Design for Safety among Design Professionals in the Botswana Construction Industry

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Abstract

Design has been identified as a contributor to adverse occupational safety and health (OSH) outcomes in construction. In spite of this, relatively fewer studies have focused on design for safety (DfS) within developing countries; Botswana being a prime example. This research investigates the extent of DfS implementation in Botswana's construction industry, and the factors that affect its implementation. A cross-sectional survey was conducted among design professionals (i.e., architects and civil/structural engineers) in the Botswana construction industry. Data were analysed using both descriptive and inferential statistics. Results revealed that a majority of respondents are aware of the concept of DfS and respondents generally consider DfS to be of high importance. Furthermore, there is a high willingness to apply DfS and a high interest in undertaking DfS related professional development training, however, engagement in DfS practices is rather moderate and participation in DfS professional development training is low. Moreover, DfS legislation as well as industry guides are considered by designers to be the most influential factor for DfS implementation in Botswana. From the results, recommendations are given including the inclusion of DfS requirements in OSH legislation and provision of DfS industry guides by the relevant design professional bodies.

Keywords: construction management; design; health & safety.

1. Introduction

The construction industry significantly contributes to the economic growth and social development of nations (Boadu et al., 2020). Notwithstanding, it is regarded as one of the most hazardous industrial sectors with a generally poor reputation regarding health and safety (International Labour Organisation (ILO), 2015). The financial burdens posed by poor health and safety performance are also well documented. For instance, in the United Kingdom (UK), the Health and Safety Executive (HSE) (2020) estimates that economic cost of occupational injury and new cases of occupational illness in construction are in excess of GBP£1billion. Several studies have shown that design decisions contribute to the occurrence of accidents and on-site injuries. One example of such a study was that by Gibb et al. (2006) which found that 50% of the 100 accidents they reviewed were preventable through decision making in the preconstruction phase. It therefore follows that design for safety (DfS), which involves designers 'designing out' hazards in the design phase to reduce accidents in later stages (Abueisheh et al., 2020), is an important practice for ensuring the safety and health of the construction workforce.

Despite the evidenced impact of design decisions on OSH performance, studies on the implementation of DfS in developing countries are not as prevalent as those within the developed nations (Manu et al., 2018a; Samsudin et al., 2022). The study by Manu et al. (2018a) indicated that the majority of DfS studies have been carried out in developed nations such as the UK and USA. This knowledge gap has led to some studies on this topic being carried out in developing countries, such as those by Manu et al. (2018b), Manu et al. (2019), Abueisheh et al. (2020), Umeokafor et al. (2021) and Samsudin et al. (2022) which examined DfS implementation in Ghana, Nigeria, Palestine, and the like. Botswana is a country in sub-Saharan Africa, with a population of about 2 million as of 2019 (The World Bank, 2021), whose construction industry plays a significant role in its economy. Despite this and the potential social and economic costs associated with poor occupational safety and health (OSH), few studies on OSH in Botswana's construction industry exist. The literature that exist, however, point to a low level of awareness and implementation of OSH practice, with studies by Musonda and Smallwood (2008), Musonda and Haupt (2009), and Musonda et al. (2012) all citing generally low levels of awareness and implementation of health and safety practices, a generally poor health and safety culture, and a low level of client interest/investment in health and safety. As very little literature on DfS exist in Botswana, the current level of practice is difficult to ascertain. To fill this knowledge gap, this research investigated: (1) the level of practise of DfS among design professionals in Botswana's construction industry; and (2) the factors that influence the practise of DfS in Botswana.

The article is structured into seven sections. Section 1 introduces the study under investigation while sections 2 and 3 review literature on the status of the construction sector OSH in Botswana, the concept of design for safety, and finally makes a case for research into implementation of DfS in the Botswana construction industry. Section 4 describes the research methodology adopted for the study. Sections 5 and 6 present and discuss the results, respectively. Finally, section 7 provides concluding remarks.

2. Literature Review

2.1 Occupational Safety and Health in Botswana Construction

The construction industry in Botswana is known to contribute heavily to occupational injury and fatalities. According to Tau and Seoke (2013), the Division of Occupational Health and Safety (DOHS) indicated that 61% of occupational deaths and 50% of all work-related injuries and accidents were attributed to the construction industry from 2006-2013. This high occupational hazard rate was backed by Mosanawe (2013), who for the same period reported that 20 (74%) of the reported 27 fatalities and 86 (55%) of the 115 accidents reported by DOSH were attributed to the construction industry. This alarming contribution to occupational accidents in Botswana is a great indicator of the need for improved OSH performance within its construction industry. Furthermore, there is under-reporting of on-site accidents as noted by Musonda and Smallwood (2008) and this means that the actual level of accidents within the construction industry could be much higher. This high contribution to accidents is a clear indication of the need for improved OSH performance within the industry.

2.2 Design for Safety

"Design for safety," "safe design," or "prevention through design" in construction may be defined as, "the integration of hazard identification and risk assessment into the design process to eliminate or minimise the risks of injury and illness to workers" (Manu et al. 2019). "It is a concept that encourages design professionals to explicitly take into consideration the occupational safety and health of construction and maintenance workers during the design phase in order to eliminate or reduce the likelihood of occurrence of harm to these workers" (Samsudin et al., 2022, p. 2). Design for safety has been a subject of study for several years. It has been identified as a potentially powerful tool to improve OSH, with it being implemented as part of legislation within the European Union (Martínez Aires et al., 2010) and being promoted by organisations such as the National Institute of occupational safety and health (NIOSH) (Toole and Erger, 2019). Furthermore, the study by Martínez Aires et al. (2010) points to the apparent positive impact of DfS on health and safety, with several studied European countries experiencing some improvement in OSH performance since the introduction of DfS legislation. Lingard et al. (2015) reported that the early selection of risk controls during the preconstruction phase would allow for better site safety performance. In addition to this, an earlier Delphi study by Behm (2005), which had a group of experts review 224 fatal accidents, revealed that 42% of the fatalities were linked to aspects of design. These studies and others (e.g. Gibb et al., 2006; Manu et al., 2014) show that design decisions can influence safety on-site and thus reinforces DfS as an important approach for OSH improvement. In spite of this, DfS implementation is affected by several factors and these are discussed next.

