FACTORS INFLUENCING DFS ADOPTION: THE CASE OF MALAYSIAN CONSTRUCTION ORGANISATIONS

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Despite the introduction of the Occupational Safety and Health in Construction Industry (Management) (OSHCIM) guidelines in 2017, little is known about the factors contributing to Design for Safety (DfS) adoption in the Malaysian construction industry. Previous studies have identified three main groups of factors for DfS implementation - organisational factors, industry related factors and external factors. To understand the DfS factors in the local Malaysian context, a gap analysis was conducted through an online questionnaire survey during four series of DfS webinars. The findings suggest that legislation, guidelines, training, client influence, and incentives were among the top five significant factors identified by construction organizations. This indicates that a strong regulatory and educational framework is crucial in promoting DfS. The study also found that different types of organizations may prioritize different factors in adopting DfS practices based on their specific needs and motivations. Understanding these factors would enable key duty holders to manage DfS more effectively throughout project lifecycles. This research contributes to the discourse on the promises of DfS as a preventive practice to improve safety and health performance in the Malaysian construction industry.

Keywords: design for safety, organisation, construction, Malaysia

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INTRODUCTION

In recent years, the topic of Design for Safety (DfS) has been progressively explored in construction literature, owing to the emergence of new regulations that govern construction practices across the world (Che Ibrahim et al., 2022a; Jin et al., 2022). DfS has been approached in various ways, for instance as a legal requirement, with Safe Design in Australia and New Zealand, and Construction Design and Management (CDM) in the UK as notable examples. It has also been adopted as a guideline on a non-mandatory or voluntary basis, such as Occupational Safety and Health in Construction Industry (Management) (OSHCIM) in Malaysia and Guidelines for addressing occupational hazards and risks in design and redesign processes in the United States. Regardless of its terminology, DfS is widely recognised as a practice that promotes occupational safety and health (OSH) outcomes (Karakhan and Gambatese, 2017), and it enables organisations to ensure optimal consideration of OSH in their design processes (Hardison and Hallowell, 2019; Che Ibrahim et al., 2020)

Despite a significant body of literature on Design for Safety (DfS) that addresses ways to make it more acceptable to academic, practitioners, and decision makers in various dimensions (e.g., practical, education), the factors and barriers that affect its effective implementation are still a major concern (Umeokafor et al., 2022). The literature suggests that certain factors, such as external factors (e.g., legal, economic, and education), industry related factors (e.g., contract, and project delivery), organisational factors (e.g., interest, training and development, collaboration), and individual factors (e.g., knowledge, and awareness), could influence and inhibit the uptake of DfS. However, it is often unclear whether the proposed factors and barriers are valid within different contexts (e.g., regulated or voluntary basis, and different geographical settings). For example, a recent study by Umeokafor et al. (2022) investigated DfS barriers in Nigeria and found that the domestic context has a significant impact on sustainable DfS growth. Another study by Che Ibrahim et al. (2022b) suggested that due to recent OSHCIM guidelines in Malaysia, continuous engagement in DfS activities could improve DfS learning.

Overall, it is apparent that developed countries such as the UK, USA and countries in the European Union have a considerable amount of research and practice in the subject of DfS (Manu et al., 2021). However, DfS concepts are still at an early stage in many developing countries, including Malaysia. Recently, there have been significant improvements to Malaysia's existing OSH guideline framework to incorporate DfS principles, known as OSHCIM. Although this framework is new to the industry, it is important to understand what factors can facilitate the implementation of DfS. Unfortunately, no quantitative studies have been conducted in Malaysia that capture these factors. To address this gap in the current DfS knowledge, the objective of this study is to examine the factors that influence DfS implementation across different types of organisations. A more in-depth understanding of these DfS dimensions can help duty holders and stakeholders make informed decisions about DfS readiness and diffusion, thereby minimising negative impacts, and improving resource efficiency towards safety and health outcomes. In addition, an understanding of the DfS implementation across different organisational types could provide insight in formulating holistic and targeted strategies and interventions for successful future implementation.

