Building a Framework for Dynamic Organisational Capabilities in Design for Safety (DfS) for Malaysian Construction Organisations

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Abstract

Purpose – Despite the growing construction subject of Design for Safety (DfS) in Malaysia, little effort has been made to understand the construction organisational DfS capability in a dynamic environment. This study aims to propose a framework for dynamic DfS capabilities for construction organisations in Malaysia.

Design/methodology/approach – A quantitative research methodology was employed for this study. Data were gathered from three hundred and six (306) practitioners from diverse construction organisations, including Government Agencies, Consultants, Contractors, and Developers in Malaysia using an online questionnaire survey during four online DfS webinars. Descriptive and inferential analysis, as well as content analysis techniques, were utilized to analyse the collected data.

Findings – Analysis of the survey data showed that all six key DfS organisational capability elements identified in the literature, which the respondents were required to assess have a strong influence on determining the DfS capabilities of construction organisations. The elements ranked as most influential include 1) DfS knowledge of the designer; 2) DfS experience of the designer; 3) Top management's commitment to DfS; 4) Design risk management; and 5) Project review. Based on these findings, a framework for dynamic DfS organisational capabilities is proposed. This framework incorporates four essential capabilities—Sensing, Learning, Integrating, and Coordinating, and is anchored by the aforementioned six key elements as foundational to deriving value from DfS practices.

Practical implications – The proposed DfS organisational capabilities framework will facilitate construction organisations' focus on the dynamic environment while striving for successful DfS practice in construction projects.

Originality/value – This study extends the DfS literature in the construction context by providing deeper insights into the conceptualisation of dynamic DfS organisational capabilities where DfS regulatory framework is still evolving. This study also highlights organisations' importance in perceiving and prioritising their abilities to sense changes, learn and internalise new competencies, integrate resources, and coordinate activities, reflecting their unique strategic focuses and operational needs toward DfS practice.

Keywords: Design for Safety, Organisation, Dynamic Capabilities, Construction

Introduction

Design for Safety (DfS) continues to be researched in construction literature (Che Ibrahim et al., 2022a; Jin et al., 2022). Interest in DfS has been promoted by different forms of the framework across various countries. For instance, it exists as legislation known as Safe Design in Australia and New Zealand and Construction Design and Management (CDM) in the UK. On a non-mandatory or voluntary basis, it is recognised as guidelines 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 terminology, DfS is recognised for improving safety and health outcomes (Karakhan and Gambatese, 2017) and enabling designers and organisations to optimise OSH practices in design processes (Hardison and Hallowell, 2019).

Although a substantial body of DfS literature addresses ways to make DfS practice more acceptable for academics, practitioners, and decision-makers in a wide range of dimensions (e.g., practical, education, sustainability, and visualisation), unclear organisational capabilities that are required for its effective implementation are still reported by many as a significant concern (Adaku et al., 2021; Che Ibrahim et al., 2022a). Although the role of organisations has been highlighted in DfS-related legislation in reducing accident occurrences (Gambatese et al., 2017), there are still limitations and challenges that continually emerge in various contexts that affect the organisational capability in DfS implementation. The ambiguity associated with regulatory prescriptions of competence and its assessment has contributed to the inability of design organisations to fulfil their duties under the DfS-related legislative and guideline framework (Manu et al., 2019; Adaku et al., 2021). The lack of clarity on the required DfS capabilities, coupled with the misconceptions, mindset, and ownership among design organisations (Behm et al., 2014), as well as the lack of competence (knowledge, skills, and experience) among designers in addressing the OSH issues during the design phase (Morrow et al., 2016), pose significant barriers to the widespread adoption of DfS.

A review of related literature has highlighted that there is a growing body of DfS research in developed countries, especially the UK, USA, and several countries within the European Union (Jin et al., 2022). In these regions, the DfS legislative framework is far more mature, leading to more advanced DfS applications, particularly in the adoption of digital technologies such as BIM and simulation-based platforms to facilitate DfS practices and capture lessons learned in case studies. In contrast, studies in developing countries, such as Vietnam, Malaysia, Botswana, and Nigeria, primarily focus on raising awareness and understanding of DfS practices among stakeholders (Jin et al., 2022; Che Ibrahim et al., 2022a). While most developing countries have yet to introduce DfS legislative frameworks, Malaysia has introduced the DfS guideline i.e. OSHCIM to encapsulate better DfS principles and practices (Che Ibrahim et al., 2022b). Despite the fact that OSHCIM is relatively new to the industry, the majority of players, especially the small and medium enterprises (SMEs) within the industry, are still adapting to the DfS practice (Ismail et al., 2021; Che Ibrahim et al., 2022b). As a result, there is a greater need to understand DfS capabilities among organisations in the construction industry due to the forthcoming mandate of the OSHCIM guideline. Although DfS studies in construction literature in developing countries are growing (see Che Ibrahim et al., 2022a), none specifically focus on capturing DfS organisational capabilities within the context of dynamic capabilities among the organisations. Such understanding in a dynamic context is critical, as the organisational construction environment has changed over time due to several conditions, in particular changes in related safety and health legislation in the Malaysian construction industry. It is worth noting that although existing DfS studies on organisational capabilities (e.g., Manu et al., 2019; Adaku et al., 2021) provide a useful insight into the organisational capability landscape, the findings in these studies were mostly framed based on responses from the UK, where DfS practice is well established in CDM regulations. These studies have not considered the dynamic context of organisational capabilities, and, thus, these studies are limited in terms of responses from those countries where DfS legislation is non-existent or has recently been developed. This gap highlights the necessity of context-specific research to understand and enhance DfS capabilities in countries like Malaysia, where the regulatory framework is still evolving. Thus, this study aims to develop a conceptual framework for dynamic organisational capabilities in DfS for Malaysian construction organisations. Specifically, the objective of this study are two-fold; firstly, to examine DfS organisational capabilities (i.e., the abilities in terms of skills, knowledge, resources, and structures within an organisation to practice the DfS) among construction organisations; and secondly, to consolidate and integrate the identified organisational capabilities with the established dynamic capability framework developed by Pavlou and El Sawy (2011). This helped to facilitate the development of a conceptual framework for a dynamic DfS organisational capability model for construction organisations. Such a framework will facilitate the DfS capability of construction organisations, including SMEs, in a dynamic environment.

