Design for Safety (DfS) Implementation in the Construction Industry: A Study of Design Professionals in Northern China

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Abstract

Purpose: Design for Safety (DfS) has been studied as an effective method to reduce injuries and fatalities in construction. Although the benefits of implementing DfS are gradually being recognised, there is limited research on DfS in developing countries, including China. Therefore, this study explores the implementation of DfS among design professionals in the northern geographical region of China.

Design/methodology/approach: Adopting the quantitative research method, a questionnaire survey was used to obtain data from 68 design professionals on various aspects of DfS implementation, and the data were analysed using descriptive and inferential statistics (i.e., T-tests).

Findings: The results show that the extent of engagement in DfS practices among the design professionals is moderate despite high awareness and positive attitude towards the concept of DfS. The results also revealed a significant difference in the extent of implementation of DfS practices between designers who have received DfS related education and training and those who have not. Furthermore, the findings reveal that DfS industry guidance and legislation are the most influential factors that affect DfS implementation in China.

Originality/value: Overall, the study offers some positive outlook of DfS implementation among design professionals in Northern China and underscores the significance of training, education, industry guidance, client influence, and legislation in efforts to enhance DfS implementation. The findings should offer a headway to assist in DfS implementation in various geographical settings in China.

Keywords: construction; design for safety; prevention through design; developing countries; China; survey

1. Introduction

The construction industry makes an important contribution to the gross domestic product of countries (see Nursjanti, 2019). Unfortunately, the incidence of accidents in the construction industry has remained high both in developing and developed countries. In 2022, there were 1,092 deaths in the US construction industry, accounting for 20% of all work-related deaths (Bureau of Labour Statistics, 2023). In the UK, 138 workers died in 2023/2024, and over one-third of the fatalities occurred in the construction sector (Health and Safety Executive (HSE), 2024). The high fatality rate has led to increasing attention to occupational safety and health (OSH) in the construction industry (Schulte et al., 2008; Kineber et al., 2023). At the same time, the effects of accident on the completion of projects are paramount as the occurrence of these accidents directly affect the duration and cost of projects (Toole et al., 2017).

The reasons for the high fatality rate in the construction industry are complex, and many studies have suggested different possible ways of controlling such accidents. For example, a study conducted by Mohammadfam et al. (2017) indicated that occupational safety and health management (OSHM) serves as a strategic mechanism for improving the OSH performance in the construction industry, thereby effectively reducing the incidence of accidents, and ensuring labour productivity. Despite such initiatives, a linkage has been found between design and the accidents that occur on construction sites. For instance, Behm (2005) investigated 224 deaths and found that 42% were related to design. Similarly, 47% of the 100 accidents that Gibb et al. (2004) investigated were design related. In a recent study, Vasconcelos et al. (2024), upon analyzing several cases of fatal construction accidents, arrived at the conclusion that incorporating safety measures into designs can eliminate about 23.6% of accident occurrences. These instances together with many others (e.g., Rantshilo et al., 2024; Sharar et al., 2024; Manu et al, 2014) provide sufficient evidence to prove that design decisions play a key role in the accidents and injuries that occur on construction sites.

These issues make the concept of design for safety (DfS) (also known as "prevention through design" (PtD) in some countries) very important in the construction industry. Due to the complex management structure, participants in construction projects tend to work in 'silos' and usually make decisions independently (Atkinson and Westall, 2010), especially between designers and builders, which can endanger the safety of workers during construction. When examining this issue, studies have shown that multi-stakeholder collaboration can promote designer participation in DfS, thereby facilitating its implementation (Toh et al., 2017). Most of the research on implementation of DfS have focused on developed countries (Manu et al., 2018). Although more empirical research has begun to examine the level of DfS implementation in developing countries in recent years (e.g., Manu et al., 2018; Manu et al., 2019; Abueisheh et al., 2020; Christermaller et al., 2022; Rantshilo et al., 2024); China, as a developing country, still has limited research on DfS, particularly an inquiry into the status quo of the implementation of DfS. DfS studies on China have mainly focused on development of digital tools such as BIM-based tools to support DfS (e.g., Yuan et al. (2019), and Xiahou et al. (2022)). This study therefore investigates the implementation of design for safety among design professionals in the Chinese construction industry with a geographical scope of Northern China. To achieve this aim, the following specific objectives were set: (1) To assess the design professionals' awareness and attitudes to the concept of DfS; (2) To determine the design professionals' extent of engagement in DfS practices; and (3) To identify the factors that influence the implementation of DfS. The subsequent sections give an overview of construction OSH in China's construction industry and explores the concept of DfS. This is followed by the research methodology applied in the study, and then after the research findings and discussion. The article closes with the concluding remarks and the study implications.

2. Literature review

2.1 Occupational health and safety in the construction industry: The context of China

With the rapid development of the Chinese economy, research regarding the Chinese construction industry has attracted interest from researchers. For example, Luo and Gale (2000) focused on the Chinese construction industry's management and administration system and the role and functions of the Ministry of Construction (MOC). Other studies discussed some management problems within China's construction sector, such as the traditional management method, the formation of project supervision, and organizational structure (Rudykh et al., 2021). In addition, the scale and importance of the construction industry in China's economic development have been increasing over the years (Ju and Solopova, 2024). More recently, the construction industry has occupied a unique position in China's economy. According to the China Construction Industry Association (CCIA) statistics in 2018 (CCIA, 2018), China's GDP reached 90 trillion yuan (about 13 trillion US dollars), and the construction industry contributed more than 26%.

As most cities in China are expanding rapidly, many large-scale construction projects are urgently needed to meet the demand for accommodation and infrastructure (Peng and Peng, 2018), which brings opportunities to thrive in the construction industry. However, the increasing number of construction project may have caused higher risks of construction accidents, and consequently a poor safety performance on construction sites that have attracted widespread attention (Yu et al., 2014). Accidents during the construction process have caused many casualties and economic losses, positioning the industry as one of the most dangerous industries (Ju and Solopova, 2024).