2.3 Factors Affecting Design for Safety

Poghosyan et al. (2018), through a systematic review of DfS studies, identified relevant factors affecting DfS implementation. This segment highlights these factors and expand on their relevance to DfS implementation.

2.3.1 Laws and Regulations

This has been identified by Poghosyan et al. (2018) as one of the main factors influencing DfS implementation. However, it was found to be one of the least researched factors. These legislative actions are done to encourage better practice by penalising poor practices. Legislations within Europe and other developed nations have already been put into place, the results of which show that the inclusion of DfS in legislation can help to improve on-site health and safety (Martínez Aires et al., 2010). Although in developing countries, health and safety records remain poor, attention is now being given to it (Umeokafor et al., 2021). Notwithstanding, it is also important to recognise how DfS legislation may influence or be influenced by other factors. Toole and Erger (2019) identified an example of this, where design firms may resist DfS practice in fear of the legal and financial risks introduced to them should DfS legislation be put in place or DfS being required in design contracts. These risks may include liability for onsite accidents and increased costs in training employees and implementing DfS practice which clients, in turn, may not be willing to pay. Thus, showing how this factor can influence or be influenced by both designer and client attitudes.

2.3.2 Client's influence

Construction clients, as the funders/initiators of construction projects, can play a pivotal role in promoting OSH management (Toole et al., 2017). Clients can improve DfS performance by introducing safety goals, selecting competent contractors and designers capable of implementing DfS practice (Toole et al., 2017). Clients can also encourage DfS implementation through the use of contracting. This would be done through the selection of the project delivery method and contract type as outlined by Toole et al. (2017), who stated the shift from a traditional design-bid-build contract to a design-build type contract can greatly encourage collaboration between designers and contractors. Toole et al. (2017) also stated that the contract type may impact a designers' willingness to engage in DfS practice particularly if they lack experience implementing DfS, with cost plus contracts being suggested as more attractive than traditional fixed cost contracts. To add to this, Toole and Erger (2019) also indicate the increased liability and associated costs can deter designers from adopting DfS, making it integral for clients to alleviate this concern through appropriate contracting.

2.3.3 Availability of DfS ICT tools

As the second most frequently researched DfS implementation factor identified by Poghosyan et al. (2018), DfS ICT tools have become one of the influencing factors discussed in recent literature, showing its apparent impact. One of the first tools used to aid in DfS was the "design for construction safety toolbox" developed by Gambetese et al. (1997). Furthermore, Martínez-Aires et al. (2018) also mention the utility of software such as building information modelling (BIM) in scheduling, with the use of 4-D computer-aided design (CAD) models helping to anticipate conflicts in the planning phase. More recently, Poghosyan et al. (2020) have proposed a web-based tool for assessing design firm's capability to implement DfS. Several other ICT tools for DfS are presented in Farghaly et al.'s (2021) systematic literature review of digital tools for prevention through design.

2.3.4 DfS education

Education plays a pivotal role in encouraging DfS practice among designers. Poghosyan et al. (2018) identified that roughly 60% of the DfS papers they analysed were on this topic; an indication of the importance of DfS education. This factor plays two significant roles; the first is the provision of knowledge on DfS practice to design professionals; and the second role of education is to shift designers' attitudes towards DfS and the causality of accidents. In terms of the shift in causality, Behm et al. (2014) identified this as being a change from the "safe people" philosophy, which identifies individual actions as the major contributor to accidents, to the "safe place" philosophy where the environment is seen as the major contributor to accidents and thus giving designers a more prominent role in mitigating construction phase hazards.

2.3.5 Designer's attitude

Designers' attitude towards the concept of DfS constitutes a key factor that affects its implementation (Abueisheh et al., 2020). Designers with a negative view of the DfS concept would be less likely to practice it. Literature has identified ways in which designer attitudes may be positively impacted, with one of the prominent ways being DfS education as previously discussed.

2.4 Design for Safety in Botswana's Construction: The Knowledge Gap

There is a lack of studies that directly research DfS and its implementation within Botswana. However, there have been studies carried out on construction-site health and safety as well as how different stakeholders contribute to health and safety performance. Table 1 summarises these studies.

Firstly, many of the studies conclude a generally poor health and safety culture and a low level of client investment in health and safety (Musonda and Smallwood, 2008; Musonda and Haupt, 2009; Musonda et al., 2012). Another study by Mwanaumo and Thwala (2012) also points to a low level of awareness of occupational diseases in the country's construction industry, likely making identifying and mitigating these particular risks more difficult. Other studies have also pointed to other barriers to OSH practice within Botswana's construction industry which include:

- The apparent uncooperative nature of the country's construction industry, identified by Mwanaumo (2012), prevents practical cooperation between the relevant stakeholders. This issue is relatively common in the industry as the fragmented nature of the construction industry has been noted to impede improved OSH performance (Musonda et al., 2012).
- The contractual issues within Botswana's construction industry. This takes two primary forms, the first outlined by Mwanaumo and Pretorius (2014) is the non-inclusion of health and safety within construction contract requirements. The second issue is the apparent prevalence of the traditional (design-bid-build) contract, with Mwanaumo and Pretorius (2014) identifying literature outlining the negative impact on OSH due to the competitive nature of this form of contracting, which favours those who exclude OSH requirements (being the cheaper option); this notion was echoed by Musonda and Smallwood (2008), and Mwanaumo (2012).

- Issues regarding the non-compliance of OSH requirements by stakeholders within the construction industry (Musonda and Smallwood, 2008; Musonda et al., 2012; Mwanaumo, 2012; Emuron, 2017). This includes the lack of desire by designers to take part in OSH (Mwanaumo, 2012) or include it in the preconstruction phase (Musonda et al., 2012). Furthermore, the enforcement of OSH legislation on construction sites appears to be lacking (Musonda and Smallwood, 2008).

