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Implementation of Design for Safety (DfS) in Construction in Developing Countries: A Study of Designers in Malaysia

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Abstract

Design for Safety (DfS) is a concept that emphasises on eliminating health and safety hazards to construction workers in the design phase. However, despite the importance of DfS implementation, there are limited studies on the DfS in developing countries, including Malaysia. This research, therefore, investigates DfS implementation among design professionals in the Malaysian construction industry through a questionnaire survey. The response was analysed by conducting descriptive analyses and inferential statistical tests. The findings revealed a high implementation of DfS practices among designers parallel with having high awareness of DfS concept and a positive attitude towards DfS implementation. However, the engagement in DfS professional training is low, despite the fact that the designers showed a high interest in DfS professional training. While the findings revealed limited association between the implementation of DfS practices and designers' professional body membership, designers' professional role, and the size of designers' organisation, the findings also showed that DfS awareness and DfS training were associated with greater implementation of DfS practices. Furthermore, the design professionals perceive DfS education, client's influence and DfS legislation as being the most important factors that affect DfS implementation in Malaysia. This study adds to the current DfS body of knowledge by providing deeper insights into the current state of designer awareness, education training, influencing factors, and DfS engagement, especially when the DfS legislative framework is in place. Such findings could serve as a guidance for other countries in the event of future developments related to DfS implementation.

Keywords: design; design for safety; construction; construction safety; Malaysia.

Introduction

It is well acknowledged that although the construction sector plays an essential role in the socio-economic development of a country, it is also one of the significant contributors to occupational accidents. The construction industry in Great Britain accounted for 79,000 work-related sicknesses, 30 fatal injuries and 54,000 non-fatal injuries in 2018/2019 (Health and Safety Executive, 2019). These occupational injuries and illnesses in Great Britain resulted in economic cost in excess of £1billion in 2017/18 (Health and Safety Executive, 2018). In 2019, the Malaysia construction sector accounted for 84 fatalities, 15 permanent disabilities and 227 non-permanent disabilities (Department of Occupational Safety and Health (DOSH), 2020a). Considering that the data is only based on investigated cases, the actual number may be higher than reported.

An investigation of 100 construction accidents in Great Britain carried out by Haslam et al. (2005) indicates that permanent work design contributed to the occurrence of almost 30% of the accidents. This highlights the significance of the concept of 'Design for Safety' (DfS) in construction. The concept of DfS has been widely accepted and implemented in several developed countries such as in the UK and Australia. The regulations regarding DfS in the UK is Construction (Design and Management) Regulations (CDM) which has been in effect since 1995 and recently revised in 2015 as (i.e., Construction (Design and Management) Regulations 2015) (Health and Safety Executive, 2015). In Australia, the National Occupational Health and Safety Commission (NOHSC) initiated a Safe Design Project in 1998/1999 to provide guidelines for the designers, manufactures, importers and suppliers to reduce risks and hazards. However, there is limited research and insights regarding DfS in developing countries (Manu et al., 2018a; 2019a), and this includes Malaysia.

In the context of Malaysia, the extent of awareness of DfS, DfS education and training as well as the implementation of DfS practices among designers are unknown. Considering the impact of design as a contributing factor in accident occurrence, an investigation into DfS in Malaysia would assist in generating insights that could help in improving the poor health and safety performance in construction, as part of the Construction Industry Development Board (CIDB)'s Strategic Plan (CSP) 2021 - 2025. Also, due to the recent introduction of DfS-based guideline, i.e., Occupational Safety and Health in Construction Industry (Management) (OSHCI(M)), along with the growing DfS engagement initiative/activities in Malaysia (Che Ibrahim and Belayutham, 2020), the need to understand the current DfS landscape in the industry, particularly in regard to the designers is timely and significant. Despite the growing interest in DfS practice in Malaysia, past studies have only focused on certain areas (e.g., current practices (Wan Azmi et al., 2017), knowledge, attitude and practice (Che Ibrahim and Belayutham, 2020; Che Ibrahim et al., 2022b), education (Che Ibrahim et al., 2021), none of these studies have captured the level of DfS engagement among wider construction designers. In fact, the recent local studies main focused on capturing the opinion on the awareness and understanding among the practitioners and academics in relation to the DfS concept rather than capturing their understanding on the DfS engagement. As OSHCI(M) is currently running on a voluntary basis (Che Ibrahim and Belayutham, 2020), such insight is critical to the development of OSHCI(M) towards having mandated legislation, through the advancements of existing DfS practical modules and the development of DfS curricula in tertiary education. Consequently, it is imperative to address the abovementioned gaps based on empirical evidence by addressing the question of *What is the current state of DfS awareness, education training among the designers in Malaysia*?, *What are the factors influencing DfS implementation in Malaysia*?, and *What are the current state of DfS engagement among the designers?.* Consequently, building upon previous DfS studies in developing countries by Manu et al. (2018a; 2019a), this study aims to investigate the DfS implementation among design professionals in the Malaysian construction industry. It is worth highlighting that even though there are studies related to the DfS engagement in other developing countries such as Nigeria (Manu et al., 2019a; Umeokafor et al., 2021), Ghana (Manu et al., 2018a) and Palestine (Abueisheh et al., 2020), the aforementioned countries have yet to establish any DfS-related policies or legislative framework as well as DfS-related initiatives. The lack of institutional pressures could hinder the progress of DfS development at the national level (Che Ibrahim and Belayutham, 2020; Ndekugri et al., 2021). Previous studies have shown that government policy, initiatives and legislation can be a major driver of health and safety improvements in the construction industry (Health and Safety Executive Construction Division, 2009; Manu et al., 2018). In contrast with the afore-mentioned countries, since Malaysia has introduced OSHCI(M) and DfS initiatives (i.e., DfS seminar, DfS hands on workshops, pilot DfS projects), thus providing insights from the Malaysian context would further contribute to the DfS body of knowledge related to the construction industry of developing countries.

The succeeding sections of the paper commence with an overview of the health and safety performance in the Malaysian construction sector. This is followed by a review of design for safety literature and the articulation of the knowledge gap pertaining to developing countries, particularly Malaysia. The research approach used in addressing the knowledge gap is then presented. Subsequently, the research findings, the discussion of the findings and conclusions are presented.

Literature Review

Design for safety in construction

Previous studies have indicated that the design professionals are responsible for the decisions made at the beginning, from the design stage until post-project implementation. Safety is associated with quality and hence, this requires quality management to consider health and safety in the design stage (Gambatese et al., 2005). It is generally understood that there is a higher opportunity to mitigate and eliminate risks during the design phase, rather than dealing with the risk during the construction phase. This will benefit not only the health and wellbeing of the construction workers, but also the end-users of the structure (International SOS Foundation, 2017). In an analysis of 450 reports of occupational injuries and deaths, it was found that one-third of the cases could have been mitigated and eliminated with DfS implementation (Behm, 2006). 42% of the fatal accidents could have been reduced by modifying the permanent works design (Behm, 2005). In a study of identifying contributing factors to 100 constructional accidents, it was shown that the changes made in the permanent work design could have reduced the frequency of construction accidents (Haslam et al., 2005). A study in Australia indicates that 44% of life-threatening accidents were caused by the design of the structure, plant and temporary works (Driscoll et al., 2008). All these studies signify the importance of the design stage to the health, safety and wellbeing of the construction workers.

