, to enhance PtD implementation in the construction industry, one of the key solutions lies in developing a robust PtD framework that addresses project roles and contractual responsibilities. In accordance to this, establishing a structured process protocol within the PtD framework is essential. This protocol should clarify and organize PtD processes, outline stakeholder roles and responsibilities, foster collaboration across all project phases, and specify the necessary documentation for PtD contracts. Thus, this step-by-step guidance will assist stakeholders in effectively implementing PtD, ultimately improving its adoption across the industry.

A. Process Protocol for PtD Implementation in Malaysian Construction Industry

Building on the need to establish a PtD process protocol for effective implementation, this section will delve into the existing process protocols within the construction industry. The evolution of these protocols began with the introduction of the RIBA Plan of Work in 1993, followed by the Generic Design and Construction Process Protocol (GDCPP) [70]. This progression continued with the development of the IPD-BIM process protocol [71]. These innovations were primarily driven by the need to address communication, coordination, and integration issues within the construction industry [72]. Over the past three decades, various studies have incorporated the principles of process protocol into different areas of construction management, including those by Al Ahbabi (2014) [71], Goulding & Alshawi (2002) [73], Andrew et al. (2007) [74], Hamid (2009) [75], Mzyece et al. (2019) [76], Kassem et al. (2014) [77], and Syed Alwi (2021) [72]. The core principles of process protocol are as follows [70], [71]:

- The process protocol encompasses the entire lifecycle of a project, from initial strategic planning through to operation and maintenance.
- It utilizes a "stage-gate" model, in which each stage undergoes a review and validation process before moving on to the subsequent stage.
- The protocol acknowledges the interdependence of activities throughout the project, ensuring that each task is aligned and contributes to the overall project duration.
- It involves all stakeholders at every phase, ensuring they receive timely and relevant information. This approach facilitates effective decision-making by prioritizing stakeholders and their needs throughout the project lifecycle.
- The protocol promotes the formation of multi-functional teams early in the construction process, emphasizing the critical importance of effective coordination among project team members.
- It incorporates a feedback mechanism at each phase, allowing for the documentation and analysis of successes and failures. This continuous feedback loop helps inform later phases and future projects, improving overall outcomes.

Accordingly, previous studies have built on the process protocol concepts introduced by Kagioglou (1998) [70], merging them with the adoption of BIM. This includes integrating the UK's CDM Regulations with BIM practices [76], fostering collaboration through IPD processes in BIM projects [76], and enhancing contract management throughout the supply chain in BIM-based construction [72]. These advancements show that process protocols can be highly effective in managing construction projects. A focus on transparency, especially in clarifying stakeholder roles and improving contract management, can greatly support BIM adoption in construction. Additionally, reviewing and validating activities at each phase ensures proper oversight and better adherence to PtD procedures. Following to that, a similar strategy could be adopted to boost PtD implementation in Malaysian construction industry. This study seeks to apply process protocol principles to reinforce PtD practices in Malaysian construction, ensuring compliance with the CDM Regulations 2024. Therefore, building on insights from the previous study, this research proposes a process protocol focused on design review assessment for CDM, outlined as follows:

- Phase 0: Strategic Settings
- Phase 1: Project Requirements
- Phase 2: Integrated Procurement
- Phase 3: Integrated Design
- Phase 4: CDM-based tender
- Phase 5: Construction
- Phase 6: Operation and maintenance

In addition, throughout the seven proposed phases, there will also be sub-phases that describes the roles and responsibilities of duty holders to fulfil all legal requirements under the CDM Regulations 2024. Hence, the proposed process protocol may improve collaboration among project stakeholders through IPD from inception until completion of the PtD-based construction projects

CONCLUSIONS

The complexity of PtD implementation in construction industry has led to concerns about legal and contractual barriers. Despite the introduction of OSHCIM 2017 and the enforcement of the CDM Regulations 2024 to regulate PtD in the Malaysian construction industry, its adoption remains limited. This is largely due to the lack of clarity surrounding the roles and responsibilities of PtD stakeholders throughout the project lifecycle, hindering effective collaboration. Traditional contracts typically involve only the client and contractor, however, successful PtD implementation requires greater coordination among all stakeholders from the early design phases to mitigate risks and hazards that could impact OSH throughout the project. Furthermore, even though guidelines and regulations exist, the unclear scope of work and PtD processes continue to be significant obstacles. Additionally, even when designers recognize the benefits of PtD for OSH, the absence of contractual