Despite these studies not focussing on DfS, they provide useful insights about the OSH landscape within the Botswana construction industry and their relevant to DfS implementation for designers.

[Insert Table 1 here]

3. Research Methods

In line with the aim of this research which seeks to study the extent of implementation of DfS principles, a quantitative research strategy was selected; this is in line with similar DfS studies carried out by Goh and Chua (2016), Manu et al. (2018a; 2019), Abueisheh et al. (2020) and Sharar et al. (2022). Furthermore, the specific quantitative research strategy chosen was a cross-sectional survey. The cross-sectional survey was considered for this study because of its several inherent strengths compared to other research methods. Bhattacherjee (2012) indicated that surveys are excellent vehicles for measuring a wide variety of unobservable data like people's preferences, traits, attitudes, beliefs, behaviours or factual information. It is also suitable for remotely collecting data about a population that is too large to observe directly (Bhattacherjee, 2012). Hence, since this study sought to identify the "trend" regarding the awareness of DfS, attitudes towards DfS, and the extent of practice of DfS in Botswana's construction industry (consisting of a large number of design professionals), the survey strategy was deemed significant.

3.1 Instrument Design and Administration

The data collection method used was a questionnaire, which was split into two main sections namely:

Section 1: This section was used to capture demographic information of participants including professional role, years of experience in their role, years of experience in the construction industry, level of education, professional body affiliation, type of work organisation and the size of their organisation (by the number of employees).

Section 2: This section was used to capture respondents' awareness of DfS, attitude towards DfS, their education and training relating to DfS, and the extent to which they implement DfS practices. The section also sought to capture respondents' perceptions regarding factors that influence DfS implementation. The measurement of these variables is shown in Table 2.

[Insert Table 2 here]

Botswana’s construction industry design professionals (i.e., architects and civil/structural engineers) constituted the population for the study. Botswana is a relatively small country with a population of about 2 million (The World Bank, 2021). Consequently, the size of its construction industry and by extension the number of design professionals in the industry will also be small relative to its population. Nonetheless, to ensure that the respondents fit the required group of design professionals, a list of 203 architectural and engineering firms in Botswana’s construction industry was compiled. This was first done using lists of registered engineers and architects with their corresponding companies found on publicly available sites, namely those of Botswana’s Architectural Registration Council (ARC) and Engineering Registration Board (ERB). The questionnaire was designed and administered online using Qualtrics online survey platform. The online questionnaire was sent by email to the firms with a request for a designer within the firms to complete the survey.

To further enhance participation in the survey, cooperation was also requested from the ARC and ERB, and other professional bodies including the Association of Consulting Engineers Botswana (ACEB), Botswana Institute of Engineers, and Architects Association of Botswana (AAB); whose contact details are readily available on their corresponding websites. These organisations were asked to distribute the designed questionnaire to their registered members. The survey was opened from January 2021 to March 2021, and it was interspersed with reminders.

Overall, the online survey distribution yielded 57 useable responses from architects and civil/structural engineers. The response size of the survey is comparable to the survey response sizes from DfS studies in other countries/context of similarly relatively small populations (see Abueisheh et al. (2020) and Goh and Chua who reported response sizes of 60 for Palestine (West Bank) and Singapore, respectively).

3.2 Methods of Analyses of Data

The data from the online survey was initially exported into Microsoft Excel format for screening and coding and subsequently exported into IBM Statistical Package for Social Sciences (SPSS) Statistics. The methods of analyses included both descriptive and inferential statistical analyses. The descriptive statistics includes frequencies distributions, mean score and standard deviations. The inferential statistical analyses are t-tests, in particular one sample and independent samples.

The one-sample t-test was applied to determine a generic view of: respondents’ level of implementation of DfS; respondents’ attitude towards the DfS; and the extent of influence of the factors that affect DfS implementation (Abueisheh et al., 2020). The independent samples t-test was used to ascertain group differences in respondents’ level of implementation of DfS based on the demographic characteristics of the respondents (Field, 2013). Thus, the independent samples t-test was used to ascertain whether there are any associations between the demographic profile of the respondents (e.g., their role, professional affiliation, DfS education and training relating to DfS) and their level of implementation in DfS practices.

For instance, regarding level of implementation of DfS practices, the one-sample t-test with t-test value of 3.5, which approximates to “4” (i.e., “often”) on the 5-point scale was used. Given the link between design and adverse OSH outcomes in construction (Behm, 2005; Haslam et al., 2005; Cooke and Lingard 2011; Manu et al., 2014), this research, like other studies (e.g. Abueisheh et al., 2020) adopted the logical view that DfS should be integral to design work and therefore the extent of frequency of designers’ engagement in the DfS practices should be at least “often”; more so given that the fifteen DfS practices are prominent practices relevant for the mitigation of significant causes of accidents, injuries and illnesses in the construction industry. Consequently, based on the one-sample t-test applied to the fifteen DfS, a practice with a mean score frequency of engagement which is significantly larger than 3.5 was deemed to be implemented at least “often” by designers.

4. Results

This section presents the outcomes of the data analyses within the following sub-sections.

4.1 Background Information of Participants

Table 3 presents the background information of the research participants. From the table, it can be seen that the responses were split between engineers and architects with the majority of responses (65%) being architects. Furthermore, the majority of the respondents are members of a professional body (91%) and had prior knowledge of the concept of DfS (91%). In addition to this, the table also shows that most of the respondents have either Ba**c**helor’s degrees (28) or Masters Degrees (23), with the 2 categories making up 89% of the responses received.

[Insert Table 3 here]

Figure 1 shows the level of experience and role of the respondents within the construction industry. The figure depicts that the group have a high level of experience both in their role and within the industry, with the average number of years in their role being 11.98 and, in the construction industry being 16.98. Furthermore, most of the responses were from those with over 6 years of experience, with 50 (i.e., 88%) and 44 (i.e., 77%) respondents having over 6 years of experience in the industry and their roles, respectively (see Figure 1).