Design for Safety (DfS) is a concept that integrates the health, safety and wellbeing of the workers in the design of a construction project (Toole and Gambatese, 2008; Gambatese, 2019). The concept emphasises on the elimination and reduction of construction site hazards in the design stage (Behm, 2005). The concept is also known as 'prevention through design', 'safety in design', 'safety by design', 'health and safety by design', 'safe design', 'design risk management', 'construction design management' and 'construction hazards prevention through design' (Poghosyan et al., 2018). The idea of DfS in construction industry emerged from the fact that the design of a project is a major contributing factor in the occurrence of injuries and fatalities. Regarding the concept of DfS, it is anticipated that the decisions made during the design stage would be able to significantly eliminate or at least mitigate health and safety risks during the construction stage (Gambatese, 2019). This is done by identifying any possible hazards on a site, high-risk procedures or in maintenance tasks throughout the project (Gambatese, 2019). The idea of DfS also aligns with the 'hierarchy of control', which indicates that the most effective ways in controlling or managing hazards are elimination and substitution (The National Institute for Occupational Safety and Health, 2015). By prioritising the safety of the construction workers, the implementation of DfS is believed to be able to increase the productivity of the workers, reducing the frequency of injuries and fatalities which in return increase the quality of the work (Gambatese, 2019). As the collaboration between the designers and the contractors continues to grow with the implementation of this concept, the safety of the operations and maintenance tasks will improve and hence prevent any delays in project delivery (Toole et al., 2013; Gambatese, 2019).

Knowledge gap regarding (DfS) in the Construction Literature

The subject of DfS in construction domain has gained growing interest among the scholars in both developed and developing countries. Recent reviewed DfS studies (See Che Ibrahim et al., 2022a) have indicated that a significant increase of DfS research can be found from 2015. However, the intention here is not to review the broader literature on DfS in construction but rather to focus on recent research (from 2015 onwards) that focuses on capturing the context of DfS knowledge and practice in various geographical contexts (See Table 1). For example, in developed countries, studies mainly sourced from the UK, Australia, New Zealand, South Korea and cover wide-ranging DfS perspectives. In particular, Bong et al. (2015) found that ability to have specific DfS guidelines could facilitate the of designers on safety-related design requirement. Also, they emphasised that procurement arrangements and code of practice should be integrated with the regulation to ensure effective of DfS implementation. This is supported by findings from Guo et al. (2021) where more DfS details should be incorporated in the legislations to act as force mechanism in enhancing the DfS knowledge. Furthermore, because DfS practise necessitates the collaboration of many teams and stakeholders, previous researchers have highlighted the complexities of different professionals' perspectives on DfS implementation. According to studies conducted in the United States (e.g., Gambatese et al., 2017; Tymvios and Gambatese, 2016), DfS practise is viewed as adding value to existing design practise, despite the fact that aspects of legal (e.g., regulations, contractual), economic (e.g., professional fees, cost), and training (e.g., practical, digital technologies) need to be significantly improved. Similarly, previous researchers in the United Kingdom (e.g., Sacks et al., 2015; Morrow et al., 2016) and South Korea (Soh et al., 2020) have emphasised that such aspects should be prioritised to frame and facilitate designers' DfS understanding and appreciation for safety and health.

The DfS subject has also seen some significant interest among scholars in developing countries. The fact that the fatalities in the construction industry in this region are among the highest (Manu et al., 2018b; Che Ibrahim and Belayutham, 2020), governments are initiating an innovative approach to improve the OSH in the construction sector. For instance, studies by Goh et al. (2016) and Toh et al. (2017) in Singapore found that although the implementation of DfS regulation in the country has gained positive supports from wider stakeholders, the need for improvement on the knowledge-based initiatives is significant to further enhance the industry DfS knowledge and practices. Additionally, significant increase of DfS research in Malaysia has been noted for the past years mainly due to the introduction of OSHCI(M). Studies mainly focus on capturing the awareness and readiness of stakeholders towards DfS; for instance, the readiness of designers towards safety and health (Wan Azmi et al., 2017), DfS knowledge, attitude and practice (Che Ibrahim and Belayutham, 2020) and DfS designer competence (Ismail et al., 2021). Other researchers, in particular in sub-Saharan African (i.e., Ghana and Nigeria), Palestine and Kuwait have also shown interest on the DfS practice in the construction sector. The aforementioned studies found a similar pattern of low DfS engagement due to a lack of institutional pressure, particularly mandated regulations. In addition, the findings suggested that the absence of regulations must be supplemented by significant collaboration efforts among stakeholders to ensure their ongoing commitment.

Despite the fact that the importance of DfS has been highlighted around the world, the limitations of DfS studies in developing countries remain significant; for example, a review by Manu et al. (2019) found that more than half of the 97 DfS journal articles they reviewed were related to the UK and USA), while a recent review study by Samsudin et al. (2022) discovered that only 16 out of 218 (7 percent) DfS articles were focused on developing context. Furthermore, despite the fact that research in Malaysia is expanding significantly in a variety of areas (e.g., KAP, education, and awareness), studies focusing on capturing the wider DfS context and DfS engagement through the use of a psychological measurement remain elusive. Such knowledge could aid in better understanding of DfS implementation, particularly in meeting Malaysia's OSHCI(M) requirements.

Table 1 The example of DfS studies (from 2015 onwards) in the construction domain.

Countries	**Examples of Authors**	**Focus**	**Findings**
USA	Gambatese et al. (2017); Tymvios and Gambatese (2016)	DfS motivation; DfS improvement	Most stakeholders viewed DfS as a positive enhancement to design practice (long-term impact on maintenance and operation), collaboration, and safety and health practices.
United Kingdom	Sacks et al. (2015); Morrow et al. (2016)	DfS concept; DfS application	Different opinions among designers on how they understand the term health and safety. The use of ICT could enhance their knowledge and attitude towards DfS
Australia	Bong et al. (2015)	DfS responsibilities	DfS Guidelines able to facilitate the designers' understanding on the safety-related design requirements
New Zealand	Guo et al. (2021)	DfS KAP	Despite current legislation encouraging collaborative DfS engagement and fostering a positive DfS attitude, more efforts towards enhancing DfS knowledge is needed.
South Korea	Soh et al. (2020)	DfS process and improvement	Differences among professionals on how the DfS improvements should be prioritised in order to improve its engagement
Singapore	Goh et al. (2016); Toh et al. (2017)	DfS KAP	High support from wide ranging stakeholders in the industry but DfS knowledge and practice need further improvement
Malaysia	Wan Azmi et al. (2017); Wan Azmi and Misnan (2018); Che Ibrahim and Belayutham (2020); Ismail et al. (2021)	DfS KAP; DfS competence	Majority of construction key stakeholders has been very supportive, but DfS knowledge, attitude and practice still requires improvement through several mechanisms
Nigeria	Manu et al. (2019); Umeokafor et al. (2021); Umeokafor et al. (2022);	DfS implementation; DfS barriers; DfS statutory and workability	Positive opportunities to further enhance DfS knowledge, skills and attitude due to high interest but the current DfS engagement is low.