DfS studies on organisational capabilities

The subject of organisational safety has gained interest in recent years as it provides a greater extent for economic and ethical reasons, hence enhancing organisational profits and productivity in managing construction projects (Deepak and Mahesh, 2024). In particular, organisations that integrate safety considerations during the design phase aid in proactive hazard identification and mitigation, decreasing construction-related accidents, injuries, and fatalities (Behm et al., 2014; Hallowell and Hansen, 2016). Despite the importance of DfS in accident prevention, organisational capabilities are a prerequisite to successful implementation (Manu et al., 2019). These capabilities are the collective skills, knowledge, resources, and structures within an organisation that enable the successful implementation of DfS (Manu et al., 2019). Despite emphasising the need to have capable organisations to practice DfS (e.g., PART 3: Appointment of designers and contractors, Section 3.1 and 3.2 of OSHCIM; PART

3: Health and safety duties and roles, Regulation 8 of Construction Design and Management (CDM) 2015 in the UK; PART 3: Duties of Designer and Contractor, Regulation 9 of DfS 2015 in Singapore), the context of assessing competence or capabilities is limited. In addition, a review of existing organisational assessments (e.g., Construction prequalification questionnaires (PAS 91) in the UK, Checklist of Consideration for Principal Designers and Designers in OSHCIM) has recognised that the current tools are limited in nature and characteristics as they are primarily descriptive and checklist-based. Scholars have initiated efforts to quantify the explicit characteristics of DfS's organisational capabilities. Specifically, it delves into two key contributions: the frameworks proposed by Manu et al. (2019) and Adaku et al. (2021).

Manu et al. (2019) proposed an initial framework for categorising 18 capability attributes within six primary categories. These categories are competence (pertaining to the design staff's competence level); strategy (reflecting the integration of DfS into the organisation's vision and the dedication of top management); corporate experience (related to the past experience of implementing on projects); systems (encompassing the necessary systems, processes, and procedures for DfS implementation); infrastructure (encompassing physical as well as information and communication technology resources); and collaboration (involves both inter-organisational and intra-organisational collaboration). They highlighted the relative priority of these 18 attributes via an expert focus group, the Delphi method, and a multi-criteria decision-making method. They stressed that the attributes related to competence and strategy in DfS capability hold the highest significance.

Aside from the empirical work by Manu et al. (2019), Adaku et al. (2021) proposed a conceptual model for organisational DfS capabilities, encapsulating attributes such as competence, learning ability, reputation, organisational governance and management systems, and infrastructure. The proficiency of an organisation, anchored firmly in its staff's collective skills, expertise, and backgrounds, forms an integral part of its essential capabilities, directly influencing its operational efficiency across diverse levels. In addition, an organisation's capacity to evolve and absorb new knowledge, whether derived from internal sources or external influences, facilitates its alignment with the dynamic business and economic environments. Reputation, a vital element, is built over time through consistent performance, often granting the organisation a competitive edge. Moreover, efficient governance and management systems for resource allocation, development, and retention are essential for sustaining exceptional performance. Lastly, infrastructure, comprising physical assets, ICT frameworks, financial systems, and control mechanisms, supports organizational processes, enhancing productivity and fostering excellence.

By integrating the elements of DfS capabilities proposed by Manu et al. (2019) and Adaku et al. (2021), it can be seen that both findings emphasise the importance of leadership commitment, competent personnel, collaboration, and communication, integration of the DfS process, organisational learning, and continuous improvement in guiding organisations to develop and enhance their DfS capability. Both studies also recognise the multi-dimensional nature of organisational capability and suggest that the capabilities of organisations should be considered at different levels, ranging from the task, project, programme, and portfolio levels. The capabilities required at each level may vary, and it is important to assess and measure organisational capability at the appropriate performance specificity or requirement level.

Building the Theoretical Framework

This study adopted a theoretical framework based on organisational DfS capability-related studies (see Manu et al., 2019; Adaku et al., 2021) as a foundation to construct a DfS organisational capabilities framework. In particular, the study by Manu et al. (2019) identified six key elements related to organisational DfS capability: 1) Competence, 2) Strategy, 3)

Infrastructure, 4) System, 5) Collaboration, and 6) Corporate Experience. These elements went through an extensive validation and verification process through three focus group sessions with eight UK construction and OSH professionals, as well as three rounds of Delphi survey involving 28 – 32 experts. The UK has been implementing CDM regulations for the past two decades and has demonstrated a significant reduction in risk at the source (CIDB, 2019). Furthermore, given that OSHCIM has similar characteristics to the CDM in the UK (due to its adaptation from CDM regulations 2015), the elements identified and verified by Manu et al. (2019) would be a valuable foundation for this DfS study. In adopting these elements, the level of specificity that might influence the organisational capability towards DfS practice were also considered. Adaku et al. (2021) suggested that the capabilities of an organisation in managing OSH are dynamic at different levels (i.e., task, project, programme, and portfolio). For this study, the capability is focused on the level of 'Project' in building and infrastructure construction projects.

In addition, to further enhance the applicability of this framework to the local Malaysian context, these elements were cross-matched with the five elements of OSHCIM; 1) Risk Management approach; 2) Appointing the right organisations; 3) Supervision, Instruction and Information; 4) Cooperating, communicating and coordinating and 5) Consulting with workers.

In the realm of "*competence*", the organisation places a premium on risk management, prevention, and coordinated action. This underscores its commitment to preempting hazards and nurturing a preventive, safety-driven mindset. "*Corporate Experience*" exhibits a seasoned stance, highlighting the strategic importance of selecting fitting organisation and personnel, coupled with vigilant supervision, cooperative teamwork, effective communication, and engagement—a collective wisdom drawn from past endeavours. The concept of "*multidimensional collaboration*" underscores the synergy between cooperative endeavours and worker engagement, revealing that safety thrives when nurtured across departments and through inclusive participation. The *"system"* highlights a systemic infusion of risk management, supervision, and coordination, embedding safety in the organisation's DNA. "*Infrastructure"* is related to infusing risk management and cooperation into the physical and technological aspects; while "*Strategy"* is concerned with harmonising organisational selection with worker consultation, indicating an overarching commitment to safety that permeates vision and day-to-day operation. Collectively, it can be seen that all six elements can address the five OSHCIM principles and hence integrate value, fostering a culture of shared responsibility and robust DfS practices.

Research Methodology

Research strategy and approach

Aligned with the research objective of comprehending the context surrounding the knowledge gap in Malaysia's current state of DfS organisational capability, the research strategy employed for this study was a survey. Also, given that this study focused on answering the research question, "What are the dynamic organisational capabilities required for DfS practice?", a quantitative research approach was adopted to systematically collect and analyze numerical data from the questionnaire survey responses. This approach was chosen due to its suitability for capturing stakeholder perceptions and insights about specific attributes, i.e., organisational capabilities (Fellows and Liu, 2015)

Survey design

The questionnaire consisted of four sections; the first section aimed to capture the respondents' demographic details. Subsequently, the second section assessed the degree to which respondents regard the attributes of organisational capability (adopted from Manu et al., 2019) as important for DfS implementation within the Malaysian construction industry. This assessment used a five-point Likert scale (1 = not at all important, to 5 = extremely important).