Finally, a wide range of organisation types formed the survey sample, with their operation taking place in a fairly wide variety of regions. As shown in Figure 2, the majority of respondents work within architectural firms, making up 60% of the sample.

[Insert Figure 1 here]

[Insert Figure 2 here]

4.2 Designers' Awareness, Attitudes and Knowledge of Design for Safety

Table 4 presents the results of designers' awareness, training and professional background in DfS. The table depicts a very high level of awareness of the DfS concept with 52 (91%) respondents indicating they had been aware of the concept before this research. This is further backed up by the large majority of respondents, 42(74%), indicating they had received lessons on DfS as part of their formal education.

The respondents' attitudes towards DfS are shown in Figure 3. From the figure, many (70%) give the concept a very high level of importance, with none giving it the importance of less than moderate. The designers' willingness to apply DfS, their interest in DfS training and their preferred training method are shown in Table 5. From the table, all 57 respondents indicated they would apply DfS if given a choice. This is supported by the large majority (96%) of the respondents also showing interest in future DfS training.

[Insert Figure 3 here]

[Insert Table 4 here]

[Insert Table 5 here]

4.3 Factors affecting the practice of DfS

Drawing from the literature review on the factors that affect the practice of DfS, six factors were given to the participants to rate the extent to which the factors influence the practice of DfS. As shown in Figure 4, laws and regulations (M=3.77, S. D=0.982) were rated as the most influential with industry guides and standards (M=3.74, S.D=0.992) following closely behind. One sample *t*-test was carried out to determine if the mean score of the importance of the DfS factors is significantly larger than the mean test value of 3.5. From Table 6, it can be seen that two out of the six factors had their mean scores significantly greater than the test value of 3.5. This indicates that, the respondents consider the influence of the two factors to be at least "high".

[Insert Figure 4 here]

[Insert Table 6 here]

4.4 Level of Engagement in DfS Practices

The level of engagement in DfS practices was gauged by examining the frequency of participants' engagement in 15 practices that were identified in the literature. From the one-sample t-test analysis (shown by Table 7), eight of the 15 DfS practices were carried out at least often. In addition to this, only 4 (26%) practices had a mean value below 3.5 indicating the majority of practices are carried out at least sometimes.

4.4.1 Independent Samples T-Test

The independent samples t-tests were carried out to explore whether there are statistically significant differences in the mean of the frequency of engagement in the 15 DfS practices by the following clusters:

- those who are members of professional bodies vs. those who are not
- those with prior DfS education and those without
- those who have received DfS training vs. those who have not
- Architects vs. Civil Engineers.

The following are the results of the four tests. For conciseness, only the significant results (i.e., p (2-tailed) ≥ 0.05) are presented below and summarised in the Tables 8-10.

Regarding professional body membership, only two practices were found to have levels of implementation that were significantly different, namely practices DfS-P.13 and DfS-P.10. Concerning prior DfS education, only three practices were found to be statistically significantly different namely practices DfS-P.1, DfS-P.3, and DfS-P.5, all of which relate to material specification. In all 3, those with prior education had reported a higher mean score indicating more frequent practice as illustrated in Table 8. Also, regarding prior DfS training, two practices were found to have levels of implementation that were significantly different, namely DfS-P.4 and DfS-P.6. For both practices, those with prior training had better levels of engagement with higher mean scores as illustrated in Table 9. Finally, no significant differences were found in terms of the respondents' profession (i.e., Civil/Structural Engineers vs. Architects).

[Insert Table 7 here]

[Insert Table 8 here]

[Insert Table 9 here]

[Insert Table 10 here]

5. Discussion

The results from the data analyses offer a valuable insight regarding the status of the concept of DfS in Botswana. These results also provide indications about DfS characteristics and the factors which affect its practice in Botswana.

From the responses received, only 8 of the 15 practices (53%) are carried out at least often. This is relatively higher than the levels of engagement in DfS practices reported in other developing country context. Studies by Manu et al. (2018a) for Ghana, Manu et al. (2019) for Nigeria and Abueisheh et al. (2020) for Palestine all reported fewer than 50% of the examined practices being carried out at least often. As stated by Toole and Erger (2019) and buttressed by Umeokafor et al. (2021), it is important to note that the implementation of every practice at all times may not be needed due to the unique nature of the projects, and the engineers' role in considering occasionally conflicting design criteria to achieve the project goals. This means certain practices may not be implemented at the discretion of the designer due to other project criteria e.g., impact on cost or schedule. Nonetheless, the findings indicate a little over 50% of the examined practices are performed at least often indicating an overall moderate level of implementation. Despite this, there is still cause for concern as several of the practices associated with major causes of accident (e.g., work at height and in confined space) are carried out less frequently, particularly DfS-P.10 (i.e., minimising or eliminating the need to work at heights), DfS-P.11 (i.e., minimising the need to work in confined spaces), and DfS-P.13 (i.e., following a structured procedure to carry out risk assessments). As such despite the moderate level of implementation, the overall level of DfS implementation is still lagging and more efforts are needed to improve DfS practise within the country.

From the one-sample t-test carried out on the factors affecting DfS implementation, it was found that industry guides and standards, as well as government legislation, were the 2 most influencing factors from the perspective of the respondents. As identified in the literature review, weaknesses in OSH legislation and enforcement have been an issue within Botswana's construction industry. This result suggests further work is still required to implement and enforce relevant OSH legislation as a route to enhance DfS implementation.