Ghana	Manu et al. (2021)	DfS implementation	DfS engagement is low although awareness and interest are high.
Palestine	Abueisheh et al. (2020)	DfS implementation	DfS readiness and engagement is very low owing to wide-ranging of local barriers / challenges.
Kuwait	Sharar et al. (2022)	DfS implementation	The frequency of DfS engagement is generally moderate

Research Strategy

In view of the research aim to obtain a generalised understanding of issues pertaining to the afore-described knowledge gap on DfS implementation among designers in Malaysia's construction industry, a quantitative research strategy, which is a survey, was used. The survey approach is suitable for such purpose i.e., elicit the perception of stakeholders against particular attributes (Fellow and Lui, 2015; Creswell and Creswell, 2018), and this is further corroborated by its use in other developing countries to investigate the status of DfS implementation among design professionals in construction (see Manu et al., 2018a; 2019a; Abueisheh et al., 2020).

Questionnaire Design

A questionnaire was designed for the survey and it consisted of the following sections:

Section 1: This section captured the background information of the respondents including their role in the construction industry, experience in the current role and in the industry. This section also requested information on the level of education of the respondents, their professional body membership and the type and size of the respondents' firm. The questionnaire did not capture any personal identifiable information about participants and therefore was completely anonymous.

Section 2: This section gathered the information related to DfS. The questions used in this section included yes/no questions, Likert scale questions, single answer questions and open-ended questions.

- The respondents were asked about their awareness of the concept of DfS prior to participating in this study.
- The engagement of the respondents in 15 DfS practices was assessed using a 5-point Likert scale (1=Never, 2=Rarely, 3=Sometimes, 4=Often, 5=Always). The 15 DfS practices were adopted from previous DfS studies (Manu et al., 2018; 2019a; Abueisheh et al., 2020).
- The attitude of the respondents regarding the importance of DfS implementation was assessed using a 5-point Likert scale (1=Not important, 2=Low importance, 3=Moderate importance, 4=High importance, 5=Very High Importance). The respondents were also asked whether they would implement DfS in their design work if given the choice.
- The respondents were asked to rate the extent to which they perceive several factors would influence the implementation of DfS. The influence of the factors was rated using a 5-point Likert scale (1=Not at all, 2=Low, 3=Moderate, 4=High, 5=Very High).
- The respondents were also asked to provide responses regarding their education and training in relation to DfS, their interest in attending training related to DfS and the preferred method of training.

Questionnaire Administration

The respondents for this research are the design professionals in the Malaysian construction industry, in particular architect and engineers. Design professionals were targeted because the study's focus is to examine DfS implementation among this group of construction professionals. Due to the difficulty in obtaining participation in construction safety research surveys (see Manu et al., 2014), a pragmatic approach was used to help achieve a good response. As there is no accessible record of all design professionals in the Malaysia construction industry, the initial plan was to have a list of design firms (as a means to reach design professionals) from Yellow Pages Malaysia online directory, Board of Engineers Malaysia, Board of Architects Malaysia and the Malaysian Institute of Architects. The intention was so that from these sources, a sampling frame could be designed. However, the information from the stated sources proved to be limited as they only show the list of engineering companies and architectural firms (i.e., 161 engineering companies and 327 architectural firms, making a total of 488 design companies). As a result, industry contacts known to the researchers as well as LinkedIn was used as a potential source to assist in reaching design professionals in Malaysia. From all the mentioned sources, a list of design companies and potential design professionals was created to serve as a sampling frame for administering the questionnaire via online survey tools. The link to the survey was emailed in a cover letter to the list of design companies and design professionals. In the cover letter/email, the receiver was also asked to forward the survey link to other design professionals they know within their company or professional network. This approach was to enable a snowballing effect of questionnaire distribution (Manu et al., 2018a) in order to improve the number of responses to be obtained. When the online survey closed, 172 response cases were obtained. The data from the online questionnaire survey was exported to CSV (Excel) format. Data screening was conducted to remove response cases with excessive missing data as well as for respondents who are not designers. The data screening exercise resulted in 118 useable response cases.

Data Analyses

Using Microsoft Excel, the screened data were coded into numerical data and subsequently exported to IBM Statistical Package for Social Sciences (SPSS) 23 software for quantitative analyses including descriptive analysis and inferential statistical tests.

The descriptive statistical analysis included frequencies, means and standard deviation (Creswell and Creswell, 2018). On the other hand, inferential statistical tests included one sample t-test, and independent samples t-test (Creswell and Creswell, 2018). The one sample t-test was used to test whether there is a significant difference between a sample mean and a test-value. The test-value of 3.5 (see Mahamadu et al., 2018) was used based on the expectation that the level of implementation/engagement in DfS practices should be at least 'often' given the importance of DfS in the prevention of accidents (Manu et al., 2018a; 2019a; Abueisheh et al., 2020). In the questionnaire, a 5-point Likert scale was used to assess the extent/level of designers' engagement in the DfS practices. The test-value of 3.5 approximate to the scale point of "4" which is interpreted as "often".

Additionally, the one sample t-test was used to analyse the perceptions of the designers regarding the extent to which several factors would influence the implementation of DfS. A test value of 3.5 was used. Thus, based on the 5-point Likert scale, a factor is deemed to have at least a "high" influence if its mean score is significantly greater than 3.5 (which approximates to 4 i.e., "high" influence on the Likert scale). Furthermore, independent samples t-test and analysis of variance (ANOVA) was also used to explore associations between the extent/level of designers' engagement in the DfS practices and their demographic characteristics. Overall, the fact that of this study consist of variety the structure of data, the distribution of the data, and variable type, such variety of analysis is critical to show whether an observed pattern in relation to DfS implementation (understanding, factors, engagement) is due to intervention or chance.

Results

The results of the analysis of data are presented in the subsequent sub-headings.