China has made efforts in OSH for construction safety by promulgating laws, regulations and technical specifications, such as the Labour Law (1995), the Construction Law (1998) and the Law of Working Safety (2002). Specifically, Construction Law (1998) states that “prevention has been given top priority to conduct safety management” and makes mandatory requirements for safety management in all phases of the project cycle (i.e., design, construction, and commissioning) (Shang et al., 2006). For example, as required, the contractor must be responsible for the workers’ safety on the construction site. However, Feng et al. (2023) stated that violations of this law are common due to uncontrolled market behaviour and limited execution resources. Regulations are strict, but sanctions for non-compliance and violations are ambiguous (Feng et al., 2023). Therefore, unless a serious accident occurs, contractors are unlikely to be punished. In addition, three administrations are responsible for OSH management in different regions of China, leading to a complex and obscure responsibility for safety supervision.

Although the concept of occupational safety and health management system (OSHMS) has been established in the Chinese construction sector for many years, its implementation has been voluntary (Chen et al., 2023). The traditional safety risk management has always focused on identifying and eliminating on-site hazards, which are generally done by project contractors (Zhang et al., 2022), instead of design professionals, who are mainly responsible for the safety of end-users rather than construction workers (Almaskati et al., 2024). This situation has continued in the construction industry in China to date, even though the Construction Engineering Safety Management Ordinance (2003) stipulates that all parties involved in construction activities have responsibilities to ensure the safety of workers on-site. Among them, design institutes and firms must prevent safety accidents caused by unreasonable design, consider the needs of construction occupational safety and health, and specify key parts of design documents related to construction safety. By introducing this regulation, the Chinese construction industry acknowledges that clarifying the designer's responsibility for construction site safety can contribute to OSH improvement. However, despite the strengthening of construction safety regulations in China, DfS as a proactive approach is not as embedded in the country's construction safety regulatory framework and industry practice as compared to other countries (e.g., UK, Singapore, and countries in the European Union) where there are dedicated DfS regulations that have stimulated its practice (Toh et al., 2017; Yue et al., 2020; Martínez-Aires et al., 2024). Furthermore, one of the few DfS studies on China points to limited awareness of DfS, particularly in the subway engineering sector (Yue et al., 2020). Nonetheless, it is envisaged that the promotion of digital construction technologies (such as Building Information Modelling) and industrialised construction in China could help to stimulate acceptance of DfS in the industry (Yue et al., 2020). Notwithstanding these developments, the dearth of literature on DfS practice in China necessitates that more studies are conducted to yield further insights that can inform its wide acceptance and implementation in China.

2.2 Design for safety (DfS)

Among many factors that negatively impact safety, design is considered to have an enormous impact on safety performance. Haslam et al. (2005) investigated 100 non-fatal injuries and found that changes in design can eliminate up to 50% of accidents in the construction industry. In addition, Hui (2015) pointed out that 44% of the fatal cases in Singapore's construction sector in 2012 may have been prevented if the design of safety elements had been included in the design stages. From these studies, it is evident that design for safety can be a useful measure to reduce the number of accidents, injuries and deaths in the construction industry (Tymvios and Gambatese, 2016). Overall, these studies highlight the importance of design for the safety of construction sites. Consequently, the established connection between design and accidents has instigated several national legislations requiring designers to design for workers' safety (Poghosyan et al., 2018).

The American Society of Civil Engineers (ASCE) has identified the importance of design for construction safety (Gambatese et al., 2005) and regarded it as a key consideration for construction safety. Its Policy Statement Number 350 stipulates that designers and engineers have the responsibility to consider safety and constructability. Similarly, in 1992, the European Union stipulated that safety should be considered once the design phase starts, and designers should bear the legal responsibility according to the law. Subsequently, the Construction Design and Management regulations (CDM) of the United Kingdom in 1995 clearly stated that designers are responsible for ensuring that construction design avoids the foreseeable risks that construction workers may face. Likewise, designers in Australia are given similar responsibilities. The NSW Construction Policy Steering Committee (2000) states that the safety management strategy of the design process should include consideration of OSH within the construction process. Similar regulations are introduced in the Construction Engineering Safety Management Ordinance in China (2003). Aside acknowledging the importance of design for safety in construction, studies have also considered the factors that can influence its implementation (Poghosyan et al., 2018). The factors are discussed in the following section.

2.3 Factors that affect design for safety implementation

Researchers report that there are influential factors to the implementation of DfS; for example, the designer's changing attitude towards DfS, the establishment of incentive mechanism, the designer's increasing understanding of the concept, and the degree of construction safety knowledge at the design stage (Gambatese et al., 2005). In a survey conducted by Goh and Chua (2016), the main challenges of DfS implementation were identified as financial burden, lack of guidance and clear assignment of responsibilities. Similarly, Tymvios and Gambatese (2016) found the obstacles to implementing DfS to be financial cost, laws, and contracts. The following sections summarise several influencing factors from the literature.

2.3.1 Designer attitude

Considering DfS at the design phase is a crucial step to achieving its implementation. Besides, recent research also confirmed that a designer’s attitude is an important factor influencing the actual practice (Toh et al., 2017). For example, the research carried out by Tymvios and Gambatese (2016) found that among the four groups of respondents engaged in different construction-related work, the majority of people in the group of designers are the most reluctant to accept the concept of DfS. On the other hand, some empirical studies in other countries indicate that designers are positive about DfS (Gambatese et al., 2005; Toh et al., 2017). Based on this, it is logical to conclude that if designers have positive attitude towards DfS, the implementation should be better. However, the results of other studies suggest that even if designers have positive attitudes towards DfS, the implementation of DfS may still be low (Abueisheh et al., 2020), thereby signalling that DfS implementation could result from an interplay of multiple influencing factors.

2.3.2 Education and training

Reviewing past literature, many papers pointed out the importance of education and training in DfS for effective implementation (Gambatese et al., 2005; Toh et al., 2017). Gambatese (2000) states that reasons for the lack of participation of design professionals in implementing DfS include the lack of education and training in avoiding safety issues on construction sites and their inability to guide on-site activities. Similarly, Toole (2005) believes that the designer's lack of understanding of the construction process is a major obstacle that hinders designers from improving the workers' safety. These views are also supported by Behm et al. (2014), who found that education would affect the designers' views on accident causation and prevention. Sacks et al. (2015) conducted a study showing that consulting and communicating with experienced construction professionals can influence designers to consider safety issues when adjusting design details. Therefore, education and training are regarded as effective measures for promoting the implementation of DfS.