The third section focused on asking participants to rate the extent to which the four elements of dynamic capability (i.e., Sensing Capability, Learning Capability, Integrating Capability, and Coordinating Capability), as drawn from Pavlou and El Sawy (2011), contribute to DfS implementation in a dynamic environment. The evaluation of these four elements of dynamic capability was conducted utilising a five-point Likert scale, where respondents rated the items on a scale of 1 (not at all) to 5 (very high). Finally, the fourth section contained an open-ended section for participants to provide comments on how to improve the DfS organisational capabilities.

Survey administration

To administer the survey, a questionnaire was developed utilising the SurveyMonkey platform and made accessible to industry professionals who attended a series of online DfS webinars (4 no.) conducted in 2022 in Malaysia. These webinars are part of the engagement series by DOSH between May and August 2022 with stakeholders to promote OSHCIM practices. Thus, these webinars served as a platform for data gathering due to their capacity to encourage engagement among participants with shared expertise. Additionally, they helped establish a foundation for understanding expectations related to DfS implementation (Ørngreen and Levinsen, 2017). The purposive sampling method was used to select individuals with academic and practitioner backgrounds based on the following criteria: (1) currently working on or managing projects in the construction industry, and (2) academics and postgraduate students from accredited engineering programmes in Malaysia. This approach ensures they can provide abundant, pertinent, and varied data relevant to the field of construction OSH (Fellow and Liu, 2015). A cumulative total of 871 participants engaged across the four webinar sessions, with an average of 185 participants per session. The initial invitation for each session reached out to more than 250 potential respondents, including professionals from the DOSH industrial network who attended OSHCIM workshops and seminars. Additionally, academics and postgraduate students from Malaysian institutions offering engineering programs with an interest in construction safety received invitations through the researcher's network. A total of 460 responses were gathered from 871 participants. Of these, 306 were identified as usable. Responses from academia, students, and non-construction-related organisations were excluded from the analysis. The number of usable responses aligns well with recent DfS studies, such as the 33 responses in Saudi Arabia (Hassanain et al., 2022) and the 89 responses in Malaysia (Che Ibrahim et al., 2022b).

Data Analysis

The data from the questionnaire survey was analysed using Microsoft Excel and IBM SPSS Version 26 Software. The survey data, being ordinal and nominal, were examined using descriptive (mean and frequencies) and inferential statistics to identify variations in DfS factors among professionals from different stakeholder organizations – contractors, consultants, government agencies, and developers/owners. Given the unequal sample sizes across these organisations, normality tests (Kolmogorov-Smirnov and Shapiro-Wilk) were conducted to validate the data distribution. The results showed that the significance value (p) for all six elements was less than 0.05, indicating a non-normal distribution (Fellow and Liu, 2015). As a result, a non-parametric analysis approach was applied. Specifically, the Kruskal-Wallis H Test was used to compare distinct organisational characteristics and their capabilities, measured on a scale, ensuring an accurate assessment of differences among the various stakeholder groups in relation to DfS factors. In cases where significant differences emerged (i.e. p values less than 0.05 were accepted as the threshold for statistical significance), further pairwise comparisons using Dunn's test were conducted through the post-hoc test to identify significant differences between group means (Che Ibrahim et al., 2022c).

To develop the conceptual framework, survey findings, particularly from sections 2 and 3, were reviewed and consolidated. A content analysis was conducted to systematically categorise organisational capabilities based on four dynamic characteristics. Additionally, feedback from the survey's open-ended comments was analysed by converting raw data (quotations) into specific keywords to identify relevant DfS capabilities linked to the proposed dynamic capabilities. This content analysis allowed for a structured examination of themes and patterns within the study's context (DfS organisational capabilities) to ensure that categories and relationships from the earlier data adequately covered the research context (Fellow and Liu, 2015).

Results and Discussion

Demographic information of respondents

Table 1 shows the demographic characteristics of respondents who participated in the survey. Out of the total respondents, 71.6% were males, while 28.4% were females. The respondents' average years of experience within the construction industry were 10 years. In terms of the distribution based on the nature of the organisation, 'Micro' enterprises constitute the smallest category. The 'Small' enterprises represent a larger group, accounting for approximately 28%. The most prominent category is 'Medium' enterprises, making up almost half of the total, representing 39.8%. From the analysis of the demographic data, it is observed that the contractors make up the largest proportion, accounting for approximately 39.54% of the total respondents. They are followed by consultants, who constitute about 25.16% of the respondents. Government Agencies are represented by 22.88% of the respondents, while Developer/Owner organisations comprise the smallest group, with about 12.42% of the total. The professionals' disciplines are predominantly Civil and Structural Engineers (55.56%), with Mechanical and Electrical Engineers (9.48%) and Architects (3.59%) also represented. Quantity Surveyors and other disciplines accounted for smaller proportions of the sample.

Regarding designations, the most common roles among the respondents were Designers (e.g., Engineers, Architects, Quantity Surveyors) at 33.01% and Managers (e.g., Project, Construction, QAQC, HSE) at 37.91%. Directors and Coordinators had smaller representations. In terms of academic qualifications, the majority of respondents held a Bachelor's degree (51.96%), followed by a master's degree (MSc) (27.45%). A smaller percentage held a Ph.D. (1.63%), while Diplomas (16.01%) and Certificates (0.98%) were also represented. Among the professional qualifications, Engineers (Ir.) had the highest representation (18.95%), followed by Technologists (Ts.) (16.99%). Architects (Ar.) and Surveyors (Sr.) were less represented.

Table 1: Demographic information of respondents

Demographic information		**Distribution**	
		Freq.	%
Age	21 - 25	14	4.58
	26 - 30	43	14.05
	31 - 35	68	22.22
	36 - 40	73	23.86
	41 - 50	78	25.49
	> 50	30	9.80
Nature of Organisation	Private (Micro)	30	9.80
	Private (Small)	84	27.5
	Private (Medium)	122	39.8
	Government	70	22.9
Organisation	Government Agencies	70	22.88
	Consultant	77	25.16
	Contractor	121	39.54
	Developer / Owner	38	12.42
Disciplines of Professional	Civil & Structural	170	55.56
	Mechanical & Electrical	29	9.48
	Architect	11	3.59
	Quantity Surveyor	6	1.96
	Other	15	4.90
Designation	Designer (e.g., Engineer / Architect / Quantity Surveyor)	101	33.01
	Manager (e.g., Project, Construction, Design, QAQC, HSE)	116	37.91

Demographic information		Distribution	
		Freq.	%
	Director	17	5.56
	Coordinator	2	0.65
	Other	1	0.33
Academic Qualification	Degree	159	51.96
	Master (MSc)	84	27.45
	PhD	5	1.63
	Diploma	49	16.01
	Certificate	3	0.98
Professional Qualification	Engineer (Ir.)	58	18.95
	Architect (Ar.)	5	1.63
	Surveyor (Sr.)	4	1.31
	Technologist (Ts.)	52	16.99
	Others	-	-

Key elements of DfS organisational capability

Table 2 displays the results of the questionnaire survey on the key elements of DfS organisational capability. It is worth noting that, to demonstrate variations between organisations, the mean values were grouped into four stakeholder organisations: G1: Contractor, G2: Consultant, G3: Government Agencies, and G4: Developer / Owner. The key elements of organisational capability across different organisations are analysed as follows.