The demographic information of the research participants

Table 2 indicates the respondents' background information, such as their professional role, the highest level of education and membership of a professional body. Most of the respondents are civil/structural engineer (i.e., 82.2%). Regarding their highest level of education, 69.5% of the respondents have bachelor's degree. The table also indicates that 78% of the respondents are members of a professional body. (e.g., Malaysian Institute of Architects; The Board of Architects Malaysia; The Institution of Engineers Malaysia; and Board of Engineers Malaysia).

Table 2 also presents the respondents' experience in the construction industry and in their current role. A majority of the respondents have experience of over 10 years in the construction industry (i.e., 42.4%). The respondents have a mean score of 11.5 years of experience (standard deviation= 8.93) in the construction industry and 10.4 years of experience (standard deviation= 7.66) in the current role. The results shows that a large proportion of the respondents (i.e., 30.5%) work in medium size firms (i.e., 50-249 employees). The results also shows that most of the respondents (i.e., 22%) work in a general building/civil engineering contractor firm. This is followed by general building/civil engineering contractors (22%), government agencies (20%), architectural and engineering firms (19%).

Table 1 General background information of the respondents.

Demographic characteristic	Frequency	Percentage
Professional Role		
Architect	17	14.4
Civil/Structural Engineer	97	82.2
Other (mechanical and electrical engineer, interior designer, formwork designer, and site engineer)	4	3.4
Highest level of education		
Diploma	1	0.8
Bachelor's degree	82	69.5
Master's degree	32	27.1
PhD degree	3	2.5
Professional body membership		
Yes	92	78.0
No	26	22.0
Respondents' experience		
0-5 years	37	31.4
6-10 years	33	28.0
Over 10 years	47	39.8
No response	1	0.8

Type of Organisation		
Government Agencies	24	20
General Building / Civil engineering contractors	26	22
Architectural & engineering firm	22	19
Architectural firm	14	12
Project management consultancy	9	8
Housing / Real estate developer	5	4
Others	18	15
Size of the respondents' organisation.		
Micro (1-9)	25	21.2
Small (10-49)	27	22.9
Medium (50-249)	36	30.5
Large (Over 250)	24	20.3
No response	6	5.1

The attitude of designers towards design for safety

The findings from the questionnaire survey show that the respondents acknowledge the importance of DfS implementation on construction projects. As shown in Table 3, majority of the respondents (i.e., 50.8%) rated the importance of DfS implementation as "very high importance". Table 3 also indicates that the respondents have high interest and would apply DfS in their works if they were given a choice. This signifies a positive attitude from the respondents regarding DfS implementation.

Table 2 The importance, interest and factors influencing the DfS implementation

Element	Frequency	Percentage
Importance		
Not important	0	0
Low importance	1	0
Moderate importance	11	9.3
High importance	46	39
Very high importance	60	50.8
Interest		
Yes	118	100
No	0	0

Factors Influencing	Level of Importance
DfS lessons in formal education	4.19
Client' influence	4.17
Legislation	4.08
Industry guidelines	4.01
Professional development training	3.92
ICT software applications	3.69

Design for safety awareness, education and training among designers

As shown in Table 4, the majority of the respondents (90.7%) have awareness of the DfS concept. 68.6% of the respondents have taken DfS lessons as part of the formal education and 44.9% of the respondents have undertaken DfS professional development training. The results show that 94.9% of the respondents have an interest in undertaking DfS professional development training. Concerning the respondents' preferred methods for undertaking the DfS professional development training, 51.7% of the respondents prefer to have an online course or study materials. 74.6% of the respondents prefer to attend a seminar or workshop.

Table 4: Design for safety awareness, education and professional development training

Item	Frequency	Percentage (%)
Awareness of the DfS concept		
Yes	107	90.7
No	11	9.3
Received DfS lessons as part of formal education		
Yes	81	68.6
No	36	30.5
No response	1	0.8
Received professional development training regarding DfS		
Yes	53	44.9
No	64	54.2
No response	1	0.8
Interest in DfS professional development training		
Yes	112	94.9
No	5	4.2
No response	1	0.8
Preferred method of DfS professional development training[a]		
Online course/study materials	61	51.7
Attending seminar/workshop	88	74.6
No response	5	4.2

aNote: Multiple preferences in DfS professional development training leads to a total percentage of more than 100%

Factors that affect the implementation of design for safety

Based on the reviews of literature, various factors (see Table 3) have been captured and discussed regarding the DfS implementation in the construction industry. In the questionnaire survey using a 5-point Likert scale (1= Not at all; 2= Low; 3= Moderate; 4= High; 5= Very high), the respondents were required to rate the extent to which six different factors influence DfS implementation.

As shown in Table 3, the respondents ranked DfS lessons in formal education as the most influential factor in DfS implementation. However, availability of ICT software applications was ranked to be among the least influential factors. One sample t-test was conducted to identify which of the factors have a mean value that is significantly greater than 3.5 (p (1-tailed) < 0.05), which approximates to 4 (i.e., high influence) on the 5-point Likert scale. The results, as shown in Table

5, indicates that the respondents consider all the six factors to have at least a high influence on DfS implementation.

Table 5 One sample t-test for the factors affecting DfS implementation.

Factors	N	Mean	Std. Deviation	Std. Error Mean	Test Value = 3.5					
					t	df	Sig. (1-tailed)	Mean Difference	95% Confidence Interval of the Difference	
									Lower	Upper
DfS lessons in formal education	117	4.19	1.11	0.10	6.730	116	0.000	0.688	0.49	0.89
Clients' influence	117	4.17	1.147	0.106	6.328	116	0.000	0.671	0.46	0.88
Legislation	117	4.08	0.832	0.077	7.500	116	0.000	0.577	0.42	0.73
Industry guidelines	117	4.01	0.836	0.077	6.583	116	0.000	0.509	0.36	0.66
Professional development training	117	3.92	0.811	0.075	5.642	116	0.000	0.423	0.27	0.57
ICT software applications	118	3.69	0.824	0.076	2.458	117	0.008	0.186	0.04	0.34

Designers' engagement in design for safety practices

The extent of engagement in the 15 DfS practices investigated among the respondents was captured and rated using a 5-point Likert scale. As shown in Table 6, more than 50% of the respondents engage in 11 out of 15 practices, in which the respondents undertake them as "often" or "always". As mentioned previously, the designers are expected to engage at least "often" in the DfS practices by reason of the significance of DfS to improving the status of health and safety in the construction industry. One sample t-test was conducted to determine whether the mean frequencies of the engagement in DfS practices can be considered as being at least "often" (Manu et al., 2018a; 2019a). The one sample t-test was conducted based on a t-value of 3.5 because the rounding up of 3.5 equals to 4 and this corresponds to "often" on the Likert scale. To put it concisely, the DfS practice that has a mean value of greater than 3.5 (p (1-tailed) $\leq$ 0.05) is considered being implemented "often" by the respondents. As shown in Table 7, there are 11 (i.e., 73%) of the 15 DfS practices that can be considered as being implemented "often" by the respondents. This reflects a high and positive level of engagement in DfS practices.