2.3.3 Clients' influence

Clients' decisions and requirements may indirectly lead to construction accidents (Suraji et al., 2001; Rodrigues et al., 2015). Additional incentives from clients, direct instructions and contract requirements, are needed to motivate designers to promote OSH (Tymvios and Gambatese, 2016). Moreover, the results of recent empirical studies have revealed that clients' influence is a vital factor that promotes the implementation of DfS (Goh and Chua, 2016; Abueisheh et al., 2020; Christermaller et al., 2022). In particular, some of DfS measures, such as eliminating toxic substances in construction materials could be included in the project contract drawn up by clients to generate motivation in design professionals to practice DfS. Besides, the fact that some clients pay great attention to reputation could also incentivise designers to promote the implementation of DfS (Goh and Chua, 2016). Gambatese et al. (2005) have a similar view, as they further discussed the importance of clients prioritising safety. Other studies focused on particular stakeholders in the design stage also support the importance of clients in promoting safety. For instance, a study by Goh and Chua (2016) highlighted that engineers generally believe that clients have the most significant influence on their practice of DfS. Despite the evidence, a review by Poghosyan et al. (2018) demonstrates that although the client's impact may be the most influential factor on DfS implementation, there is limited published studies on this factor.

2.3.4 Legislation

DfS legislation is also an important driver in the implementation of DfS. In many countries, construction parties have a legal duty to manage OSH and are pressured to promote and encourage the implementation of DfS (Toole et al., 2017). This has encouraged researchers to assess the perception of legislation in different national contexts. For instance, Abueisheh et al. (2020) reported that legislation is considered to be an influential factor for DfS implementation among design professionals in Palestine. Malaysian construction engineers, surveyed by Che Ibrahim and Belayutham (2020), hold a similar view, that there must be institutional pressures, including formal and informal regulations, norms and practices, to ensure the successful implementation of DfS in Malaysia. They also believe that these pressures can significantly influence the behaviour of the project clients in the adoption of DfS. From the literature review by Usman (2015), it can be concluded that the implementation of DfS has improved in countries that adopt OSH legislation, such as the United Kingdom and Australia.

3. Research Methodology

A quantitative research approach was adopted to obtain a generic perspective of issues regarding DfS implementation among design professionals in China. The quantitative approach makes use of questionnaires to obtain data from appropriate respondents. Other studies of similar nature (e.g., Goh and Chua, 2016; Manu et al., 2018, 2019; Abueishah et al., 2020) have used this approach.

3.1 Design of survey instrument

The questionnaire was the main survey instrument used to gather data for the study. The questionnaire was divided into two parts. The first part gathered background information of the participants, including professional roles, working experience (within their role and the construction industry sector), location of work, education level, professional membership, the type and size of the participants' work organisation, and the professional association membership of the organization where they work. The items or questions regarding the background information were obtained from previous design for safety studies (Goh and Chua, 2016; Manu et al., 2018, 2019; Abueishah et al., 2020).

The second part of the questionnaire gathered information about the participants' understanding of the concept of DfS before engaging in the survey; their attitude to DfS (i.e. their perceived importance of DfS and interest in implementing DfS in their work); their education and training regarding DfS; how frequently they implement DfS practices; and their views on the factors that affect the implementation of DfS. The questionnaire items or questions regarding the gathered information were also obtained from previous design for safety studies (Goh and Chua, 2016; Manu et al., 2018; 2019 Abueishah et al., 2020). Regarding the frequency of implementation of DfS practices, the questionnaire adopted a five-point Likert scale (i.e. 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always) to measure the frequency of implementing 15 DfS practices adopted from the literature (e.g., Manu et al., 2018, Abueisheh et al., 2020). These 15 practices are related to the causes of work-related illnesses and injuries that workers commonly experience on construction sites, such as working at height, work in confined spaces, and using hazardous materials. The extent of influence of the factors that affect the implementation of DfS (see Poghosyan et al., 2018; Abueisheh et al., 2020) was measured using a Likert five-point scale (1 = Not at all; 2 = low; 3 = moderate; 4 = high; 5 = very high).

3.2 Survey administration

The population for the study comprised design professionals. Such professionals usually work in design institutes, architectural and engineering design firms, general building/civil engineering construction firms, and engineering and consulting companies in China. Given China's large land area and population (Donald and

Benewick, 2005), it would be difficult to cover the design professionals within the entire country. Therefore, the survey focused on the northern part of China, comprising 16 municipalities and provinces: Beijing Municipality, Tianjin Municipality, Heilongjiang, Jilin, Liaoning, Hebei, Henan, Shanxi, Shandong, Shaanxi, Inner Mongolia, Qinghai, Ningxia, Gansu, Xinjiang, Xizang). This sampling by geographical location was necessary because although only a section of China, Northern China encompasses a diverse set of municipalities and provinces that together provide a substantial representation of China's construction industry practices. The Northern region offers a broad cross-section of urban, sub-urban and rural areas that capture varying degrees of development, infrastructure and safety practices. Hence, examining DfS implementation in this region could reveal useful insights. A list of 381 design companies located in these Provinces and Municipalities was created from online business directory for construction organizations in China (see https://www.jobui.com). Company information such as name and email addresses, was retrieved from the directory. Relevant organisations were selected purposively in order to locate relevant design professionals who would reflect a good representation of the population for the study.

The questionnaire (in Microsoft Word version) was developed into an online survey using the Select Survey tool, and the link to this online questionnaire was emailed to the orgnisations using an email address obtained from the aforementioned online business directory. Additionally, the Microsoft Word version of the questionnaire was attached to the email as an alternative to the online survey. Furthermore, to help improve participation and access to potential participants through snowballing approach, the email asked the prospective respondents to forward the questionnaire to other design professionals within their professional networks.