Table 2: The responses on the key elements of DfS organisational capability

Element	***Overall Mean*** (n=306)	***Mean values for each organisation G1*** (n=121)	***G2*** (n=77)	***G3*** (n=70)	***G4*** (n=38)	***Standard Deviation***	***Significant p***	***Pair-wise comparison (when p < 0.05)***	***Adj. Sig.***
Competency									
DfS skills of the designer	3.91	3.98	3.86	3.76	4.05	0.83	0.152	-	-
DfS knowledge of the designer	4.05	4.10	3.99	3.97	4.18	0.79	0.418	-	-
DfS experience of the designer	3.99	4.08	3.80	3.91	4.26	0.81	0.018	G2 – G4 (X = -46.454) G3 – G4 (X = -35472)	0.005 0.034
DfS continuous professional development	3.90	3.98	3.91	3.66	4.08	0.82	0.033	G3 – G1 (X = 32.538) G3 – G4 (X = -41705)	0.009 0.013
Designer access to competent advice	3.89	3.96	3.87	3.81	3.92	0.78	0.645	-	-
Designer recruitment and role definition	3.85	3.88	3.73	3.86	3.97	0.82	0.473	-	-
Corporate Experience									
Company/design office experience	3.77	3.81	3.73	3.70	3.89	0.84	0.598	-	-
Collaboration									
Intra-organisational collaboration	3.81	3.89	3.77	3.67	3.92	0.81	0.229	-	-
Inter-organisational collaboration	3.80	3.82	3.81	3.63	4.05	0.85	0.107	-	-
Infrastructure & Infostructure									
Information communication technology	3.80	3.88	3.66	3.76	3.89	0.82	0.317	-	-
Physical work resources	3.78	3.88	3.57	3.77	3.89	0.87	0.144	-	-
Strategy									
Company policy in relation to DfS	3.90	3.96	3.78	3.79	4.13	0.83	0.088	-	-
Top management commitment to DfS	4.13	4.16	3.97	4.10	4.39	0.83	0.075	-	-

Element	*Overall Mean* (n=306)	*Mean values for each organisation* *G1* (n=121)	*G2* (n=77)	*G3* (n=70)	*G4* (n=38)	*Standard Deviation*	*Significant p*	*Pair-wise comparison (when p < 0.05)*	*Adj. Sig.*
Research and innovation	3.82	3.89	3.69	3.76	4.00	0.84	0.219	-	-
System									
Design quality management	3.90	3.98	3.78	3.81	4.05	0.79	0.191	-	-
Design risk management	4.02	4.08	3.91	4.00	4.11	0.78	0.441	-	-
Project review	4.00	4.11	3.96	3.90	3.92	0.80	0.265	-	-
Management of outsourcing/subcontracting	3.91	4.02	3.78	3.83	3.97	0.85	0.225	-	-

Note: G1 (Contractor), G2 (Consultant), G3 (Government Agencies), and G4 (Developer/Owner)

Competency

The competency-related capabilities include “DfS skills of designer”, “DfS knowledge of designer”, “DfS experience of designer”, “DfS CPD training”, “Designer access to competent advice,” and “Designer recruitment and role definition”. Regarding “DfS skills of the designer,” the ratings demonstrate a remarkable consistency across all groups, with mean values ranging from 3.76 to 4.05. This indicates that all the different stakeholders regard “DfS skills of designer” to be of high importance for DfS implementation in Malaysia. This indicates a prevailing favourable perception of the importance of designers’ competency in DfS skills for DfS implementation in Malaysia. The variance in mean ratings is relatively narrow, signifying that designers are universally recognised for possessing robust DfS skills. There is a high mean score across all categories for “DfS knowledge of the designer”, ranging from 3.97 (Government Agencies) to 4.18 (Developer / Owner). This shows that all the different stakeholders also deem “DfS knowledge of designer” to be of high importance for DfS implementation in Malaysia. With the recent introduction of OSHCIM guidelines, having equipped knowledge might influence the stakeholder’s readiness to ensure effective DfS implementation (Che Ibrahim et al., 2022b). In terms of “DfS experience of the designer,” the mean scores range from 3.80 (Consultant) to 4.26 (Developer / Owner), suggesting that stakeholders across different organisations perceived that having substantial experience with DfS practices are critical towards DfS practice. This could imply that designers within these organisations have engaged in DfS initiatives and gained valuable experience implementing DfS principles. In addition, this could also indicate that there is active use of DfS knowledge related to safety measures among designers in the SMEs (Deepak and Mahesh, 2024).

Regarding “DfS CPD training,” the group means range from 3.66 (Government Agencies) to 4.08 (Developer / Owner). This aspect is rated the highest by the Developer / Owner organisation, which strongly emphasises providing continuous training for designers in these organisations. Such commitment is required to ensure they are fulfilling the legislative requirements on DfS continuously (Gambatese et al., 2017). The results also suggest that organisations perceive a balanced and equitable provision of competent advice to designers. Role definitions and recruitment practices for designers are similarly valued. Having such a Competent advisers, such as professional engineers or technologists, can enhance designers' hazard recognition skills using available information and materials during the design phase (Hallowell and Hansen, 2016).

Despite the fact that the lack of significant p-values suggests that differences in these elements are not statistically notable among the groups, the Kruskal-Wallis Test revealed that there were no significant differences in the size of the organisation. However, there were significant differences in two competency-related capabilities (i.e., DfS experience of the designer and DfS continuous professional development, $p < 0.05$) among the types of organisations. The Post-hoc Test revealed that designers in Consultant ($p = 0.005$, $p \leq 0.05$) and Government Agencies (both $p = 0.034$, $p \leq 0.05$) were significantly different from Developers in terms of DfS experience. This might indicate that consultant might prioritise their DfS capability in those attributes. Such capability is important as consultants such as architects could act as the principal designers, taking greater responsibility for the DfS practice, while designers from government agencies might require such capabilities to conduct checking and monitoring of the DfS implementation. The significant differences highlight that certain organisations may invest more in developing specific DfS competencies, possibly reflecting their roles and responsibilities within the construction process. In addition, the test provided strong evidence of a difference ($p \leq 0.05$) between the mean ranks of one pair of groups in the element of DfS continuous professional development between Government Agencies and Contractors ($p = 0.009$, $p \leq 0.05$) as well as Developer ($p = 0.013$, $p \leq 0.05$). This suggests that government agencies may offer more opportunities for CPD activities due to organisational policies requiring specific hours of annual training and available financial resources, indicating a greater emphasis on structured professional development in DfS.