Table 6 The level of engagement of the respondents in DfS practices

Code representing design for safety practice	Design for Safety Practices[a]	Frequency of Engagement in Design for Safety practice					
		Never (%)	Rarely (%)	Sometimes (%)	Often (%)	Always (%)	Often and always (%)
DfS. P1	I design to avoid construction operations that create hazardous fumes, vapour and dust (e.g. disturbance of existing asbestos and cutting blockwork and concrete).	9.3	7.6	18.6	7.6	56.8	64.4
DfS. P2	I specify materials that require less frequent maintenance or replacement.	3.4	3.4	19.5	14.4	59.3	73.7
DfS. P3	I specify materials that are easier to handle such e.g. light weight blocks.	2.5	12.7	32.2	13.6	39	52.6
DfS. P4	I design to take into account safe movement of site workers, plants, & equipment on a project site during construction.	1.7	5.9	13.6	17.8	61	78.8
DfS. P5	I specify materials that have less hazardous chemical constituents.	4.2	6.8	28.8	16.9	43.2	60.1
DfS. P6	I eliminate materials that could create a significant fire risk during construction.	5.1	7.6	19.5	19.5	48.3	67.8
DfS. P7	I design to position buildings/structures to minimise risks from buried services and overhead cables.	4.2	5.1	17.8	17.8	55.1	72.9
DfS. P8	I design to mitigate possible adverse impact a project could have on safe movement of the general public during construction.	3.4	5.1	11	17.8	62.7	80.5
DfS. P9	I design elements (e.g. walls, floors, etc.) so that they can be prefabricated offsite.	5.9	9.3	52.5	11	21.2	32.2
DfS. P10	I design to minimise or eliminate the need to work at height.	9.3	17.8	36.4	11	25.4	36.4
DfS. P11	I design to minimise or eliminate the need for workers to work in confined space.	7.6	11	36.4	13.6	31.4	45.0
DfS. P12	I highlight unusual construction considerations	4.2	5.1	28.8	11	50.8	61.8

	that have safety implications to the contractor e.g. key sequence of erecting/construction.						
DfS. P13	I follow a structured/systematic procedure for undertaking design health and safety risk assessment e.g. using a tool, template or form for design health and safety risk assessment.	6.8	7.6	17.8	11.9	55.9	67.8
DfS. P14	I produce designs that enable ease of building/constructing.	4.2	1.7	17.8	11.9	64.4	76.3
DfS. P15	I prepare hazard identification drawings which show significant hazards that may not be obvious to a contractor.	16.9	16.9	27.1	8.5	30.5	39.0

[a]Note: Design for safety practices were adopted from Manu et al. (2018a; 2019a) and Abueisheh et al. (2020)

Table 7 Results for one sample t-test for the frequency of engagement in DfS practices.

Code representing design for safety practice	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**	**Test Value = 3.5**					
					t	**df**	**Sig. (1-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
DfS. P8	118	4.31	1.076	0.099	8.215	117	0.000	0.814	0.62	1.01
DfS. P4	118	4.31	1.025	0.094	8.529	117	0.000	0.805	0.62	0.99
DfS. P14	118	4.31	1.090	0.100	8.023	117	0.000	0.805	0.61	1.00
DfS. P2	118	4.23	1.089	0.100	7.268	117	0.000	0.729	0.53	0.93
DfS. P7	118	4.14	1.142	0.105	6.127	117	0.000	0.644	0.44	0.85
DfS. P13	118	4.03	1.291	0.119	4.422	117	0.000	0.525	0.29	0.76
DfS. P12	118	3.99	1.180	0.109	4.524	117	0.000	0.492	0.28	0.71
DfS. P6	118	3.98	1.205	0.111	4.354	117	0.000	0.483	0.26	0.70
DfS. P1	118	3.95	1.383	0.127	3.529	117	0.000	0.449	0.20	0.70
DfS. P5	118	3.88	1.171	0.108	3.539	117	0.000	0.381	0.17	0.59
DfS. P3	118	3.74	1.180	0.109	2.185	117	0.015	0.237	0.02	0.45

DfS. P11	118	3.50	1.252	0.115	0.000	117	0.500	0.000	-0.23	0.23
DfS. P9	118	3.32	1.093	0.101	-1.769	117	0.040	-0.178	-0.38	0.02
DfS. P10	118	3.25	1.276	0.117	-2.093	117	0.019	-0.246	-0.48	-0.01
DfS. P15	118	3.19	1.461	0.135	-2.331	117	0.011	-0.314	-0.58	-0.05

The Results of the Independent Samples t-test

The independent samples t-test was carried out to explore associations between the extent of engagement in DfS practices by the designers and other variables including their demographic characteristics and DfS awareness, training and education. This study, therefore, explored whether there is a significant difference in engagement in DfS practices between the following groups:

- Participants who have DfS awareness **vs.** participants who do not.
- Participants who are associated to a professional body **vs.** participants who are not.
- Participants who have received DfS lessons as a part of formal education **vs.** participants who have not.
- Participants who have received DfS training **vs.** participants who have not.
- Participants who are working as architects **vs.** participants who work as civil/structural engineers.
- Participants who are working in micro, small and medium organisation **vs.** participants who are working in large organisation.

The following subsection only shows the DfS practices for which significant outcomes were obtained (p (2-tailed) ≤ 0.05). The results are summarised in Table 8 to Table 11.

Based on the independent samples t-test, the results indicate that awareness of DfS has an effect on the implementation of DfS practices, given that significant outcomes were obtained for 9 out of the 15 (i.e., over half of the) DfS practices (as shown in Table 8).

The independent samples t-test based on designers' professional body membership yielded no significant result.

The independent samples t-test based on receipt of DfS lessons indicated that receipt of DfS lessons as part of formal education had a limited effect on the implementation of DfS practices, given that only two practices (i.e., less than a quarter of the 15 practices) showed a significant outcome (as shown in Table 9).

Regarding the participation in DfS training, the results show that participation in DfS training has an effect on the implementation of DfS practices, given that 10 practices (i.e. over half of the DfS practices) showed significant outcomes (as shown in Table 10).
The independent samples t-test based on professional role, which compared architects and civil/structural engineers, showed that there is no significant difference.

The result for independent samples t-test based on designers' organisation, which compared micro, small and medium organisations to the large organisation yielded no significant outcomes.

Regarding the participants' highest level of education, the result indicates that highest level of designers' education has a minimal effect on the implementation of DfS practices, given that only one practice (i.e., less than a quarter of the 15 practices) showed a significant outcome (as shown in Table 11).

Table 8 Independent samples t-test based on DfS awareness.