RELATED DFS STUDIES IN MALAYSIAN CONTEXT

DfS research in Malaysia has been on the rise in recent years, largely due to the implementation of OSHCI(M). The main focus of these studies has been on assessing the preparedness and understanding of stakeholders regarding DfS. For example, Che Ibrahim and Belayutham (2020) examined the knowledge, attitude, and practices of civil engineers on DfS guidelines, finding that factors such as education and training, industry related factors, and organisational factors were crucial for advancing their knowledge, attitude and practice (KAP). Che Ibrahim et al. (2021) analysed the extent of DfS education in civil engineering programmes at seven public universities in Malaysia and discovered that it was virtually non-existent. Ismail et al. (2021) further used Che Ibrahim et al.'s (2020) designer DfS competence framework to survey 85 construction-related designers on their perception of DfS competence. The study found that knowledge-based attributes, design and construction experience, hazard-related skills, and collaboration skills were the primary attributes required for effective DfS practice. Che Ibrahim et al. (2022a) expanded on the validity of DfS competencies by comparing them across three developing countries, namely Malaysia, Nigeria, and South Africa. The study identified a common pattern in these countries whereby designers possessed basic knowledge, skills, and experience in DfS but lacked the ability to analyse, synthesise, and evaluate advanced characteristics of DfS competence, especially regarding experience and skills. Christermaller et al. (2022) found limited association between the implementation of DfS practices and designers' professional body membership or the size of their organization, but DfS awareness and training were associated with greater implementation. DfS education, client influence, and legislation were identified as key factors affecting DfS implementation. Che Ibrahim et al. (2022b) suggested that creating a culture of shared DfS learning and continuous engagement in education and training could improve DfS learning. Che Ibrahim et al. (2022c) conducted a recent study in which they utilised the established designer DfS competence framework to create an index based on 18 critical attributes and their corresponding weights. This index has the potential to serve as a means for clients, designers, or design organisations to conduct an initial evaluation of designers' DfS competence in construction. Despite the increasing attention on DfS in Malaysia, limitations in understanding what influences successful DfS implementation remain elusive. This information could be useful in meeting Malaysia's OSHCI(M) requirements and improving DfS implementation.

FACTORS INFLUENCING DFS IMPLEMENTATION

This discussion is focusing on the various factors that influence the diffusion of DfS in the construction industry. A set of key factors influencing the adoption of DfS covering the three main domains; external factors, industry related factors and organisational factors was identified through the literature review exercise. The main factors identified include the availability of digital applications, early education of stakeholders, institutional pressure, practical guidelines or code practices, the recognition of DfS benefits from clients, new coordinating role in DfS management, incentives and funding from governments, and innovative contractual and procurement approaches.

The availability of digital applications such as Building Information Modelling (BIM) has been found to have a positive link with DfS, especially in visualising the construction process model to assess safety hazards (Zhang et al., 2015). Early education of stakeholders has also been identified as a key factor in DfS diffusion as the significant gap in knowledge and skills among designers necessitates the need for formal education at an early stage to establish the basic foundation of safety knowledge (Toole, 2017; Che Ibrahim et al., 2021).

Institutional pressure through legislation is another factor that greatly influences the adoption of DfS. The need for practical guidelines or code practices, specific guidance, or code of practice that focuses on the activities and interaction during design can improve the lack of safety experience and competence among existing designers in the industry (Morrow et al., 2016). The recognition of DfS benefits from clients has also been identified as an important factor influencing DfS as proactive owner leadership is crucial to initiate DfS as well as to monitor the DfS expectation in the design review process (Tymvios and Gambatese, 2016).

Innovative contractual and procurement approaches have also been considered in an attempt to enhance DfS implementation (Gambatese 2019). Efforts to promote DfS should also be one of the driving factors towards ensuring the effective DfS implementation. Wider communication efforts could influence owners and other duty holders on the awareness as well as enhancement of the technical skills and collaboration needed to perform DfS successfully (Karakhan and Gambatese, 2017). Incorporating DfS education into curricula at an early stage, as well as establishing one-stop centers for DfS education materials, can also facilitate the wider communication of DfS.