Corporate experience

The “Corporate Experience” capability pertains to the organisation’s overall experience with DfS practices. The mean scores across all organisations are fairly close, ranging from 3.70 for Government Agencies to 3.89 for Developers / Owners. This suggests that organisations have perceived different levels of importance on the levels of experience in DfS practices. In particular, G2 (Consultant) and G3 (Government Agencies) have higher mean ratings, indicating that they perceive their companies' or design offices' importance as dependent on the internal and external environment to drive the DfS principle. The significance of these organisations may result from their direct influence on DfS practice, with the former focusing on implementation and the latter on compliance. In contrast, G1 (Contractor) and G4 (Developer/Owner) have slightly lower mean ratings, suggesting they may perceive less importance of having experience in DfS practices within their organisations. Despite the absence of significant differences in post hoc tests, this overall similarity in mean scores across groups suggests a generally shared acknowledgment of the importance of corporate experience in DfS, though the extent and focus of such experiences may vary. The variations in perceived corporate experience could be attributed to differences like involvement and focus undertaken by each group. For instance, in the case of OSHCIM, government initiatives drive its direction, leading to active participation from related agencies such as DOSH and the PWD in strategic planning. Consultants often engage in DfS activities, exposing them to various DfS scenarios and opportunities to accumulate experience (Ismail et al., 2021). In contrast, contractors and developers/owners may have a narrower scope of work related to safety and health in the planning phase, which could limit their exposure to various DfS implementations (Gambatese et al., 2017). Nevertheless, such organisational learning experiences on DfS could influence interventions to reduce at-risk work behaviors or promote safe work behaviors over the project life cycle (Jitwasinkul and Hadikusumo, 2011).

Collaboration

This is assessed in terms of collaboration within the organisation and with external entities toward DfS implementation. The mean ratings for “Intra-organisational collaboration” range from 3.67 (Government Agencies) to 3.92 (Developer / Owner), indicating a generally positive perception of DfS collaboration within organisations. This suggests that smaller organisations recognise the importance of teamwork and internal collaboration to perform a coordinated set of tasks and resources in driving DfS practices (Adaku et al., 2021). In addition, continuous initiative towards instilling a safety culture and commitment among the SMEs could also facilitate positive collective mindfulness on the code of conduct and policies towards better collaboration (Belayutham and Che Ibrahim, 2019). Notably, Developer/Owner organisations exhibit slightly higher mean ratings, suggesting a greater focus on nurturing collaboration is critical, possibly due to broader departments or disciplines within their establishments encompassing a more comprehensive array of operational activities.

In terms of “Inter-organisational collaboration,” the mean ratings range from 3.63 (Government Agencies) to 4.05 (Developer / Owner). This suggests that while the importance of collaboration between organisations is generally perceived positively, there are variations across the groups. The Developer / Owner and Consultant organisations demonstrate higher mean ratings, potentially highlighting on the importance of building partnerships and alliances to facilitate DfS implementation, especially in collaboration with contractors (Guo et al., 2021). On the other hand, Government Agencies have slightly lower mean ratings, suggesting potential areas for enhancing inter-organisational collaboration endeavors. Such limitations might be due to several factors such as bureaucratic barriers, regulatory constraints, and competing priorities that hinder effective collaboration with external organisations. These endeavors hold significance as prior research (e.g., Karakhan and Gambatese, 2017; Ismail et al., 2021) has emphasised the government's pivotal role in advancing DfS practices through legislation, procurement, and incentives. The impact of procurement on the practice of DfS has been recognised as one of the main factors that promotes improved collaborative safety among organisations (Che Ibrahim et al., 2022b). Furthermore, the utilisation of digital platforms to influence the DfS practice has also been acknowledged as a significant component in improving both Inter and Intra-organisational collaboration (Farghaly et al., 2022). The lack of significant p-values suggests that the differences in mean values of these elements across organisations are not statistically significant. This finding suggests a broadly shared recognition among all types of organisations of the critical role collaboration plays in DfS implementation. Despite this common understanding, the slightly higher ratings for Developers/Owners and Consultants could indicate their proactive efforts in fostering collaborative practices, while the lower scores for Government Agencies might point to existing challenges in enhancing collaborative endeavors, potentially due to regulatory constraints or structural contractual complexities.

Infrastructure & Infostructure

The Infrastructure & Infostructure element evaluates the availability of resources, specifically "ICT resources" and "Physical work resources," to support DfS implementation within organisations. Across the organisations, the mean ratings for "ICT resources" range from 3.66 (Consultant) to 3.89 (Developer / Owner), indicating a generally positive perception of the availability of ICT resources to support DfS practices. This suggests that organisations recognise the importance of leveraging technology and digital tools in facilitating efficient and effective DfS implementation. Such ICT resources are crucial as they could facilitate knowledge-based systems, automatic rule checking, hazard visualisation, and safety training for designers (Farghaly et al., 2022). Nonetheless, such accessibility and inclusivity concerns of the technology must be meticulously addressed within the organisation to ensure the training and execution of such practices can be implemented effectively (Hallowell and Hansen, 2016; Jin et al., 2019).

Regarding “Physical work resources,” the mean ratings range from 3.57 (Consultant) to 3.89 (Developer / Owner). These ratings indicate variations in the availability and adequacy of physical resources for DfS implementation. The Developer / Owner organisation reports the highest mean rating, suggesting that it perceives the importance of its organisation to possess better physical work resources to support DfS practices. This could be attributed to their typically advantageous financial standing, enabling them to operate in more favourable locations or offices. On the other hand, Consultant and Contractor organisations have lower mean ratings, indicating a potential need for improvement in the availability of physical resources within their organisations. This could stem from smaller organisations prioritising flexibility and responsiveness in meeting market demands (Belayutham and Che Ibrahim, 2019). Such resources must be provided to ensure continuous practice-level social and organisational action, minimising the fragmentation between the actors within the organisation (Cidik and Phillips, 2021). The lack of significant p-values suggests that the differences in mean values of these elements across organisations (based on their sizes and types) in equipping themselves with infrastructure and infostructure are not statistically significant. This indicates a shared understanding among organisations about the importance of ICT and physical resources in supporting DfS practices. Higher ratings from Developers/Owners may reflect their greater financial capacity, while lower ratings from Consultants and Contractors suggest challenges in resource allocation due to limited funding.