From the subsequent analysis using the independent samples t-test, it was also found that the following factors have limited effect on DfS implementation:

- Membership of professional bodies did not appear to be associated with higher frequency of engagement across the 15 practices. This is surprising as one may intuitively expect DfS would form part of the industry' standards of best practice promoted by the relevant professional bodies; a notion which was also held by previous DfS studies (Manu et al., 2018a, 2019; Abueisheh et al., 2020; Sharar et al., 2022). This suggest professional bodies within the country may not place high emphasis on DfS practices and may not promote them; i.e., there could be a limited availability of standards and guidance from these bodies regarding DfS. Professional bodies could seek to incorporate or raise the prominence of OSH-related practices in industry standards or guidance, thus, helping to raise the profile of DfS among the design community and other stakeholders in the industry.
- Significance of prior DfS education**:** from the analysis, it was found that three practices; DfS-P.1 (i.e., design to avoid operations that create hazardous fumes), DfS-P.3 (i.e., specification of lightweight material), and DfS-P.5 (i.e., specification of material with less hazardous chemical constituents), were performed more often by those with prior DfS education. This illustrates the importance of education not only in encouraging frequent practice but also seemingly increasing

designer awareness of a variety of hazards e.g., hazardous fumes and materials with hazardous chemical constituents. This is particularly important as Mwanaumo and Thwala (2012) identified the lack of health risk awareness on construction sites in Botswana. While this referred to contractor awareness, a lack of awareness by contractors may also point to designers not making sufficient effort to communicate risks and taking precaution to mitigate them. Nonetheless, the association with prior DfS education with higher engagement with only three out of the 15 practices suggests that DfS education may overall have a relatively limited bearing on engagement in DfS practices by designers in Botswana. While this does not imply that DfS education is unimportant, it shows that there may be more significant drivers of DfS implementation such as the availability of industry standards and guidance and DfS related legislation as confirmed by the results in Table 5.

- Significance of prior DfS training: from the analysis, it was found that 2 practices; DfS-P.4 (i.e., design to accommodate on-site movement) and DfS-P.6 (i.e., design to eliminate hazardous to eliminate significant fire risks during construction), were carried out more frequently by designers with prior DfS training. These two practices indicate a possible greater level of awareness of onsite operations and their related risks by those trained in DfS. This shows the potential of professional training to address one of the barriers to DfS identified by Poghosyan et al. (2018) and Che Ibrahim Che Khairil et al. (2020), which is a lack of designer knowledge on construction processes/a lack of construction knowledge. Nonetheless, the association between prior DfS training and higher engagement with only two out of the 15 practices also suggests that DfS training may overall have a relatively limited bearing on engagement in DfS practices by designers in Botswana. Once again, while this does not imply that DfS training is unimportant, it may be symptomatic of the influence of more significant drivers of DfS implementation such as the availability of industry standards and guidance and DfS related legislation as confirmed by the results in Table 5.

6. Conclusions

In the light of the knowledge gap pertaining DfS in Botswana, this study has examined DfS implementation among designers in Botswana's construction sector. The key conclusions emanating from the findings are as follows.

a) The level of DfS practice in Botswana: the findings indicate the level of DfS implementation within Botswana is generally moderate. Compared to the situation in other developing countries, the results for Botswana were found to be relatively higher; whereby in the other countries fewer than 50% of the examined practices were carried out at least often. Despite this, the level of DfS implementation in Botswana still needs improvement as several key DfS practices were carried out less often.

b) Factors affecting DfS implementation in Botswana: it was discovered that DfS legislation and industry guides and standards are the most influential factors for DfS implementation in Botswana. The subsequent independent samples t-test revealed that within Botswana, DfS in the formal education, DfS training and membership of professional body are perceived by designers to have limited bearing on frequency of engagement in several DfS practices. While this does not suggest that these factors have no importance to DfS implementation, it underscores the influence of other more potent factors such as legislation and industry guides and standards.

In view of the above, multi-stakeholder concerted efforts are needed across the construction industry, to augment the implementation of DfS among design professionals in Botswana's construction industry. The findings from this study do not only apply to the construction industry in Botswana. With DfS studies gradually gaining roots in other sub-Saharan African (SSA) countries, (e.g., Ghana and Nigeria), this study further contributes its portion and provides valuable lessons to the industry in the wider SSA. The findings from this study in agreement with that from other studies conducted in SSA has revealed that, policy makers in consultation with industry players could consider phased introduction of DfS related legislation in order to provide further impetus for DfS practise. Such phased legislation could commence with an initial voluntary application of some DfS requirements (with the view to stimulating interest) followed by gradual introduction of mandatory requirements. Introduction of any DfS related legislation in the construction industry of any SSA country should be coupled with adequate enforcement in view of the lax enforcement of OSH legislation in developing country context (Umeokafor et al., 2022). Furthermore, design professional bodies and other industry bodies in such countries should seek to create DfS standards and guides or incorporate such materials into existing standards and guides. Through this, designers in SSA can be better equipped to implement DfS solutions on projects.

Though the survey research strategy comes with its own advantages, it is associated with several disadvantages. Key disadvantages of the choice of this strategy on this study are the non-response bias and sampling bias of the respondents. The non-response bias was seen in the response rate of 57 out of the 203 Architectural and Engineering firms identified in the Botswana construction industry. Although this response rate was enough for the statistical analyses to be performed, a greater percentage of respondents from these firms could have better solidified the findings from this study. A major recommendation will be for future studies to increase the response rates of the professionals operating in these firms in the Botswana construction industry. The responses obtained could further be buttressed with some qualitative studies to enhance insights into the state of the DfS implementation in the construction industry in Botswana.