Code representing design for safety practice	Awareness of DfS	N	Mean	Std. Dev.	Std. Error Mean	t-test for Equality of Means						
						t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
											Lower	Upper
DfS. P1	Yes	107	4.07	1.294	0.125	3.197	116	0.002	1.347	0.422	0.513	2.182
	No	11	2.73	1.679	0.506							
DfS. P3	Yes	107	3.86	1.094	0.106	3.705	116	0.000	1.314	0.355	0.612	2.017
	No	11	2.55	1.368	0.413							
DfS. P5	Yes	107	3.96	1.098	0.106	2.399	116	0.018	0.872	0.363	0.152	1.591
	No	11	3.09	1.578	0.476							
DfS. P6	Yes	107	4.08	1.125	0.109	2.931	116	0.004	1.084	0.370	0.352	1.817
	No	11	3.00	1.549	0.467							
DfS. P8	Yes	107	4.42	0.942	0.091	2.232	11	0.048	1.148	0.514	0.011	2.284
	No	11	3.27	1.679	0.506							
DfS. P9	Yes	107	3.42	1.037	0.100	3.170	116	0.002	1.057	0.333	0.397	1.717
	No	11	2.36	1.206	0.364							
DfS. P11	Yes	107	3.58	1.213	0.117	2.183	116	0.031	0.852	0.390	0.079	1.625
	No	11	2.73	1.421	0.428							
DfS. P12	Yes	107	4.07	1.135	0.110	2.154	116	0.033	0.793	0.368	0.064	1.522
	No	11	3.27	1.421	0.428							
DfS. P14	Yes	107	4.44	0.953	0.092	4.500	116	0.000	1.439	0.320	0.806	2.073
	No	11	3.00	1.483	0.447							

Table 9 Independent samples t-test based on receipt of DfS lessons as part of formal education.

Code representing design for safety practice	Received DfS lessons as part of formal education	N	Mean	Std. Deviation	Std. Error Mean	t-test for Equality of Means						
						t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
											Lower	Upper
DfS. P9	Yes	81	3.49	1.062	0.118	2.865	115	0.005	0.605	0.211	0.187	1.023
	No	36	2.89	1.036	0.173							
DfS. P13	Yes	81	4.19	1.216	0.135	2.141	115	0.034	0.546	0.255	0.041	1.052
	No	36	3.64	1.397	0.233							

Table 10 Independent samples t-test based on DfS training.

Code representing design for safety practice	Participation in DfS training	N	Mean	Std. Deviation	Std. Error Mean	t-test for Equality of Means: t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference: Lower	Upper
DfS. P1	Yes	53	4.26	1.077	0.148	2.426	111.734	0.017	0.592	0.244	0.109	1.076
	No	64	3.67	1.554	0.194							
DfS. P3	Yes	53	3.98	0.990	0.136	2.212	114.450	0.029	0.466	0.210	0.049	0.882
	No	64	3.52	1.285	0.161							
DfS. P4	Yes	53	4.53	0.846	0.116	2.292	113.942	0.024	0.419	0.183	0.057	0.781
	No	64	4.11	1.129	0.141							
DfS. P6	Yes	53	4.42	0.949	0.130	3.655	114.233	0.000	0.743	0.203	0.340	1.146
	No	64	3.67	1.248	0.156							
DfS. P7	Yes	53	4.51	0.800	0.110	3.489	107.029	0.001	0.681	0.195	0.294	1.068
	No	64	3.83	1.292	0.161							
DfS. P9	Yes	53	3.62	1.004	0.138	2.946	115	0.004	0.576	0.195	0.189	0.963
	No	64	3.05	1.090	0.136							
DfS. P10	Yes	53	3.53	1.203	0.165	2.279	115	0.025	0.528	0.232	0.069	0.988
	No	64	3.00	1.285	0.161							
DfS. P11	Yes	53	3.83	0.995	0.137	2.861	113.167	0.005	0.627	0.219	0.193	1.061
	No	64	3.20	1.371	0.171							
DfS. P12	Yes	53	4.25	1.054	0.145	2.072	115	0.041	0.448	0.216	0.020	0.877
	No	64	3.80	1.250	0.156							
DfS. P14	Yes	53	4.55	0.774	0.106	2.113	108.473	0.037	0.391	0.185	0.024	0.758
	No	64	4.16	1.211	0.151							

Table 11 Independent samples t-test based on the highest level of education.

Code representing design for safety practice	Highest education	N	Mean	Std. Deviation	Std. Error Mean	t-test for Equality of Means						
						t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
											Lower	Upper
DfS. P15	Up to undergraduate degree	83	3.36	1.402	0.154	2.030	116	0.045	0.590	0.291	0.014	1.166
	Postgraduate degree	35	2.77	1.536	0.260							

Results of ANOVA

One-way ANOVA test with a Bonferroni correction (i.e., Bonferroni post hoc test) was undertaken to explore the association between the engagement in the DfS practices and respondents' years of experience in their professional role (grouped as 1-5 years; 6-10 years; and over 10 years). Tables 12 and 13 show the significant outcomes for three out of the 15 practices (i.e., DfS. P4, DfS. P6, and DfS. P7). Overall, the ANOVA results indicate that years of experience in design role has a limited effect on implementation of DfS practices, given that only three practices (i.e., less than a half of the 15 practices) showed a significant outcome.

Table 3 ANOVA results based on designers' years of experience in role.

Code representing design for safety practice	**Comparison**	**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
DfS. P4	Between Groups	9.837	2	4.918	4.975	0.008
	Within Groups	112.693	114	0.989		
	Total	122.530	116			
DfS. P6	Between Groups	15.859	2	7.930	5.906	0.004
	Within Groups	153.064	114	1.343		
	Total	168.923	116			
DfS. P7	Between Groups	12.895	2	6.447	5.444	0.006
	Within Groups	135.020	114	1.184		
	Total	147.915	116			
DfS. P8	Between Groups	7.882	2	3.941	3.572	0.031
	Within Groups	125.776	114	1.103		
	Total	133.658	116			

Table 13 ANOVA Post Hoc Test (Multiple Comparisons Bonferroni)

Dependent Variable	(I) Experience in role category	(J) Experience in role category	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
DfS. P4	0-5 years	6-10 years	-.472	.238	.150	-1.05	.11
		More than 10 years	-.683*	.219	.007	-1.21	-.15
	6-10 years	0-5 years	.472	.238	.150	-.11	1.05
		More than 10 years	-.211	.226	1.000	-.76	.34
	More than 10 years	0-5 years	.683*	.219	.007	.15	1.21
		6-10 years	.211	.226	1.000	-.34	.76
DfS. P6	0-5 years	6-10 years	-.483	.277	.253	-1.16	.19

		More than 10 years	-.875*	.255	.002	-1.49	-.26
	6-10 years	0-5 years	.483	.277	.253	-.19	1.16
		More than 10 years	-.392	.263	.417	-1.03	.25
	More than 10 years	0-5 years	.875*	.255	.002	.26	1.49
		6-10 years	.392	.263	.417	-.25	1.03
DfS. P7	0-5 years	6-10 years	-.749*	.261	.015	-1.38	-.12
		More than 10 years	-.686*	.239	.015	-1.27	-.10
	6-10 years	0-5 years	.749*	.261	.015	.12	1.38
		More than 10 years	.063	.247	1.000	-.54	.66
	More than 10 years	0-5 years	.686*	.239	.015	.10	1.27
		6-10 years	-.063	.247	1.000	-.66	.54

*. The mean difference is significant at the 0.05 level.