Strategy

The Strategy category examines the presence and effectiveness of organisational strategies related to “DfS company policy,” “Top Management commitment to DfS,” and “Research and Innovation. “The mean ratings for “DfS company policy” range from 3.78 (Consultant) to 4.13 (Developer / Owner) across the organisations, indicating a generally positive perception of having specific policies in place to guide DfS implementation. The Developer / Owner organisation reports the highest mean rating, suggesting that it perceives the importance of its organisation as having well-defined policies supporting DfS practices. Given that developers often encompass multiple departments; it becomes essential to establish policies that promote collaborative efforts among these departments. In contrast, Consultant and Contractor organisations have slightly lower mean ratings, indicating potential areas for improvement in formalised DfS policies. In addition, certain design firms may lack the necessary rules to provide guidance to project team members in order to minimise OSH risks during project delivery (Manu et al., 2019). Regarding “Top Management DfS commitment,” the mean ratings range from 3.97 (Consultant) to 4.39 (Developer / Owner). These ratings indicate a generally high level of importance on the commitment from top management across all organisations toward DfS implementation. This suggests that organisations recognise the importance of leadership support in driving successful DfS practices. Acknowledging this could lead to a shift in the behavior of designers, transitioning from mere compliance to a more dedicated commitment. Such management commitment and leadership are two of the factors facilitating the integrated feature of safety intervention within organisational behaviors (Jitwasinkul and Hadikusumo, 2011). Consequently, this shift could contribute to the ongoing and sustainable effective DfS implementation (Che Ibrahim et al., 2022a). In terms of “Research and Innovation,” the mean ratings range from 3.69 (Consultant) to 4.00 (Developer / Owner). The findings revealed that Developer/Owner organisations and Government Agencies (such as DOSH and CIDB) are perceived as displaying a stronger commitment to

DfS research and innovation, which can be attributed to their diverse range of resources. The lack of significant p-values suggests that, despite some variations, all organisations recognize the importance of DfS strategies, though the extent of their development and execution may vary based on organisational structure and capacity.

System

The System category evaluates the systems and processes related to DfS implementation, including “Design quality management,” “Design risk management,” “Project review,” and “Management of outsourcing”. The mean ratings for “Design quality management” range from 3.78 (Consultant) to 4.05 (Developer / Owner) across the organisations, indicating a generally positive perception of the importance of design quality management systems in place for DfS. This suggests that organisations recognise the importance of maintaining high design standards and ensuring the quality of DfS practices. The slight variations in mean ratings suggest that some organisations (e.g., the in-house design team in Government agencies) may have more robust design quality management systems compared to others, potentially resulting in better outcomes and fewer design-related issues during DfS implementation. Shifting organisational culture towards structural interventions through the implementation of wider management systems could influence the culture of building safety practices (Cidik and Phillips, 2021). The element of “Design risk management” received mean ratings ranging from 3.91 (Consultant) to 4.11 (Developer/Owner). These ratings collectively suggest a favourable perspective regarding the efficacy of design risk management systems in recognising, evaluating, and alleviating risks linked to DfS. This implies that organisations are proactive in facilitating designers in addressing potential risks and are committed to ensuring safe and sustainable design outcomes (Hallowell and Hansen, 2016). Also, such system can serve as a guide to designers in respect of their DfS competence development (Adaku et al., 2021).

For "Project review," the mean ratings range from 3.90 for Government Agencies to 4.11 for Contractors. Organisations agreed that "Project reviews" provide an opportunity to assess design outcomes, identify areas for improvement, and capture lessons learned for future projects. The slight variations in mean ratings suggest that some organisations may have more formalised and comprehensive project review processes, enabling them to derive greater value and insights from the iterative review activities.

In terms of "Management of outsourcing," the mean ratings range from 3.78 (Consultant) to 4.02 (Contractor). These ratings indicate variations in the effectiveness of managing the outsourcing or subcontracting for DfS projects. The findings indicate that regardless of the nature of an organisation, improved management practices involving well-defined roles, and effective communication channels are essential to address potential challenges such as coordination issues or difficulties in maintaining consistent DfS practice. Having such a management system could facilitate continuous engagement among the designers with the DfS practice within the organisations (Hassanain et al., 2022). The lack of significant p-values suggests that organisations value systems to facilitate and monitor DfS practices, reflecting a shared commitment to DfS principles.

Framework of Dynamic DfS Organisational Capabilities in Construction

In today's rapidly evolving construction industry, characterised by technological advancements, regulatory complexities, and complex client requirements, dynamic capabilities have gained significant importance. These capabilities, as defined by Teece et al. (1997), refer to an organisation's ability to adapt and reconfigure its operational competencies and resource base to meet changing market demands. Such capabilities are seen as vital for construction organisations aiming for sustained competitive advantage in a shifting business landscape. This research explores the organisational DfS capabilities essential for navigating dynamic environments, drawing on the conceptual dynamic capability framework proposed by Pavlou and El Sawy (2011). The framework identifies four key capabilities: *Sensing Capability*, *Learning Capability*, *Integrating Capability*, and *Coordinating Capability*, which are critical for addressing unpredictable challenges and fostering a sustainable competitive edge in the construction sector. These dynamic capabilities also form the foundation for organisational agility, enabling companies to proactively detect market shifts, assimilate new knowledge, and integrate resources to adapt to constant changes. The adoption of Pavlou and El Sawy's (2011) model as a means of articulating "dynamic capabilities" has been widely recognized by scholars as both actionable and well-defined (Beltran and Ramesh, 2017). Analyzing responses related to the four dynamic organisational capabilities (see Table 3) reveals variations across different stakeholder groups. Consultants were observed to have relatively lower mean ratings across the four capabilities, possibly due to a focus on specialised expertise, such as design activities, rather than the broader context of safety capabilities, including identifying DfS requirements, learning DfS knowledge, integrating these into design processes, and implementing DfS measures. In contrast, Contractors showed consistently higher ratings than Consultants, reflecting their adaptability in learning and implementing DfS practices across construction projects. Developers received the highest ratings across all capabilities, indicating strong confidence in their ability to innovate, adapt, and coordinate efforts in managing DfS practices. Government Agencies also demonstrated strength, especially in Integrating and Coordinating Capabilities, which may reflect the complexities of aligning various governmental functions and responding to diverse industry needs toward better safety outcomes.