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Figure captions

Figure 1: Level of experience within industry and role

Figure 2: Respondents' firms

Figure 3: Respondents view of the importance of DfS

Figure 4: Mean rating for factors affecting DfS implementation

Table captions

Table 1: Literature on Construction OSH in Botswana

Table 2: Instrument design

Table 3: Background information on respondents

Table 4: Respondents prior awareness, education, and professional relating to DfS

Table 5: Willingness to apply DfS, interest in DfS training, and preferred training method

Table 6: One-Sample t-test of Factors Affecting the Practice of DfS

Table 7: One-Sample t-test of DfS Practices

Table 8: Independent Samples t-test based on Professional Body Membership (Significant Results)

Table 9: Independent Sample t-test based on DfS Education (Significant Results)

Table 10: Independent Samples t-test based on DfS Training (Significant Results)

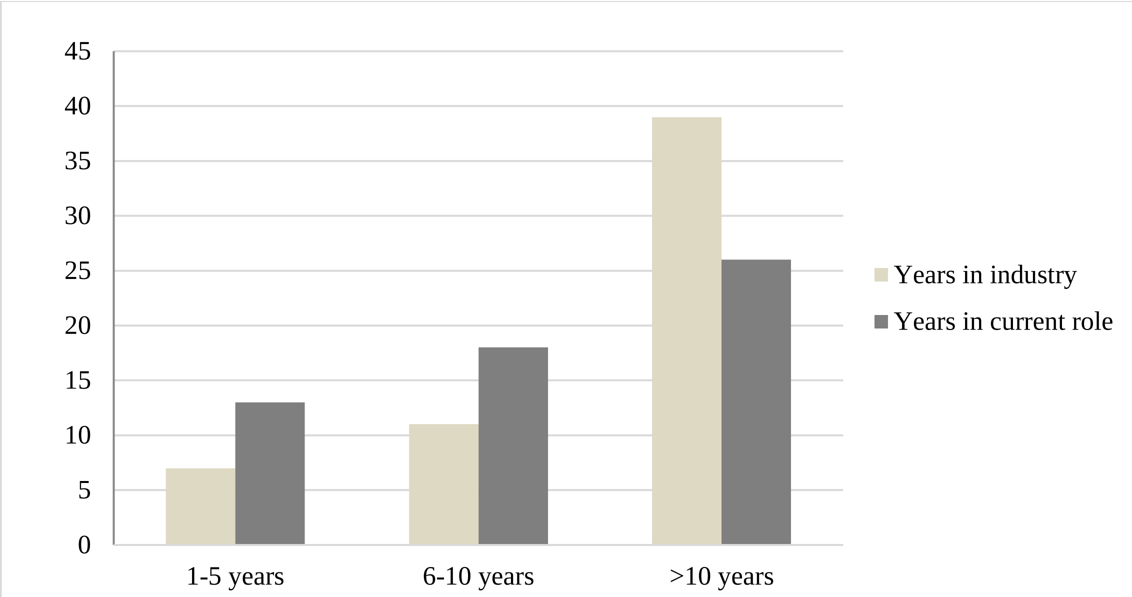

Figure 1: Level of experience within industry and role

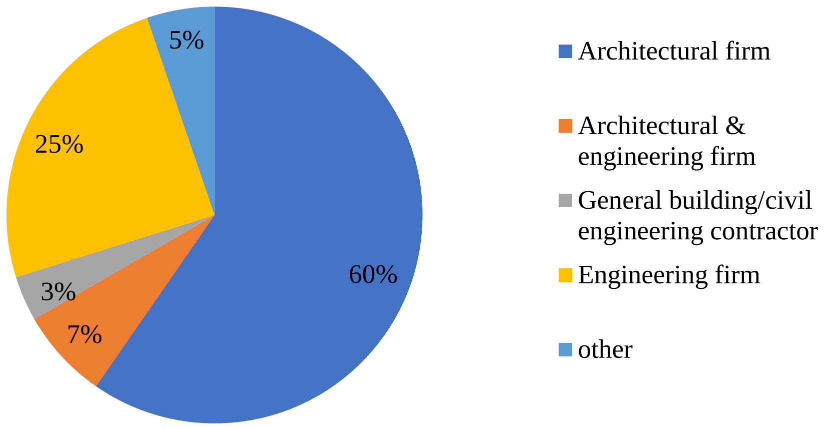

Figure 1: Respondents’ firms

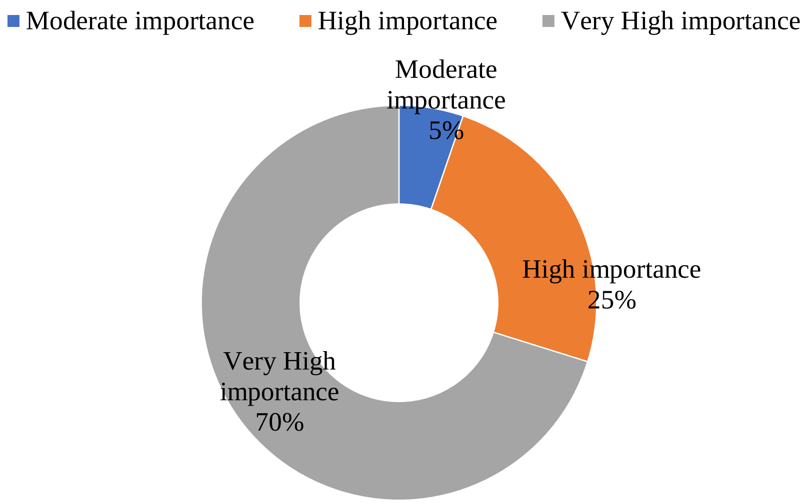

Figure 3: Respondents view of the importance of DfS

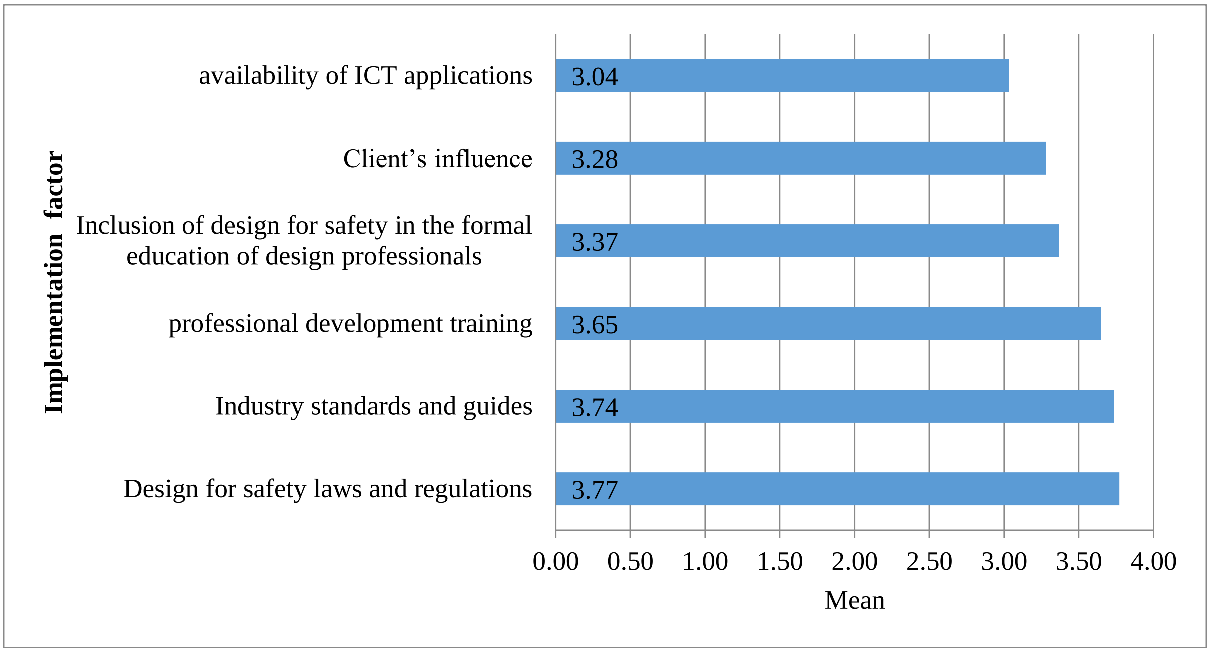

Figure 4: Mean rating for factors affecting DfS implementation

Table 1: Literature on Construction OSH in Botswana

Author	Year	Focus of study
Musonda and Smallwood	2008	This research analysed OSH performance on-site by use of questionnaires.
Musonda and Haupt	2009	This research used structured interviews with project managers from 2 major public client organisations. This study concluded client involvement in OSH was lacking and that the OSH culture within the country was lacking, with no outlined protocol present.
Mwanaumo	2012	Study identified the non-collaborative nature of the country's construction industry further exasperated by the contracting method used. In addition, study makes legislation being unclear about the responsibilities of those in the construction industry. Study also identifies a lack of hazard awareness as a cause of poor OSH practice.
Musonda et al.	2012	Reports a study conducted in Botswana and South Africa on how construction clients could influence OSH performance on projects.
Mwanaumo and Pretorius	2014	Investigated the effect of contractor selection and requirements on OSH compliance in Botswana.
Emuron	2017	Investigated the hazards that are most commonly found at construction sites.

Table 2: Instrument design

Variable	Measurement
Respondents' awareness of DfS	Respondents responded with a Yes/No as to whether they were aware of the DfS concept prior to taking part in the study
Respondents' implementation of DfS	Based on a 5-point scale (5 = always; 4 = often; 3 = sometimes; 2 = rarely; and 1 = never), the respondents were asked to indicate their level of frequency of engaging in DfS practices.