The survey was conducted in the native language of the respondents, i.e., Chinese. This means the questionnaire was translated from English to Chinese. To ensure that the translation reflected the meaning of the original questionnaire, the back-translation method was employed. Additionally, the lead researcher (who is fluent in both English and Chinese) did the initial translation of the questionnaire from English to Chinese. Subsequently, another member of the research team who is an experienced researcher in the subject domain and is also fluent in both English and Chinese cross-checked the translation to ensure accuracy. Feedback from the cross-checking was used to refine the questionnaire before it was finally administered.

Overall, following the administration of the survey, 68 responses were obtained and used for analyses.

3.3 Data analyses

The data obtained were initially inputted into Microsoft Excel for screening and then exported to IBM Statistical Package for Social Sciences (SPSS) Statistics version 23. Descriptive statistical analyses (i.e., frequencies, means and standard deviations) and inferential statistical analyses (i.e., independent samples t-test and one-sample t-test) were conducted. This study considered that DfS should be an integral component of the design process given the established linkage between design and construction OSH. Subsequently, the expectation held by this research, in line with other DfS studies (e.g., Abueisheh et al., 2020), was that the level of designers' engagement in the DfS practices should be "often" at the least (if it is not "always"). This assertion was necessary considering that the examined 15 DfS practices are connected to mitigating major causes of construction accidents, injuries, and illnesses.

The level of engagement in DfS practices was gauged by examining the frequency of participants' engagement in DfS practices (using the five-point Likert scale). The one-sample t-test was conducted using 3.5 as the test value. The test value of 3.5 was used because 3.5 approximates the nearest scale point of 4, which is interpreted as "often" based on the scale descriptors. Thus, from the one-sample t-test, a practice with a mean frequency of engagement that is significantly greater than 3.5 can be deemed to be implemented at least often by designers. This approach of assessing the level of designers' engagement in DfS practices was also applied in other DfS surveys (e.g., Abueisheh et al., 2020).

Independent samples *t*-tests is useful in exploring differences in respondents' views regarding an issue (Field, 2013); hence, was used to determine the differences in DfS implementation among various groups within the sample. This was used to explore associations between respondents' characteristics (e.g., their DfS awareness, education, training, professional body membership, and work experience) and the implementation of DfS.

4. Results and Discussion

The results of the analyses are presented and discussed in the following sections. The discussion contextualises the results within existing DfS literature.

4.1 Background information of participants

Table 1 shows the respondents' background information. Among all the respondents, more than half of them are civil/structural engineers (61.8%), 26.5% of them are architects, and 11.8% are other professional roles (i.e., cost engineers). More than 90% of participants have obtained a bachelor's degree or above. However, only 17.6% of the total respondents are members of the construction industry association. Furthermore, since the recognition and qualifications of design organisations are also important (Lin and Tian, 2004), a question on whether the respondents' design organisations have joined a professional organisation was also asked. The results (Table 1) show that only about half of the respondents' organizations are members of professional associations, such as China Civil Engineering Society, Neimenggu Construction Industry Association, and Xian Construction Industry Association.

In addition to the organisation's qualifications, the results also demonstrate the types and sizes of the companies studied. As shown in Table 1, most of the participants (around 90%) work in architectural design institutes and design companies. In addition, according to the enterprise classification standard issued in the Statistics on the Classification of Large, Medium, Small and Micro Enterprises (National Bureau of Statistics of China, 2018a, 2018b, 2018c), the size of the design organisation was divided into four categories according to the number of employees. As shown in Table 1, companies with less than 200 employees account for 66.2%; companies with 201-600 employees account for 20.6%; companies with 601-3000 employees account for 11.8%, and companies with more than 3000 employees only account for 1.5%.

The participants' work experience in their current role and in the construction industry is shown by Table 1. A majority of them (over 45%) have work experience between 6 and 15 years, while 38% and 13% of respondents have 1-5 years and more than 15 years' work experience, respectively. Overall, the average work experience in current role was approximately 10 years (Std. deviation = 7.11), and the average work experience in the construction industry is close to 15 years (Std. deviation = 8.24). Generally, respondents who participated in the survey have sufficient work experience in the construction industry.

[Insert Table 1]

4.2 DfS education and training

The percentages of design professionals who have received relevant DfS education and those who have not are very close according to the responses (44% and 56%, Table 1), but the number of people who have participated in the training is less than a quarter of the number of people who have not participated in the training (see Table 1). In addition, among the 49 respondents who are interested in participating in the training, 39 participants are interested in participating in online courses and 22 are interested in participating in seminars.

4.3 Participants' awareness and attitude to DfS

Although fewer than 50% of participants have received DfS education or training, 66.2% of the participants were aware of the concept of DfS prior to completing the survey as shown by Table 1. In addition, the percentage of participants who are willing to implement DfS is similar to those who have been aware of the concept of DfS, which account for 69%, as shown in Table 1. Regarding participants' attitudes towards the importance of implementing DfS, from Table 1, it can be observed that all participants believe that the importance level of DfS implementation is medium or above; about 76.4% of participants think that the importance is high or very high. The one-sample t-test was used to further ascertain whether the mean value of the participant's attitude is higher than the test value of 3.5 (which is approximated to 4 in the Likert five-point scale). The results indicate that the mean is significantly greater than 3.5 (M = 4.10, SD = 0.756; t(67) = 6.578, p (1-tailed) < 0.001); therefore, it is reasonable to conclude that most participants believe that the implementation of DfS is of high importance.

From the above findings, it is evident that, generally, there is moderate level of DfS awareness among the surveyed design professionals, the majority of whom have a positive attitude towards the implementation of DfS. This level of awareness is better than that reported by Yue et al. (2020) as regards the subway engineering sector in China. However, the positive attitude towards DfS revealed by this study is in sync with that also reported by Yue et al. (2020) where over 70% of the surveyed respondents indicated support for DfS implementation. Although less than half of the surveyed respondents in this study have received DfS education and training, the vast majority are interested in participating in DfS training with a preference for online courses. Studies in other countries (e.g., Malaysia (Christermaller et al., 2022) and Botswana (Rantshilo et al., 2024)) have similarly reported a high interest in DfS training among design professionals.