Table 3: The responses on the dynamic organisational capability

Dynamic Capabilities	Descriptions	Organization			
		Consultant	Contractor	Developer	Government Agencies
Sensing Capability	Identifying and understanding safety requirements and opportunities for the market	3.52	3.59	3.82	3.71
Learning Capability	Acquiring new knowledge and updated with the latest safety practices and regulations	3.51	3.64	3.92	3.76
Integrating Capability	Fostering individual knowledge toward collaboration and coordination within their organizations and across external stakeholders	3.52	3.70	3.95	3.81
Coordinating Capability	Supporting the effective coordination and management of safety-related activities	3.58	3.65	3.97	3.79

Identifying and emphasising the four dynamic organizational capabilities has enabled the establishment of a framework relating to six key elements of organisational DfS capability: 1) Competence, 2) Strategy, 3) Infrastructure, 4) System, 5) Collaboration, and 6) Corporate Experience. The relationships between dynamic capabilities and these key elements were framed based on their characteristics. For instance, the need for knowledge, skills, and experience drives the efficient identification of new market opportunities. Additionally, the capacity for organisational learning is influenced by continuous mechanisms that enhance domain-specific knowledge and skills among designers. Strategic recruitment and collaborative practices ensure continuity by integrating knowledge within the organisation, while allocating and deploying resources strategically coordinates DfS measures for operational processes. Accordingly, the dynamic DfS organisational capabilities framework (see Figure 1) developed based on these elements highlights how strengthening these capabilities is crucial for success in the dynamic construction sector.

First, the *sensing capability*, represented by DfS competencies - skills, knowledge, and experience of designers, forms the basis for identifying safety-related challenges in construction. The organisation's ability to identify DfS-related opportunities evolves significantly when DfS requirements become mandatory, aligning ordinary capabilities with strategic goals and fostering a safety-conscious culture (Nedzinskas et al., 2013). In environments where DfS expertise is required, organisations with these competencies make more effective decisions, sustaining a competitive advantage (Adaku et al., 2021). Continuous support from organisational leadership, focusing on a professional competency framework for diverse teams, is crucial (Jia, 2022). Conversely, the absence of DfS competency hinders sensing capability, as seen in studies from Pakistan and Saudi Arabia (Che Ibrahim et al., 2022a). This lack impedes stakeholder engagement and fails to create the competitive advantage necessary for adopting DfS in the construction industry.

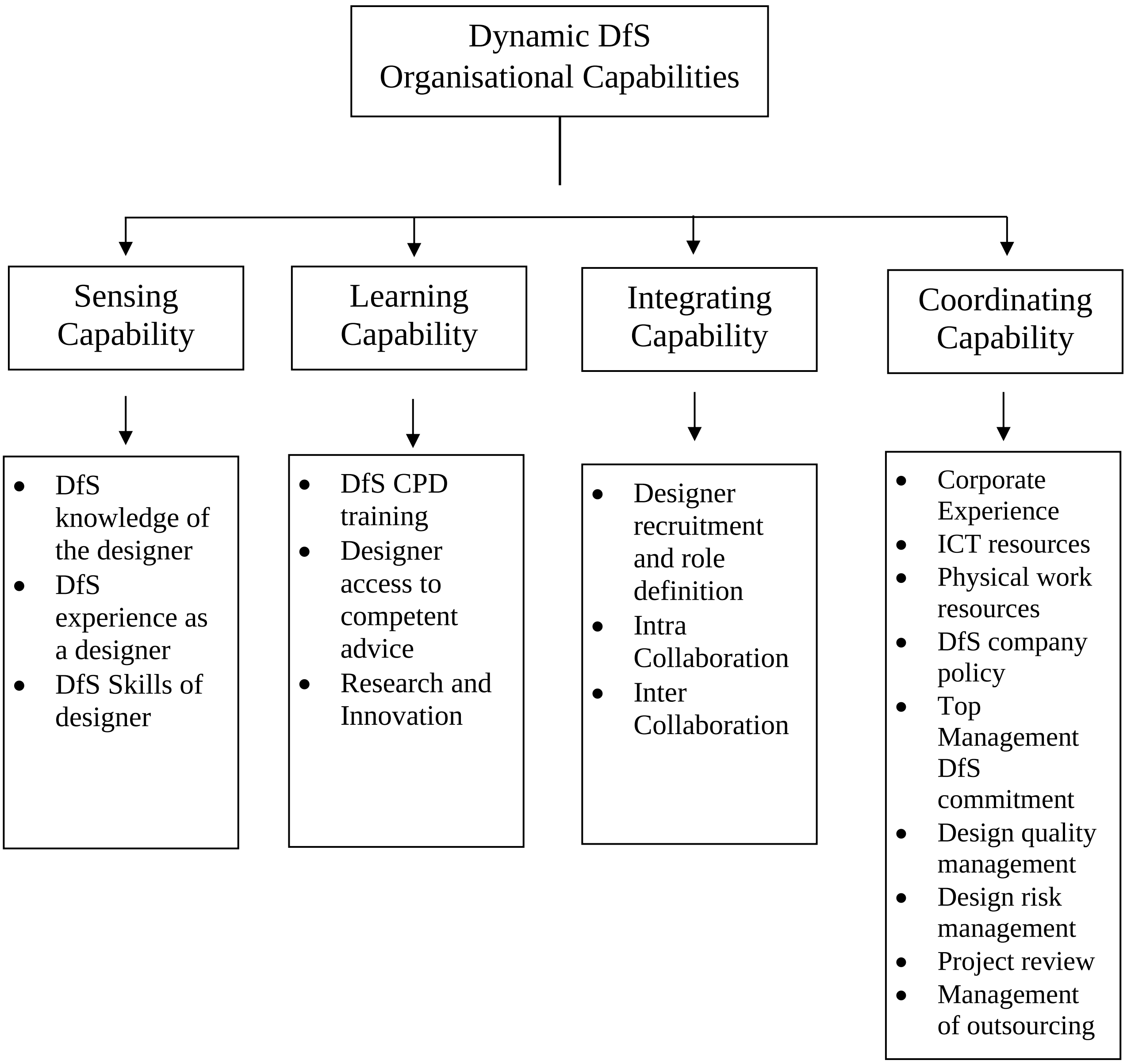

Figure 2: Conceptual framework of Dynamic DfS organisational Capabilities

Learning capability is crucial for enhancing an organisation's DfS practices. By investing in continuous professional development and providing access to expert advice, organisations empower designers to stay updated on the latest DfS practices and regulations. As DfS is relatively new, acquiring this knowledge improves designers' competencies, integrating it into practices that emphasize organisational learning and resilience (Jia, 2022). This approach enables stakeholders i.e., consultants, contractors, and government agencies to prioritize safety in design, construction methods, and policy refinement (Che Ibrahim et al., 2022a). Scholars like Guo et al. (2021) and Phan and Zhou (2023) highlight the importance of top management's support for learning activities. This support should encompass knowledge sharing, communication, and collective learning (Ozmec et al., 2015). Allocating financial resources is also essential to adopt recent technologies that facilitate DfS, such as Building Information Modeling (BIM) and Virtual Reality, to meet DfS regulations (Abueisheh et al., 2020; Jin et al., 2019). Investing in learning is vital for enhancing designers' absorptive capacities by nurturing technical and collaborative skills needed for DfS implementation. Additionally, investment in DfS research, especially in larger organisations, is a necessary supplement to learning activities, creating more opportunities and fostering a DfS-focused culture (Manu et al., 2019).