Earlier research has emphasised the significance of utilising tools and resources in the process of designing for safety. The incorporation of an array of qualitative and quantitative tools, in addition to various resources such as educational and design materials, can play a critical role in educating and informing designers about DfS solutions (Gambatese et al., 2007). Digital technologies and resources like design guidelines, checklists, and best practices can also offer an innovative and valuable means for designers to consistently apply DfS principles (Tymvios, 2017; Poghosyana et al., 2020).

RESEARCH METHOD

In order to gain a comprehensive understanding of the contextual factors that contribute to DfS implementation in Malaysia, a quantitative methodology was employed using a questionnaire survey. This method facilitates rapid gathering of information from a variety of stakeholders on specific characteristics (Fellow and Lui, 2015). To administer the survey, a questionnaire was designed using the SurveyMonkey platform and was made available to multiple stakeholders during four online DfS webinars held in 2022. The webinars were utilised as a platform for data collection as they facilitated greater interaction with participants who share a common domain and helped to establish expectations regarding DfS implementation (Ørngreen and Levinsen, 2017).

The questionnaire consisted of two sections. The first section aimed to gather demographic information from the respondents, while the second section assessed the level of importance of factors for DfS implementation. The level of importance was assessed using a five-point Likert-scale (ranging from 1 = not at all important to 5 = extremely important).

Over the four series of the webinars, a total of 871 participants (with an average of 125 per session) participated in the webinar. The initial invitation was sent to over

150 potential respondents through an industrial network of experts that have previously attended OSHCIM workshops and seminars. Out of the 871 potential respondents, 389 responses were received and 347were useable responses. The number of useable responses is considered appropriate when compared to the number of responses from other DfS studies (e.g., 33 responses reported in DfS studies in Saudi Arabia (Hassanain et al., 2022) and 89 responses reported in DfS studies in Malaysia (Che Ibrahim et al., 2022b).

Descriptive statistical analysis, including the mean and frequencies, was applied to the obtained data in Microsoft Excel and executed in IBM SPSS 26 Software. Inferential analysis was also used to ascertain variations in DfS factors across organisations.

Out of the 347 responses received, 68.9% were male and 31.1% were female. On average, the respondents had 15 years of experience in the construction industry. In terms of their organisations, 37.5% identified as contractors, 21.3% as government agencies, 26.2% as consultants, and 15.0% as developers/owners. Notably, 41% of the respondents were registered professionals (such as professional engineers, architects, surveyors, and technologists) under their respective professional bodies.

RESULTS AND DISCUSSION

Factors influencing DfS implementation

The table provides results on the factors that influence Design for Sustainability (DfS) implementation in organisations, based on the mean values and standard deviations for each factor. The study surveyed a total of 347 participants from four different organisations (G1 = consultant, G2 = contractor, G3 = government agencies, and G4 = developer/owners), with each organisation consisting of a different number of participants (n=91, n=130, n=74, and n=52, respectively).

The factors examined in the study are: (1) availability of digital software applications for DfS, (2) professional development training relating to DfS, (3) industry guidelines/practical guidance or codes for DfS, (4) introduction of legislation relating to DfS, (5) clients' motivation relating to DfS implementation, (6) inclusion of DfS lessons in formal education, (7) introduction of DfS coordinator in every project, (8) establishment of contractual agreement that embraces DfS, (9) more collaborative project delivery, (10) more outreach and communication efforts on DfS, (11) government should provide incentives for companies, and (12) a simple and effective tool for facilitating DfS practice.

The mean values for each factor range from 3.877 to 4.078, indicating that participants generally believe that all of these factors are influential for DfS implementation. However, there are some variations in mean values across the different groups, with developer/owners consistently having the highest mean values for each factor, followed by government agencies, consultants, and contractors. This suggests that developers/owners and government agencies may have a greater interest or knowledge in DfS compared to consultants and contractors.