4.4 Engagement in DfS Practices

The level of engagement in DfS practices was gauged by examining the frequency of participants' engagement in 15 practices. From Table 2, which presents the results, it is evident that 11 out of the 15 practices are implemented "often" or "always" by participants. To check whether the average frequency of engagement in the practices is at least "often", the one-sample t-test was performed. The mean value was set at 3.5, indicating that practices with an average frequency of participation being significantly greater than 3.5 can be considered as implemented at "least". The results of the one-sample t-test (based on p (1-tailed) ≤ 0.05) indicate that nine out of 15 practices are undertaken at least "often", accounting for 60% of the 15 practices. The nine practices are as follows: DfS-6 (M = 4.29, SD = 0.811; t(67) = 8.070, p (1-tailed) < 0.001); DfS-14 (M = 4.28, SD = 0.514; t(67) = 12.508, p (1-tailed) < 0.001); DfS-7 (M = 4.24, SD = 0.813; t(67) = 7.462, p (1-tailed) < 0.001); DfS-3 (M = 4.19, SD = 0.718; t(67) = 7.941, p (1-tailed) < 0.001); DfS-5 (M = 4.00, SD = 1.022; t(67) = 4.034, p (1-tailed) < 0.001); DfS-12 (M = 3.99, SD = 0.763; t(67) = 5.246, p (1-tailed) < 0.001); DfS-4 (M = 3.97, SD = 0.791; t(67) = 4.905, p (1-tailed) < 0.001); DfS-8 (M = 3.94, SD = 0.844; t(67) = 4.309, p (1-tailed) < 0.001); and DfS-11 (M = 3.74, SD = 0.956; t(67) = 2.030, p (1-tailed) = 0.023).

[Insert Table 2]

Among the 15 DfS practices examined in the survey, the one sample t-test results indicate that nine of them (i.e., over half) are implemented "often" or "always". This suggests a moderate extent of DfS implementation among design professionals in this geographical region of China. Whereas a higher level of implementation would be more appreciable, the moderate level of implementation in comparison with the perception of a low implementation of DfS in China within literature (e.g., Yue et al., 2020) gives a positive signal that there is potential for DfS to become gradually embedded over time in China. Nonetheless, the results in this study are out of sync with the findings from other developing country contexts (e.g., Nigeria (Manu et al., 2019), and Palestine (Abueisheh et al., 2020)) where the implementation of DfS has been reported to be low, showing that the extent of DfS implementation in different developing countries may vary.

4.4.1 Independent Samples t-test for Engagement in DfS Practices

Independent sample t-test was used to assess whether the mean frequency of implementing DfS practices, considered as dependent variable, has significant statistical difference between two independent groups, such as participants who have received DfS training and those who have not. Six groups (representing independent variables) were considered:

1. participants who are affiliated to a professional body compared to those who are not;
2. participants' whose organisation is a member of a professional association compared to those whose organisations are not;
3. participants who are aware of DfS compared to those who are not aware
4. participants who have received education regarding DfS compared to those who have not;
5. participants who have received DfS training compared to those who have not;
6. and participants who are willing to implement DfS compared to those who are not.

The following are the results of the tests. For conciseness, only the significant results (i.e. p (2-tailed) $\leq$ 0.05) are presented below.

There is a significant difference in only two practices for participants who are members of an industry association versus those who are not. The two practices are DfS-9 (t(66) = -3.009, p (2-tailed) = 0.002), and DfS-13 (t(46.583) = -4.517, p (2-tailed) < 0.001). Likewise, by comparing whether or not participant's organisation is a member of an industry association, a significant difference was observed in a few practices. The practices are DfS-10 (t(66) = 4.301, p (2-tailed) < 0.001), DfS-11 (t(66) = 2.154, p (2-tailed) = 0.035), and DfS-14 (t(65.961) = 2.569, p (2-tailed) = 0.012).

Regarding the group of participants with or without awareness of the DfS concept, there is a significant difference for nearly half of the practices (i.e., 7 of 15 practices), as illustrated in Table 3. The most notable difference lies in the following two groups: (a) whether or not participants have received education (there are a total of 12 practices: DfS-1, DfS-3, DfS-4, DfS-5, DfS-6, DfS-8, DfS-10, DfS-11, DfS-12, DfS-13, DfS-14, and DfS-15, with p(2-tailed) $\leq$ 0.05); and (b) whether or not participants have undergone training (there are ten practices: DfS-3, DfS-4, DfS-5, DfS-7, DfS-8, DfS-10, DfS-11, DfS-12, DfS-13 and DfS-15 with p(2-tailed) $\leq$ 0.05). The results are shown by Tables 4 and 5. The last independent samples t-test is between participants who have an interest in implementing DfS in the work and those who have no interest. There is a significant difference in two practices. These are DfS-10 ($t(66) = 3.607$, p *(2-tailed) = 0.001*) and DfS-11 ($t(66) = 2.712$, p *(2-tailed) = 0.009*).

[Insert Tables 3-5]

From the examination of the effect of respondents' characteristics on DfS implementation, it was found that respondent's professional body affiliation, professional body affiliation of respondent's organisation, DfS awareness, and willingness to implement DfS have limited bearing on DfS implementation. On the other hand, the independent sample t-test results indicate that DfS education and training have a significant effect on extent of engagement in DfS practices. These suggest that DfS education and training are among key factors affecting the implementation of DfS practices among designers in Northern China's construction industry. Research in Singapore also found that training and education are important for DfS implementation (Goh and Chua 2016; Toh et al., 2017). This view is, however, partly corroborated by other studies. For instance, while Christermaller et al. (2022) based on their survey of design professional in Malysia reported that participation in DfS training has an effect on the implementation of DfS practices, they also reported that receipt of DfS lessons as part of formal education had a limited effect on the implementation of DfS practices. On the other hand, Rantshilo et al.'s (2024) survey of design professionals in Botswana revealed that neither the participation in DfS training nor receipt of DfS education had much bearing on the implementation of DfS practices. Consequently, the evidence from this study coupled with those from other studies show a lack of consensus about the effect of DfS training and education on the implementation of DfS practices. While this lack of consensus does not necessarily imply that DfS training and education are not influential factors, it shows that the extent of the effect of these may vary in different national contexts. Furthermore, their effect may be tempered by other DfS implementation influencing factors or other contextual issues.