Discussion of Results

The findings from the questionnaire survey provide information regarding the status of DfS in Malaysia construction industry. The questionnaire survey also captured factors that may influence the DfS implementation in Malaysia construction industry.

The designers in Malaysia construction industry portray a very high level of awareness and positive attitude towards the DfS concept (shown in Table 3 and 4). The high awareness and positive attitude towards DfS are also reflected by the high engagement in DfS implementation (shown in Table 6 and Table 7). Despite the fact that studies in other developing countries (e.g., Nigeria, Ghana, Palestine, and Kuwait) have shown that high awareness does not necessarily reflect DfS engagement, previous scholars in the United States (e.g., Gambatese et al., 2005; Gambatese et al., 2017b) found that designers' DfS awareness and attitude have a direct impact on DfS engagement. The findings of this research regarding the designers' DfS awareness (Table 3), DfS attitude (Table 3) and extent of engagement in DfS practices (Tables 6 and 7) align with this claim, especially given that DfS awareness was also associated with a significantly greater implementation of 9 out of 15 practices, as shown in Table 8. The respondents ranked DfS lessons in formal education as the most influential factor in DfS implementation (Table 4). This is supported by Che Ibrahim and Belayutham (2020) where having formal education could facilitate the development of DfS knowledge and attitude of graduates. While it is well acknowledged that client is the greatest motivator (see Goh and Chua, 2016; Che Ibrahim and Belayutham, 2020), having legislative framework (such as OSHCI(M)) and comprehensive DfS code of practice and guidelines could also act as the enabler for DfS diffusion. Such mechanisms have been identified as a potential enabler in facilitating DfS implementation in countries such as the United Kingdom (Morrow et al., 2016) and New Zealand (Guo et al., 2021), though a study in Australia (Bong et al., 2015) revealed that stakeholders are still unconvinced that the practice will be promoted through regulation. In contrast, the availability of ICT software applications was ranked to be among the least influential factors. The initiative towards adopting disruptive technologies (e.g., BIM) in the local construction industry is relatively new (Che Ibrahim and Belayutham, 2020), whilst the capability of construction stakeholders in embracing these technologies is still growing, resulting in widely unexplored territory between technologies and safety. As presented in Table 6 and Table 7, the designers show a high level of engagement in DfS practices. The high implementation of DfS practices in the Malaysia construction industry contradicts with previous DfS implementation research in other developing countries (i.e., Ghana; Nigeria; and Palestine) where a low level of engagement in DfS practices (was probably due to the lack of early education in the curricula) (Umeokafor et al., 20220 by designers was observed. A key difference between the previous contexts and Malaysia is that Malaysia has recently introduced DfS regulatory guidelines (i.e., the OSHCI(M)), and there is none in the other developing countries. As reflected by the respondents' perceptions in Table 4 regarding the influence of DfS legislation, the introduction of the recent OSHCI(M) in Malaysia, which places a requirement for designer to eliminate, reduce or control risk during design could be a plausible explanation for the observed high level of engagement in DfS practices among the designers in Malaysia. The respondents that have received DfS lessons and undertaken DfS professional development training were expected to have higher engagement in DfS practices than those that have never received lessons and training regarding DfS. The expectation is based on the claim (Gambatese et al., 2005; Che Ibrahim and Belayutham, 2020), which is also supported by the results in Table 5, that education has high importance in DfS implementation. From Table 4, most of the respondents have received DfS lessons as part of their education. However, the independent sample t-test based on receipt of DfS lessons showed that DfS lesson had a limited association with the respondents' level of engagement in DfS practices.

The results of the independent samples t-test based on receipt of DfS lesson (see Table 9) appear to contradict the results regarding the influence of the six factors (see Table 5), which show that DfS education has a high influence on DfS implementation. However, the results of the independent samples t-test (see Table 9) could possibly rather be a reflection of the level of quality and adequacy of the DfS lessons received, instead of giving an indication of the general importance of DfS education to DfS implementation. This suggests that while DfS education has an effect on DfS implementation (as shown by Table 5), this effect may be mediated by some other factors or variables such as the quality and adequacy of the education and subsequent DfS continuous professional development training to ensure the currency and relevance of designers DfS competence. A mix of practical methodology (e.g., guidelines, tools, and case studies) is needed to improve the training process and ensure the practicality and quality of the training (Toole, 2017). Regarding the effect of DfS professional training on implementation of DfS practices, the results (shown in Table 10 where over half of the 15 DfS practices indicated the presence of significant difference) indicate that DfS training has an effect on the level of engagement in DfS practices among the designers in Malaysia construction industry. The impact of DfS professional training is also corroborated by the Table 5 which shows that the designers perceive DfS training to have at least a high impact of DfS implementation.

Studies by Gambatese et al. (2005), and Öney-Yazıcı and Dulaimi (2015) emphasised the importance of education and knowledge in DfS implementation. This is supported by the previous findings where the lack of knowledge and skills among designers related to safety and health is significant regardless the status of the DfS legislative frameworks. This is the basis of the first expectation above. The basis of the second expectation is that larger firms consider safety more often than the smaller firms (Goh and Chua, 2016). In general, the independent samples t-tests revealed that the designers' professional body membership, designers' professional role, and the size of the designers' organisation have no significant influence on DfS implementation. Additionally, the independent samples t-tests (Table 11) also showed that level of designers' education has a very limited effect on the implementation of DfS practices. However, such influence may change in a few years as DfS implementation becomes more mature among stakeholders, as evidenced by recent findings in South Africa, where organisational characteristics may have a direct influence on DfS characteristics (Che Ibrahim et al., 2022c).

Although there is a high interest among the respondents in undertaking professional development training relating to DfS (i.e., 94.9% as shown in Table 3), there is low participation in DfS professional development training (i.e., 44.9% of the respondents have undertaken training as shown in Table 4). The hindrance may include less availability of DfS training due to the influence of social, political, and economic situations in local construction context (Abueisheh et al., 2020; Manu et al., 2019a). As for the preferred method of DfS professional development training, the designers portray more interest in attending seminar and workshop (i.e., 74.9%) and less interest in online courses (i.e., 51.7%). This finding shows similarity to previous studies in developing countries: Ghana, Nigeria and Palestine (Manu et al., 2018a; 2019a; Abueisheh et al., 2020). However, given the impact of the COVID-19 pandemic which resulted in greater online engagement/interaction in place of face-to-face, this phenomenon of online engagement/interaction might also eventually drive a greater preference for online DfS training courses among designers.