Upon further analysis, it was found that among the consultants, the highest mean values (above 4.000) were for guidelines, legislation, client influence, and DfS education. This suggests that consultants consider these factors to be the most important for DfS implementation. This also indicates that consultants are influenced by external factors, as these factors provide a systematic framework and clear mandate that could help ensure the sustainability of DfS practices being integrated into the design process (Che Ibrahim et al., 2021; Adaku et al., 2021). Additionally, enhancing

DfS principles through education is also important as it can improve the knowledge, skills, and experience of future designers prior to working experience (Toole, 2017). The least influential factors for consultants are DfS coordinator, outreach, and digital application. This may be because consultants might not have direct involvement in the planning and project execution phases (depending on the project delivery method) as well as the fact that the adoption of digital technology such as BIM is still gathering pace within the local industry (Sinoh et al., 2020), limiting their applicability towards facilitating the DfS practice.

Table 1: The responses on the factors influencing DfS implementation.

Factors	Overall Mean	Mean values for each organisation				Standard Deviation	Significance (*p*)
		G1	G2	G3	G4		
	(n=347)	(n=91)	(n=130)	(n=74)	(n=52)		
Digital application for DfS	3.891	3.769	3.777	3.96	4.058	0.766	0.056
Professional development training	4.042	4.011	3.923	4.041	4.192	0.745	0.171
Guidelines / code of practice	4.072	4.121	3.908	4.068	4.192	0.778	0.077
Legislation	4.078	4.132	3.863	4.068	4.25	0.786	0.008
Client’s influence	4.044	4.066	3.908	4.027	4.173	0.817	0.207
DfS education	3.993	4.055	3.846	3.878	4.192	0.816	0.045
DfS coordinator	3.892	3.879	3.823	3.77	4.096	0.815	0.117
Contractual	3.993	3.978	3.9	3.959	4.135	0.816	0.465
Collaborative procurement	3.881	3.912	3.738	3.797	4.078	0.772	0.121
Outreach for DfS engagement	3.877	3.912	3.808	3.824	3.962	0.758	0.674
Incentive from Government	4.013	3.956	4	3.865	4.23	0.866	0.124
DfS tool	3.946	3.934	3.815	3.919	4.115	0.782	0.133

For contractors, the highest mean values are for incentive, contractual, digital application, and guidelines. It is well acknowledged that contractors are often motivated by financial incentives and such external economic incentives can increase an organisation's motivation to implement DfS practices. These incentives could come from local agencies acting as intermediaries, in addition to being provided at the national level, in order to encourage greater efforts in DfS (Karakhan and Gambatese, 2017; Che Ibrahim et al., 2022b). Contractors are typically responsible for the physical construction of a project and may view contractual agreements as a set of requirements that they must comply with in order to avoid legal and financial penalties. They may also have more insights about the day-to-day challenges of implementing safety measures on a construction site and may therefore have keen interests on how the digital application impacts safety in practice.

Among the government agencies, the highest mean values are for legislation, guidelines, client influence, and digital application. It is argued that institutional pressure, driven by local authorities, is a necessary mechanism to enhance the implementation of DfS in a country. This can help ensure compliance with safety regulations and promote a culture of safety within the construction industry (Che Ibrahim et al., 2020; Manu et al., 2021). Additionally, they place relatively high importance on client influence, indicating that they are aware of the importance of client's commitment in DfS initiatives. This is supported by several studies where clients provide the greatest motivation for organisation to practice DfS (Goh and Chua, 2016; Gambatese et al., 2017).

For developers/owners, the highest mean values are for legislation, incentive, guidelines, and training. Similarly, for contractors and government agencies, having a legal mechanism to frame the DfS ecosystem is significant, and industry-based guidelines could overcome barriers to the adoption of DfS practices, such as a lack of knowledge or awareness of the benefits of DfS. Specific incentives and training are also seen as important to ensure continuous DfS adoption and improvements. By providing organisations with the right incentives and training, they can create a culture that values safety and prioritises safety during the design process, thereby keeping up with ongoing improvements and changes in safety regulations and standards (Morrow et al., 2016). The least influential factors for developers/owners are outreach and collaborative procurement. This could be due to their limited role in decision-making for procurement and outreach and dissemination activities.