4.5 Factors Influencing the Implementation of DfS

Six factors drawn from the literature (Poghosyan et al., 2018) were examined. Results of the one sample t-test shown by Table 6 indicate that five out of the six factors have mean scores that are significantly greater than the test value of 3.5, implying that the participants consider the five factors to have a high impact on the implementation of DfS. The only factor whose mean score is not significantly greater than the test value is "computer software relating to DfS".

Regarding the six DfS influencing factors, all but one (i.e., computer software relating to DfS) are deemed by the survey professionals to have at least a high impact on DfS implementation in China's construction industry. It is noteworthy that the respondents' perceived high impact of DfS education and training is corroborated by the results of the independent samples t-test shown by Tables 4 and 5. The findings regarding the five influencing factors (i.e., industry guidance relating to DfS, legislation relating to DfS, training on DfS, inclusion of DfS in the formal education of design professionals, and the influence of clients) are also in agreement with evidence from other contexts (e.g., Malaysia and Palestine) where design professionals similarly perceive these five factors to have a high impact on implementation of DfS practices (Abueisheh et al., 2020; Christermaller et al., 2022).

[Insert Table 6]

5. Conclusions

This research investigated DfS implementation among design professionals in the construction industry of Northern China. The main conclusions drawn from the research are that:

- The level of engagement in DfS practices among designers in this geographical region can be deemed to be moderate, despite indication of a high level of awareness of DfS and a positive attitude towards its implementation.
- Despite designers showing interest in participating in DfS training, there appears to be low participation in such training among designers from this geographical region.
- Characteristics of designers, like their interest in DfS implementation, professional body affiliation, and the professional body affiliation of their organisation seem to have limited bearing on frequency of engagement in DfS practices.
- Industry guidance relating to DfS, legislation relating to DfS, DfS training, inclusion of DfS in design professionals' formal education, and clients' influence are perceived to be key factors affecting DfS implementation among design professionals in Northern China.

5.1 Implications for advancing DfS concept

Theoretically, the findings of the study contribute significantly to advancing knowledge and understanding about the DfS concept (including awareness of DfS, attitude towards DfS, extent of engagement in DfS practices, and its influencing factors) in construction, especially in the context of developing countries given that relatively fewer studies have focused on examining DfS in such geographic contexts. Most significantly, the findings of this study in conjunction with previous ones collectively begin to create/portray an insightful image of DfS in developing countries whereby while there is a good/growing DfS awareness and positive attitude towards DfS in such contexts, this outlook is juxtaposed against a low to moderate level of engagement in DfS practices in such contexts. Furthermore, there are some country variations and similarities in respect of the factors that are perceived to have significant influence on DfS implementation. This image of DfS in developing countries strengthens calls for further context-specific studies as well as context-specific interventions (rather than a blanket one-size-fits-all approach) in developing regions to enhance DfS knowledge and implementation in these areas.

5.2 Implications for practice and policy

This study provides valuable insights that hold relevance to practice and policy. Although focused on Northern China, the findings from this study could be applicable to other regions in China with similar geographical settings. Therefore, the insights provided by this study present an opportunity for stakeholders in China's construction industry to enhance DfS implementation by considering the following recommendations:

- While the indication of a moderate extent of engagement in DfS practices among design professionals is encouraging, design professionals, their professional bodies and other stakeholders ought to do more to promote greater engagement in DfS practices.
- Aligned to the above point and results regarding the influence of the five factors, government through its regulatory role as well as its role as a major construction client should seek to exert influence on the design community to implement DfS practices on projects. The government can consider introducing comprehensive DfS-specific regulations like those in other countries (e.g., UK, Singapore, etc.) but appropriately crafted for the Chinese context.
- Additionally, aside government, other construction clients should exert influence on design professionals and provide adequate resources on projects to facilitate DfS implementation.
- Moreover, regarding other influential factors, great emphasis ought to be placed on DfS education and training. While these are key influential factors, the study gives an indication of a low participation in DfS training among design professionals as well as a low coverage of DfS in the formal education of design professionals. Therefore, educational institutions (e.g., universities) that provide construction design educational courses/programmes (e.g., architecture, and civil engineering) ought to embed contents about DfS in the educational curriculum. Additionally, design professional bodies and other training providers within the industry ought to offer DfS training courses, while taking into account the preferred mode(s) of delivery (e.g., online or in-person seminar) of designers. Additionally, workplaces of designers should provide adequate resources and support to enable their design staff to regularly engage in continuing professional development regarding DfS.
- Overall, the study's findings on DfS implementation levels and influencing factors give directions to design professionals, other industry stakeholders, and policy makers as to what approaches and factors to consider and integrate into

OSH practices and policies aimed at improving construction safety performance through DfS.

5.3 Limitation and implication for research

Despite this research offering valuable insights on DfS implementation from the perspective of China, there are limitations that need acknowledging. These limitations listed below offer the opportunity for further studies to be conducted in this area.

- The scope of this research was limited to provinces in northern China, making it difficult to generalise the study's findings to the entire country. Another limitation is the sample size. Although the sample size is similar to those in other DfS studies, a larger sample size may yield additional empirical realities beyond the findings of this study. Therefore, future studies should consider increasing the sample size by extending the investigation to the other provinces of China as well as obtaining a greater number response.
- While the use of a questionnaire survey was appropriate for the aim of this study, future research could consider using qualitative methods or mixed methods. The use or incorporation of qualitative methods could help to provide deeper meaning/explanations behind the insights provided by the quantitative data.