Respondents' attitude towards the DfS	Based on a 5-point scale (5 = very high; 4 = high importance; 3 = moderate importance; 2 = low importance; and 1 = not important) respondents indicated their view regarding the importance of DfS. Furthermore, the respondents were asked to respond with a Yes/No as to whether they would include DfS in their work, if given a choice.
DfS implementation influencing factors	Respondents were asked, based on a 5-point scale (Very high; 4 = High; 3 = Moderate; 2 = Low; and 1 = Not at all) to indicate their judgement regarding the extent to which six factors influence DfS implementation.
Education and training relating to DfS	Respondents responded with a Yes/No as to whether: (1) they have undertaken DfS related training; (2) they are interested in undertaking DfS related training; and (3) they received DfS lessons as part of their formal construction design education. Regarding the training, participants who indicated an interest in DfS training were subsequently requested to provide their preferred mode of training.

Table 3: Background information on respondents

Professional Role		
	Frequency	Percentage
Architect	37	65
Civil/structural engineer	20	35
Professional membership		
	Frequency	Percentage
Yes	52	91
No	5	9
Highest level of education		
	Frequency	Percentage
Diploma	1	2
Higher National Diploma	3	5
Bachelor degree	28	49
Master's Degree	23	40
PhD degree	1	2
Other	1	2

Table 4: Respondents prior awareness, education, and professional relating to DfS

Prior DfS awareness		
	Frequency	Percentage
Yes	52	91
No	5	9
DfS training		
	Frequency	Percentage
Yes	16	28
No	41	72
Formal education involving DfS		
	Frequency	Percentage
Yes	42	74
No	15	26

Table 5: Willingness to apply DfS, interest in DfS training, and preferred training method

Willing to apply DfS if given the choice		
	Frequency	Percentage
Yes	57	100
No	0	0
Interest in future DfS training		
	Frequency	Percentage
Yes	55	96
No	2	4
Preferred training method		
	Frequency	Percentage
Online course/study materials	31	54
Attending seminar/workshop	23	41
No response	3	5

Table 6: One-Sample t-test of Factors Affecting the Practice of DfS

One-Sample Statistics						**One-sample t-test**						
						Test Value = 3.5					95% Confidence Interval of the Difference	
Implementation Factor	N	Rank	Mean	Std. Deviation	Std. Error Mean	t	df	Sig. (2-tailed)	Sig (1- tailed)	Mean Difference	Lower	Upper
Design for safety laws and regulations	57	1	3.77	0.982	0.130	2.090	56	0.041	0.021	0.272	0.01	0.53
Industry standards and guides	57	2	3.74	0.992	0.131	1.803	56	0.077	0.038	0.237	-0.03	0.50
Professional development training	57	3	3.65	1.157	0.153	0.973	56	0.335	0.167	0.149	-0.16	0.46
Inclusion of design for safety in the formal education of design professionals	57	4	3.37	1.046	0.139	-0.950	56	0.346	0.173	-0.132	-0.41	0.15
Client’s influence	57	5	3.28	1.031	0.137	-1.606	56	0.114	0.057	-0.219	-0.49	0.05
Availability of ICT applications	57	6	3.04	0.963	0.128	-3.645	56	0.001	0.000	-0.465	-0.72	-0.21