The standard deviations for each factor range from 0.745 to 0.866, indicating that there is some variability in the responses for each factor. The factors with the highest standard deviations are "incentives" and "DfS tool", suggesting that there may be differing opinions on how best to motivate organisations to implement DfS and what tools are most effective.

Upon further analysis with ANOVA test to examine the differences in perceived importance of the DfS factors across the four groups of organisations (see Table 1), it was found that there was no statistical difference between the 10 factors ($p>0.05$) except for two factors i.e., legislation ($p = 0.008$) and DfS education ($p = 0.045$). Where significant differences were found, pair-wise comparisons were performed using the Post-hoc Test. Further investigation showed a statistically significant difference in the attribute of legislation ($p = 0.013$, $p \leq 0.05$) and DfS education ($p = 0.047$, $p \leq 0.05$) between contractor and developer/owner. This suggests that contractors and developers may have different opinions on implementing DfS practices due to their different roles and responsibilities as well as perspectives and priorities in delivering the project. Contractor may view DfS as an additional cost and an impediment to project completion. They may also feel that they already have adequate safety measures in place, and that DfS would simply add unnecessary bureaucracy and paperwork. On the other hand, developers are responsible for the overall design and planning of the project. They are concerned with ensuring that the project meets all relevant regulations and standards, including safety standards. Developers may view DfS as an essential element of the design process, ensuring that safety is built into the project from the onset. While contractors may have more direct experience with construction practices, developers bring a broader perspective on safety standards and regulations.

Overall, the results can be used to identify areas of improvement as well as those areas that represent strengths for individual organisations. For example, developers/owners place the highest value on legislation, guidelines, and incentives, indicating that they are more likely to invest in safety measures and comply with regulations. Meanwhile, contractors have relatively low mean values for collaborative procurement and outreach, indicating a need for more effort in these areas to increase collective efforts towards DfS. Similarly, government agencies have lower mean values for DfS coordinator and collaborative procurement, indicating a need to focus more on innovative approaches to establish governance and frameworks for DfS implementation.

CONCLUSIONS

This study has provided an overview of the factors influencing the implementation of DfS from a Malaysian construction organisation's point of view. The most important factors that influence the implementation of DfS were adequately captured via questionnaire surveys during four separate DfS webinars with four different types of organisations within the construction industry. Overall, the results suggest that while guidelines, legislation, and training are important factors for driving DfS practices across all types of organisations, there are nuanced differences in priorities depending on the organisation's role in the construction process. In particular, there are variations in mean values across different groups, with developer/owners consistently having the highest mean values for each factor, followed by government agencies, consultants, and contractors.

Overall, the consistency of the responses suggests that different types of organisations may prioritise different factors in adopting DfS practices, based on their specific needs and motivations. It is important to understand these differences in order to develop effective strategies for promoting, implementing and monitoring DfS practices across different sectors.

The study confirmed the key factors that influence DfS, which were previously reported in the literature, within the context of developing countries. Such understanding could provide Malaysian OSH regulators (e.g., DOSH) with the basis to align the existing OSHCIM guidelines with the identified factors, enabling clear expectations, standards, and incentives for organizations to adopt and integrate DfS practices into their operations. Furthermore, related OSH training and research institutions could align their funding priorities with the identified factors. These factors could also serve as a basis for inclusion in related engineering or built environment educational curricula.

Although there were some limitations, such as unequal sample sizes, future research could broaden the scope of the study to include a larger sample size and explore a variety of organisational disciplines, such as architecture, civil and structural engineering, mechanical engineering, electrical engineering, and quantity surveying. Additionally, incorporating qualitative data (to achieve a mixed approach) could provide more insights into how and why these factors are more peculiar to certain types of organisations during their adoption of DfS.

ACKNOWLEDGEMENTS

This work described in this paper has been funded by a Research Environment Links grant (Ref No. MIGHT/CEO/NUOF/1-2022(1)) from the British Council and Malaysian Industry-Government Group for High Technology, as part of the British Council's Going Global Partnerships programme.

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