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Tables

Table 1: Descriptive statistics (Source: Authors own work)

Item	Frequency	Percent (%)
Participants' current professional role		
Architect	18	26.5
Civil/structural engineer	42	61.8
Others	8	11.8
Participants' work experience in current role		
1-5 years	26	38.2
6-15 years	33	48.5
More than 15 years	9	13.2
Participants' work experience in construction industry		
1-5 years	12	17.6
6-15 years	32	47.1
More than 15 years	24	35.3
Participant's highest level of education		
College qualification	6	8.8
Bachelor's degree	44	64.7
Master's degree	14	20.6
PhD degree	4	5.9
Participants' membership of a professional association		
Yes	12	17.6
No	56	82.4
Participants' organisation		
Design institute	49	72.1
Architectural & engineering firm	12	17.6
General building/civil engineering contractor	3	4.4
Engineering consultancy company	4	5.9
Participants' organisational size		
Micro	45	66.2
Small	14	20.6
Medium	8	11.8
Large	1	1.5
Participants' organisations that have professional association membership		
Yes	35	51.5
No	33	48.5
Participants' awareness of DfS concept in construction		
Yes	45	66.2
No	23	33.8
Participants who have received DfS education		
Yes	30	44.1
No	38	55.9
Participants who have received training related to DfS		
Yes	11	16.2
No	57	83.8
Participants who are interested in undertaking DfS training		
Yes	49	72.1
No	19	27.9
Participants' attitude towards DfS – willingness to implement DfS		

Yes	47	69.1
No	21	30.9
Participants' perceived importance of DfS		
Very high importance	23	33.8
High importance	29	42.6
Moderate importance	16	23.5
Low importance	0	0.0
Not at all	0	0.0

Table 2: Frequency of implementing DfS practices (Source: Authors own work)

Reference code for DfS practices	Description of DfS practices*	Percent (%)					
		Never	Rarely	Sometimes	Often	Always	Often or Always
DfS-1	I design to avoid construction operations that create hazardous fumes, vapour and dust (e.g. disturbance of existing asbestos and cutting blockwork and concrete).	3	16	32	25	24	49
DfS-2	I specify materials that require less frequent maintenance or replacement.	3	13	24	38	22	60
DfS-3	I specify materials that are easier to handle, such, e.g. light weight blocks.	0	0	18	46	37	83
DfS-4	I design to take into account safe movement of site workers, plants, & equipment on a project site during construction.	0	3	24	47	26	73
DfS-5	I specify materials that have less hazardous chemical constituents.	0	13	12	37	38	75
DfS-6	I eliminate materials that could create a significant fire risk during construction.	0	3	13	35	49	84
DfS-7	I design to position buildings/structures to minimise risks from buried services and overhead cables.	0	1	19	34	46	80
DfS-8	I design to mitigate possible adverse impact a project could have on safe movement of the general public during construction.	0	4	25	43	28	71
DfS-9	I design elements (e.g. walls, floors, etc.) so that they can be prefabricated offsite.	3	19	31	34	13	47
DfS-10	I design to minimise or eliminate the need to work at height.	3	6	31	43	18	61
DfS-11	I design to minimise or eliminate the need for workers to work in confined space.	0	12	26	38	24	62
DfS-12	I highlight unusual construction considerations that have safety implications to the contractor e.g. key sequence of erecting/construction.	0	3	21	51	25	76
DfS-13	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.	7	29	21	25	18	43
DfS-14	I produce designs that enable ease of building/constructing.	0	0	3	66	31	97
DfS-15	I prepare hazard identification drawings which show significant hazards that may not be obvious to a contractor.	7	34	25	22	12	34

Table 3: Independent samples t-test on participants' DfS awareness (Source: Authors own work)

DfS practices	Awareness of DfS	N	Mean	Std. Dev.	Std. Error Mean	Independent samples t-test								
						F	Sig.	t	df	*p* (2-tailed)	Mean Difference	Std. Error Mean	Confidence Interval	
													Lower	Upper
DfS-1	Yes	45	3.82	0.960	0.143	0.570	0.453	3.630	66	0.001	0.953	0.262	0.429	1.477
	No	23	2.87	1.140	0.238				38.322					
DfS-3	Yes	45	4.36	0.712	0.106	3.759	0.057	2.770	66	0.007	0.486	0.175	0.136	0.836
	No	23	3.87	0.626	0.130				49.857					
DfS-6	Yes	45	4.47	0.726	0.108	0.185	0.669	2.552	66	0.013	0.510	0.200	0.111	0.909
	No	23	3.96	0.878	0.183				37.766					
DfS-8	Yes	45	4.11	0.775	0.116	0.826	0.367	2.403	66	0.019	0.502	0.209	0.085	0.920
	No	23	3.61	0.891	0.186				39.360					
DfS-10	Yes	45	3.89	0.910	0.136	0.281	0.598	2.941	66	0.005	0.671	0.228	0.216	1.127
	No	23	3.22	0.850	0.177				47.204					
DfS-11	Yes	45	3.96	0.999	0.149	1.487	0.227	2.789	66	0.007	0.651	0.234	0.185	1.117
	No	23	3.30	0.703	0.147				59.282					
DfS-15	Yes	45	3.18	1.267	0.189	5.539	0.022		66					
	No	23	2.57	0.788	0.164			2.448	63.293	0.017	0.613	0.250	0.113	1.113

Table 4: Independent samples t-test on DfS education (Source: Authors own work)