provisions that safeguard their professional liability, fees, and insurance further impedes PtD implementation. In this case, Malaysia's existing procurement and contracting framework does not provide the required integration to facilitate PtD processes from the planning stage to the project's completion. PtD requires a departure from traditional procurement arrangements, including the introduction of new contract forms, terms, and conditions that differ from conventional contracting practices. Therefore, there is an urgent need for a new contractual instrument that refines and supports current PtD practices. The flow of design reviews in existing practices must also be revised to align with PtD requirements. In accordance to that, developing new PtD protocols that complement existing guidelines and regulations could enhance PtD implementation by clearly defining the roles and responsibilities of all project stakeholders. This study suggests that incorporating PtD practices into process protocol principles could lead to a standardized framework for managing PtD contractual obligations. Ultimately, this research aims to facilitate the evolution of construction contracts, paving the way for a more integrated and effective PtD approach in the future of the Malaysian construction industry. Fig. 5 summarized the conceptual framework for this study.

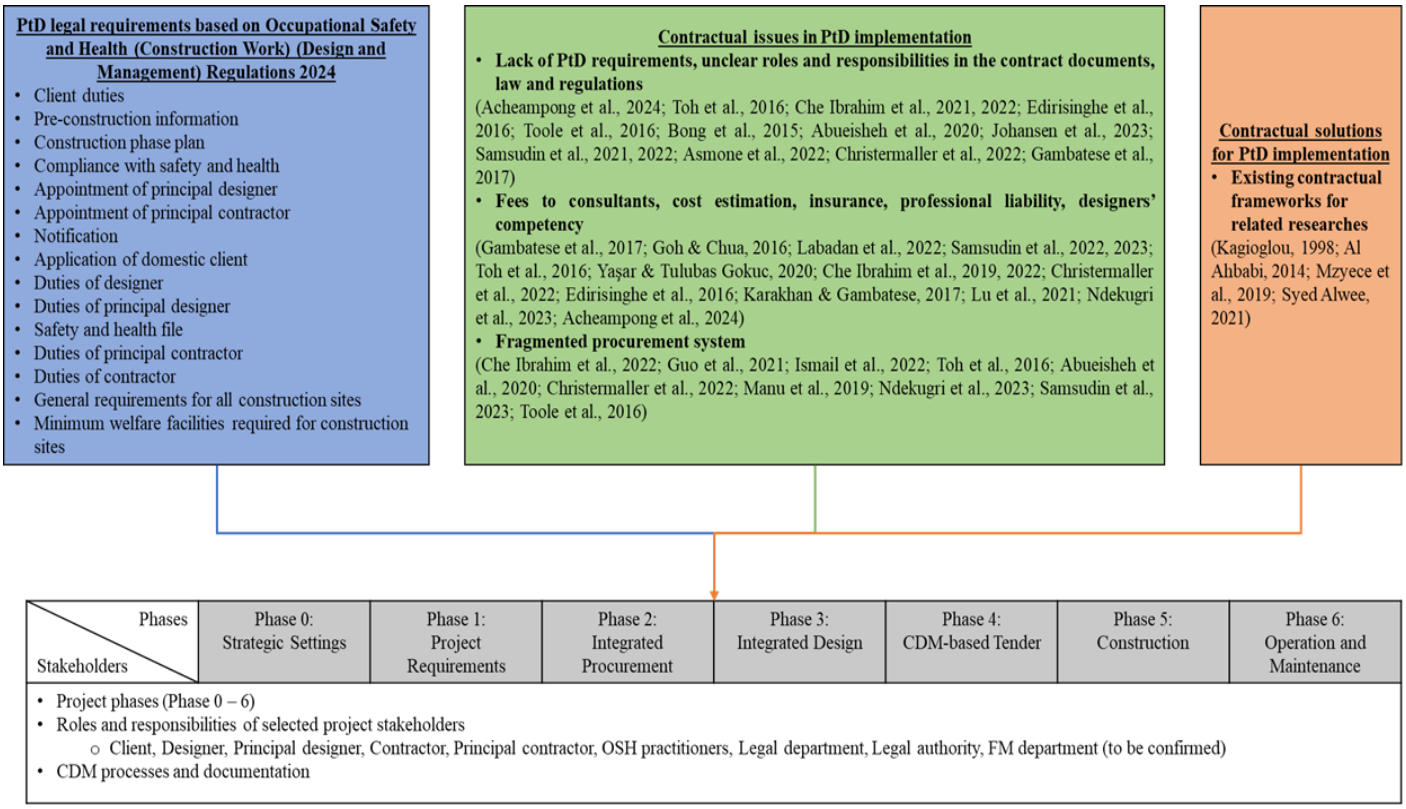

Fig. 5 Conceptual framework

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