Table 7: One-Sample t-test of DfS Practices

						One-sample t-test						
						Test Value = 3.5					95% Confidence Interval of the Difference	
One-Sample Statistics						t	df	Sig. (2-tailed)	sig (1-tailed)	Mean Difference		
Practice code*	N	Rank	Mean	Std. Deviation	Std. Error Mean						Lower	Upper
DfS-P.7	57	1	4.51	0.658	0.087	11.575	56	0.000	0.000	1.009	0.83	1.18
DfS-P.8	57	2	4.25	0.872	0.115	6.457	56	0.000	0.000	0.746	0.51	0.98
DfS-P.2	57	3	4.23	0.824	0.109	6.670	56	0.000	0.000	0.728	0.51	0.95
DfS-P.14	57	4	4.23	0.780	0.103	7.051	56	0.000	0.000	0.728	0.52	0.93
DfS-P.6	57	5	4.18	0.759	0.101	6.720	56	0.000	0.000	0.675	0.47	0.88
DfS-P.5	57	6	4.00	0.982	0.130	3.844	56	0.000	0.000	0.500	0.24	0.76
DfS-P.4	57	7	3.82	1.104	0.146	2.220	56	0.031	0.015	0.325	0.03	0.62
DfS-P.12	57	8	3.79	1.114	0.148	1.962	56	0.055	0.027	0.289	-0.01	0.59
DfS-P.1	57	9	3.70	1.267	0.168	1.202	56	0.234	0.117	0.202	-0.13	0.54
DfS-P.3	57	10	3.53	1.037	0.137	0.192	56	0.849	0.424	0.026	-0.25	0.30
DfS-P.11	57	11	3.53	0.947	0.125	0.210	56	0.835	0.417	0.026	-0.22	0.28
DfS-P.13	57	12	3.49	1.088	0.144	-0.061	56	0.952	0.476	-0.009	-0.30	0.28
DfS-P.10	57	13	2.93	1.050	0.139	-4.100	56	0.000	0.000	-0.570	-0.85	-0.29
DfS-P.9	57	14	2.84	0.978	0.130	-5.078	56	0.000	0.000	-0.658	-0.92	-0.40
DfS-P.15	57	15	2.84	1.207	0.160	-4.115	56	0.000	0.000	-0.658	-0.98	-0.34

*Notes: **DfS-P.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); **DfS-P.2:** I specify materials that require less frequent maintenance or replacement; **DfS-P.3:** I specify materials that are easier to handle such as lightweight blocks; **DfS-P.4:** I design to take into account the safe movement of site workers, plants, & equipment on a project site during construction; **DfS-P.5:** I specify materials that have less hazardous chemical constituents; **DfS-P.6:** I eliminate materials that could create a significant fire risk during construction; **DfS-P.7:** I design to position buildings/structures to minimise risks from buried services and overhead cables; **DfS-P.8:** I design to mitigate the possible adverse impact a project could have on the safe movement of the general public during construction; **DfS-P.9:** I design elements (e.g. walls, floors, etc.) so that they can be prefabricated offsite; **DfS-P.10:** I design to minimise or eliminate the need to work at height; **DfS-P.11:** I design to minimise or eliminate the need for workers to work in a confined space; **DfS-P.12:** I highlight unusual construction considerations that have safety implications to the contractor such as key sequence of erecting/construction; **DfS-P.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); **DfS-P.14:** I produce designs that enable ease of building/constructing; **DfS-P.15:** I prepare hazard identification drawings which show significant hazards that may not be obvious to a contractor. Practices adopted from previous DfS studies (e.g. Abueisheh et al., 2020).

Table 8: Independent Samples t-test based on Professional Body Membership (Significant Results)

Group statistics						Independent samples test						
											95% confidence interval of the difference	
Practice code	Membership	N	Mean	Std. Deviation	Std. Error mean	T	Df	Sig. (2-tailed)	Mean difference	Std. Error difference	Lower	Upper
DfS-P.10	Yes	52	2.79	0.977	0.135	-3.614	55	0.001	-1.612	0.446	-2.405	-0.718
	No	5	4.40	0.548	0.245							
DfS-P.13.	Yes	52	3.37	1.048	0.145	-5.802	9.144	0.000	-1.435	0.247	-1.993	-0.877
	No	5	4.80	0.447	0.200							

Table 9: Independent Sample t-test based on DfS Education (Significant Results)

Group statistics						Independent samples test: T-test for equality of means					95% confidence interval of the difference	
Practice code	Formal DfS education	N	Mean	Std. Deviation	Std. Error mean	T	Df	Sig. (2-tailed)	Mean difference	Std. Error difference	Lower	Upper
DfS-P.1.	Yes	42	3.90	1.165	0.180	2.083	55	0.042	0.771	0.370	0.029	1.514
	No	15	3.13	1.407	0.363							
DfS-P.3.	Yes	42	3.71	0.918	0.142	2.284	55	0.021	0.714	0.300	0.114	1.315
	No	15	3.00	1.195	0.309							
DfS-P.5	Yes	42	4.24	0.790	0.122	3.327	55	0.002	0.905	0.272	0.360	1.450
	No	15	3.33	1.175	0.303							

Table 10: Independent Samples t-test based on DfS Training (Significant Results)

Group statistics						Independent samples test						
						T-test for equality of means					95% confidence interval of the difference	
						T	Df	Sig. (2-tailed)	Mean difference	Std. Error difference		
Practice code	Prior DFS training	N	Mean	Std. Deviation	Std. Error mean						Lower	Upper
DfS-P.4	Yes	16	4.31	0.704	0.176	2.564	45.367	0.011	0.678	0.255	0.166	1.191
	No	41	3.63	1.178	0.184							
DfS-P.6	Yes	16	4.56	0.629	0.157	2.418	55	0.015	0.538	0.214	0.110	0.966
	No	41	4.02	0.758	0.118							