DfS practices	DfS education	N	Mean	Std. Dev.	Std. Error Mean	Independent samples t-test								
						F	Sig.	t	df	*p* (2-tailed)	Mean Difference	Std. Error Mean	Confidence Interval Lower	Confidence Interval Upper
DfS-1	Yes	30	4.03	0.809	0.148	2.873	0.095	3.857	66	0.000	0.954	0.247	0.460	1.448
	No	38	3.08	1.148	0.186			4.016	65.244	0.000	0.954	0.238	0.480	1.429
DfS-3	Yes	30	4.40	0.724	0.132	2.997	0.088	2.191	66	0.032	0.374	0.171	0.033	0.714
	No	38	4.03	0.677	0.110			2.174	60.342	0.034	0.374	0.172	0.030	0.717
DfS-4	Yes	30	4.23	0.774	0.141	0.555	0.459	2.529	66	0.014	0.470	0.186	0.099	0.841
	No	38	3.76	0.751	0.122			2.520	61.506	0.014	0.470	0.187	0.097	0.843
DfS-5	Yes	30	4.57	0.568	0.104	17.443	0.000	4.644	66	0.000	1.014	0.218	0.578	1.450
	No	38	3.55	1.083	0.176			4.970	58.269	0.000	1.014	0.204	0.606	1.422
DfS-6	Yes	30	4.53	0.681	0.124	0.366	0.547	2.223	66	0.030	0.428	0.193	0.044	0.813
	No	38	4.11	0.863	0.140			2.285	65.999	0.026	0.428	0.187	0.054	0.802
DfS-8	Yes	30	4.27	0.785	0.143	0.049	0.826	2.987	66	0.004	0.582	0.195	0.193	0.972
	No	38	3.68	0.809	0.131			2.998	63.197	0.004	0.582	0.194	0.194	0.971
DfS-10	Yes	30	4.07	0.828	0.151	0.671	0.416	3.394	66	0.001	0.725	0.213	0.298	1.151
	No	38	3.34	0.909	0.147			3.432	64.602	0.001	0.725	0.211	0.303	1.146
DfS-11	Yes	30	4.23	0.774	0.141	1.312	0.256	4.283	66	0.000	0.891	0.208	0.476	1.307
	No	38	3.34	0.909	0.147			4.365	65.587	0.000	0.891	0.204	0.484	1.299
DfS-12	Yes	30	4.37	0.669	0.122	0.042	0.838	4.066	66	0.000	0.682	0.168	0.347	1.018
	No	38	3.68	0.702	0.114			4.089	63.637	0.000	0.682	0.167	0.349	1.016
DfS-13	Yes	30	3.73	1.172	0.214	0.242	0.624	3.676	66	0.000	1.023	0.278	0.467	1.578
	No	38	2.71	1.113	0.181			3.653	60.808	0.001	1.023	0.280	0.463	1.583
DfS-14	Yes	30	4.50	0.509	0.093	11.511	0.001	3.381	66	0.001	0.395	0.117	0.162	0.628
	No	38	4.11	0.453	0.073			3.335	58.636	0.001	0.395	0.118	0.158	0.632
DfS-15	Yes	30	3.77	0.971	0.177	0.661	0.419	6.337	66	0.000	1.425	0.225	0.976	1.873
	No	38	2.34	0.878	0.143			6.261	59.194	0.000	1.425	0.228	0.969	1.880

Table 5: Independent samples t-test for DfS training (Source: Authors own work)

DfS practices	DfS training	N	Mean	Std. Dev.	Std. Error Mean	Levene's Test for Equality of Variances		Independent samples t-test						
						F	Sig.	t	df	p (2-tailed)	Mean Difference	Std. Error Mean	Confidence Interval Lower	Confidence Interval Upper
DfS-3	Yes	11	4.73	0.467	0.141	1.091	0.300	2.845	66	0.006	0.640	0.225	0.191	1.088
	No	57	4.09	0.714	0.095			3.770	20.319	0.001	0.640	0.170	0.286	0.993
DfS-4	Yes	11	4.55	0.688	0.207	0.001	0.977	2.759	66	0.007	0.686	0.249	0.189	1.182
	No	57	3.86	0.766	0.101			2.971	15.212	0.009	0.686	0.231	0.194	1.177
DfS-5	Yes	11	4.73	0.467	0.141	5.114	0.027	2.695	66	0.009	0.868	0.322	0.225	1.510
	No	57	3.86	1.043	0.138			4.399	33.024	0.000	0.868	0.197	0.466	1.269
DfS-7	Yes	11	4.73	0.467	0.141	4.515	0.037	2.260	66	0.027	0.587	0.260	0.068	1.106
	No	57	4.14	0.833	0.110			3.280	24.408	0.003	0.587	0.179	0.218	0.956
DfS-8	Yes	11	4.45	0.688	0.207	0.207	0.651	2.270	66	0.026	0.612	0.270	0.074	1.151
	No	57	3.84	0.841	0.111			2.603	16.360	0.019	0.612	0.235	0.114	1.110
DfS-10	Yes	11	4.36	0.505	0.152	3.863	0.054	2.844	66	0.006	0.837	0.294	0.249	1.425
	No	57	3.53	0.947	0.125			4.247	26.065	0.000	0.837	0.197	0.432	1.243
DfS-11	Yes	11	4.36	0.674	0.203	2.501	0.119	2.470	66	0.016	0.750	0.303	0.144	1.356
	No	57	3.61	0.959	0.127			3.127	18.823	0.006	0.750	0.240	0.248	1.252
DfS-12	Yes	11	4.55	0.522	0.157	0.192	0.663	2.792	66	0.007	0.668	0.239	0.190	1.146
	No	57	3.88	0.758	0.100			3.579	19.206	0.002	0.668	0.187	0.278	1.059
DfS-13	Yes	11	4.27	1.009	0.304	0.754	0.388	3.505	66	0.001	1.325	0.378	0.570	2.080
	No	57	2.95	1.171	0.155			3.881	15.688	0.001	1.325	0.342	0.600	2.051
DfS-15	Yes	11	3.73	0.647	0.195	5.289	0.025	2.453	66	0.017	0.903	0.368	0.168	1.638
	No	57	2.82	1.182	0.157			3.610	25.184	0.001	0.903	0.250	0.388	1.418

Table 6: One sample t-test on the degree of influence of factors affecting the implementation of DfS (Source: Authors own work)

Influencing factors	N	Mean	Rank of Mean	Std. Dev.	Std. Error Mean	Test Value=3.5					
						t	df	p (1-tailed)	Mean Difference	Interval of the Difference	
										Lower	Upper
Industry guidance relating to DfS	68	4.13	1	0.827	0.100	6.306	67	0.000	0.632	0.43	0.83
Legislation relating to DfS	68	4.12	2	0.856	0.104	5.952	67	0.000	0.618	0.41	0.82
Training on DfS	68	3.91	3	0.768	0.093	4.424	67	0.000	0.412	0.23	0.60
Including DfS in the formal education of design professionals	68	3.78	4	0.666	0.081	3.461	67	0.000	0.279	0.12	0.44
The influence of clients	68	3.74	5	1.002	0.121	1.937	67	0.028	0.235	-0.01	0.48
Computer software relating to DfS	68	3.56	6	0.761	0.092	0.638	67	0.263	0.059	-0.13	0.24