Overall, the findings suggest that having institutional pressure (i.e., legislative framework, code of practice and guidance) and wider DfS engagement (e.g., seminar, hands-on workshop, industry focus group and pilot project) could facilitate the positive diffusion of DfS. This is supported by the common pattern found in the previous DfS studies in both developed and developing countries. It is worth noting that, despite current differences in DfS legislative framework implementation, the roles of stakeholders, DfS-related initiatives, and the current culture and mindset of designers on OSH in different geographical contexts are critical to ensuring the effectiveness of DfS implementation. In Malaysia, as the current landscape of the local industry lacks collective efforts, such efforts are needed to ensure the success of DfS implementation. This has been the case (in the US) where having a collaborative mechanism, particularly in procurement, has been seen as one of the key enablers to facilitate DfS implementation (see Gambatese, 2019). Also, the common belief by the local industry that collaboration only occurs after mandatory legislation, rather than being proactive in nurturing the collaborative culture prior to any initiative such as OSHCI(M) also affects the deployment of DfS. As compared to the other developing countries, these key differences (i.e., institutional pressure and wider DfS engagement) could act as a point of discussion for other developing countries (which have similar pattern of construction OSH performance (see Manu et al., 2018b)) to initiate the DfS initiative. During this transition period, practical module and code of practice related to DfS have been developed, followed by continuous engagements through seminar and practical workshops. Also, as part of the initiative and demonstration of the approach to the industry, DOSH has initiated ten OSHCI(M) pilot projects comprised of public and private projects from 'champion' companies (i.e., developers, designers, and contractors) in the industry (DOSH, 2019). The ability to provide tangible evidence to the industry (based on established players) could facilitate faster DfS implementation at all levels. Another initiative (to ensure wider dissemination of OSHCI(M)) made by the DOSH is the appointment of DfS professionals and the establishment of certified DfS learning centers at educational institutions. Similar to previous studies (e.g., Che Ibrahim et al., 2022b, Sharar et al., 2022) continous learning is critical to ensure the sustainability of the DfS knowledge for future graduates and current practitioners. Such collaboration could further enhance the collaborative activities not only between the authorities and educational institutions, but also between the construction stakeholders on their cognitive, affective, and psycho-motor domain (through more collaborative workshops and seminars). Also, efforts towards nurturing the DfS culture has also taken place through direct engagement activities not only with the industry, but also with academics across the country. The impact attributed to these initiatives signals that a purposeful, collaborative and integrated effort at all levels (from early education to the real case studies) could be an effective stimulus for improving the OSH in the construction industry.

Limitation of the study

In this research, the respondents were expected to draw on their industry experiences and current practices to provide an unbiased view of their extent of engagement in DfS practices. While the researchers perceive that this was the case, due to the confidential and anonymous nature of administered survey, there is some possibility that some respondents may have provided responses to portray that they give due consideration to the OSH of workers. There is therefore some possibility of induced socially desirable responses whereby respondents overstate the extent to which they engage in DfS practices.

Conclusions

While the construction industry is notorious for its poor OSH performance, in developing countries such as Malaysia, the OSH performance of the industry is even worse. It is established that design decisions influence the occurrence of accidents on construction sites and this had led to the concept and practice of DfS. However, there are limited studies on DfS within the context of developing countries including Malaysia, in spite of the poor OSH performance of the construction sector in developing countries and the significance of DfS to OSH improvement. This study extends the implementation of DfS practice in developing countries in the context of showing how having DfS-related institutional drivers and initiatives could facilitate DfS implementation and practice. This study has therefore examined several issues regarding implementation of DfS by designers in Malaysia's construction sector. Based on the results, the following main conclusions can be drawn:

- The designers in Malaysia construction industry have high awareness and positive attitude towards the DfS concept. This is further reflected by a high level of engagement in DfS practices.
- The level of participation of the designers in DfS professional development training low, despite the designers having a high interest in participating in DfS training.
- The receipt of DfS lessons in formal education by designers appears to be moderate.
- In the context of the designers in Malaysia (based on the study's findings), there seems to be no or limited relationship between engagement in DfS practices and: professional body membership of designers; designers' professional role; designers' level of education; size of designers' organisation; and designers' years of experience in role. While this outcome does not necessarily mean that these items are not important at all to DfS implementation, it rather suggests that there may be other more dominant factors that affect the implementation of DfS practices among designers in Malaysia.
- DfS lessons in formal education, influence from clients, legislation are perceived by designers to be among the top most factors to have a high influence on DfS implementation in the Malaysian construction industry.

Based on the above conclusions, the following recommendations are provided:

- The introduction of the Guidelines on Occupational Safety and Health in Construction Industry (Management) (OSHCIM) seem to have contributed towards stimulation of DfS awareness, interest and engagement among designers in Malaysia. Continuous promotion and effective enforcement of the guidelines by industry stakeholders including the responsible government agency would be useful in stimulating greater DfS implementation by designers in Malaysia. With time the government would need to undertake an evaluation of the impact of the guidelines in order to ascertain relevant changes that may be needed to augment the utility of the guidelines.

- Designers show a high interest in undertaking DfS development training. Hence, professional bodies could initiate more opportunities for designers to participate in the DfS training. This could be done by conducting more seminar or workshops related to DfS. However, the prevailing COVID-19 crises may imply that online courses would currently be the most viable training route until when face-to-face interactions become the norm once again.
- The Ministry of Higher Education Malaysia (MOHE), Malaysian Qualification Agency (MQA), Engineering Accreditation Council (EAC) under Board of Engineers Malaysia and educational institutions could work closely to enhance current DfS lessons in formal education.
- There is a need to have all the stakeholders (e.g. academics, designers, clients and contractors) to understand the benefits of DfS implementation. This would be very important, especially for clients, who this research and several others have shown to have a high influence on DfS implementation.

The research findings of this study provide some theoretical contributions. The current DfS literature is dominated by perspectives from developed countries. This paper contributes to the existing literature by providing a broader perspective (DfS awareness, education training, influencing factors, and DfS engagement) on designers in developing countries (i.e., Malaysia), particularly when the DfS legislative framework is in place. The findings provide a reference point for the current state of the designer's professional capability and how to improve their development in order to ensure the success of DfS implementation. The findings of this study also provide practical implications for managers, particularly those in related design organisations, in terms of refining and facilitating DfS practise among designers in order to improve safety practise in the early design phase while also fulfilling their role as duty holders as defined by OSHCI (M). Understanding the current state of DfS practise enables managers to plan a training development programme for designers as well as prepare a mechanism to influence DfS activities within their organisations as a proactive measure to ensure the continuous development and improvement of DfS practise.

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