Integrating capability enables organisations to collectively transform individual knowledge into a shared understanding and interpretation of safety in design processes, both within and outside their organisations. The success of these integrating capabilities depends on fundamental routines such as contributing, representing, and interrelating (Nedzinskas et al., 2013). These routines can be fostered through intra-organisational collaboration, which promotes effective communication and knowledge sharing among various teams and departments. Inter-organisational collaboration, such as partnering with external stakeholders like consultants and contractors, further enhances the integration of safety practices, thereby enabling the collective pursuit of safety goals. Recent scholars (e.g., Jin et al., 2022) indicate that such collaboration is crucial for quantifying the benefits of DfS, addressing existing fragmentation (Ismail et al., 2021), and overcoming legal, economic, and contractual barriers (Tymvios and Gambatese, 2016). The adoption of collaborative procurement could also provide guidance on the formation of action situations that incentivise collaboration and teamwork (Jia, 2022). This, in turn, fosters a more collaborative culture in a dynamic environment. A diverse three-party collaboration is needed to facilitate the collaborative movement towards enhancing OHS knowledge, attitude, and practice among SMEs (Belayutham and Che Ibrahim, 2019). In addition, the recruitment and role definition of designers also plays a significant role in the integration of DfS practices. Adhering to DfS principles requires organisations to appoint individuals who align with their commitment to collaborative safety practices (Manu et al., 2019).

Coordinating capability focuses on the effective orchestration and deployment of DfS measures. Effective coordination is closely linked to the seamless integration of expertise and information. A company's or design office's experience plays a vital role in coordinating safety efforts; organisations with prior experience can leverage their knowledge to establish DfS protocols, streamline processes, and ensure compliance with safety regulations (Gambatese et al., 2017; Karakhan and Gambatese, 2017). Adequate infrastructure and information systems, including technology tools and platforms, support the coordination and management of DfS-related activities. Notable examples include work conducted by Zhang et al. (2015) on the safety modeling of fall protective systems and by Jin et al. (2019) on using 4D BIM to assess construction risks. Scholars such as Karakhan and Gambatese, 2017) have also highlighted the importance of developing a clear safety strategy and securing top management commitment for effective coordination. Such support from top management ensures the allocation of resources, establishing a DfS culture, and promoting a proactive approach to DfS practice.

Also, the use of a collaborative framework in specific procurement could provide a bottom-up perspective on how an institutionalisation process can facilitate coordination activities and, hence, influence the self-organising practice of crafting rules to manage common pool resources within an organisation. (Jia, 2022). Organisations can establish mechanisms for regular project reviews, safety audits, and feedback loops by implementing effective design quality management, risk management, and project review processes. These mechanisms enable the collection of information on safety incidents, near misses, or lessons learned and allow for systematic decisions on hazard identification, risk assessment, incident reporting, and continuous improvement of safety performance (Hallowell and Hanse, 2016; Morrow et al., 2016). Furthermore, effective management of outsourcing and subcontracting ensures that DfS requirements are communicated and enforced through well-defined contractual agreements, maintaining high safety standards across the supply chain.

Overall, the interplay between these elements enables organisations to adapt, learn, and improve their DfS capabilities in a dynamic environment over time. It is important to note that these capabilities are interconnected and mutually reinforced. For instance, sensing capability informs learning capability by identifying areas where organisations need to enhance their knowledge, experience, and skills. Integrating capability relies on the learning capability of designers to ensure that DfS knowledge is effectively shared and integrated. Coordinating capability utilises insights from both sensing and learning capabilities to guide decision-making and resource allocation for DfS-related initiatives.

Conclusion

This study aimed at advancing the understanding of dynamic DfS organisational capabilities in the construction industry, focusing on a developing country, Malaysia. This is the first formal investigation of DfS in such a context. The research builds upon existing frameworks for DfS organisational capabilities and incorporates insights from over 300 practitioners across various construction organisations in Malaysia. It identifies six key elements integral to organisational DfS capabilities: 1) Competence, 2) Strategy, 3) Infrastructure, 4) System; 5) Collaboration; and 6) Corporate Experience. These elements were observed to exert explicit and implicit importance on the evolution of construction organisations toward adopting OSHCIM. The study further reveals that the extant dynamic environment in the construction sector necessitates organisational adaptability to maintain a competitive edge. These insights have culminated in formulating a framework for dynamic DfS organisational capabilities. The framework put forward four key capabilities, Sensing, Learning, Integrating, and Coordinating, which are instrumental in shaping dynamic DfS organisational capabilities. The framework suggests the interplay among these four capabilities, anchored by the aforementioned six key elements, as foundational to deriving value from DfS practices.

This study advances DfS knowledge in construction, both theoretically and practically. The theoretical foundation (i.e., DfS framework) established in this study provides a systematic overview of DfS capabilities by integrating organisational and dynamic capabilities for DfS adoption. It serves as a valuable reference for academia and industry, providing a benchmark for developing countries to enhance their DfS capabilities where organisational limitations are evident. Drawing on the framework of dynamic organisational capabilities, this insight can be integrated into existing DfS-related guidelines. This will facilitate a practical understanding of how different organisations perceive and prioritise their capacity to sense changes, internalise new competencies, integrate resources, and coordinate activities, thereby reflecting their unique strategic focus and operational needs.

While this study makes significant efforts to address gaps in the DfS literature (i.e., organisational capabilities in developing countries), three limitations were acknowledged.

First, the study's findings originated in the Malaysian context and focused on specific target groups (i.e., those who attended related DfS activities), necessitating additional international research with wider sampling for the generalisability of the DfS organisational elements and the four dynamic capabilities. Secondly, the study employs a quantitative methodology; future investigations could benefit from qualitative approaches, such as focus groups or case studies. Such methodologies could provide richer insights into the interplay between organisational characteristics and these capabilities, thereby addressing challenges commonly faced by construction organisations, particularly SMEs, such as resource limitations, informal organisational structures, and niche specialisations. Thirdly, the framework proposed is conceptual and does not take into account the different characteristics of organisations and has yet to been empirically validated. Consequently, the nature of different organisations with different operational strategies and the extent of the interdependence among these capabilities present an avenue for further research, posing potential challenges in operationalising the framework.

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