Design for Safety in Construction in Sub-Saharan Africa: A Study of Architects in Ghana

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Abstract
Design for safety (DfS) is an important mechanism for addressing accidents in construction. In the main, DfS studies have largely focussed on various regions of the world other than sub-Saharan Africa (SSA). Through a questionnaire survey, this study investigated the DfS awareness and practice amongst architects in the Ghanaian construction sector. Data analysis revealed that there is a low engagement in DfS practice despite a high level of awareness of DfS amongst architects. There is a high interest in DfS training juxtaposed against a low engagement in DfS training. DfS practice is not associated with: awareness of the concept of DfS; engagement in DfS professional development training; receipt of DfS education; membership of professional body; years of experience in role; and the company size. Concerted efforts by industry stakeholders, including clients, educational institutions and design professional bodies would be required to encourage the application of DfS amongst architects and other design professionals within the Ghanaian construction environment. Furthermore, more studies on DfS within the SSA context are required in order to profile DfS awareness and practice amongst design practitioners and other industry stakeholders within the region.

Keywords: construction; design for safety; sub-Saharan Africa; survey; Ghana.

1.0 Introduction

Occupational accidents are unplanned occurrences in the workplace that result in injuries or illnesses to workers, or damage to property (Hughes & Ferrett, 2008). Whereas occupational accidents are not peculiar to any particular industrial sector, the construction sector has a poor reputation in this regard. In many countries, tragic outcomes of accidents such as injuries and illnesses are commonly reported in construction. For instance, in Singapore and Malaysia, the construction sector consistently accounted for the highest number of fatal injuries for over the 4-year period of 2012-2015 (Ministry of Manpower, 2017; Department of Occupational Health and Safety, 2017). Similarly, high numbers of occupational injuries have been reported in other countries including the United Kingdom (UK) and the United States of America (USA) (Health and Safety Executive, 2016; Bureau of Labor Statistic, 2016). In Thailand, industrial activities including construction, machine installation, and water-well digging accounted for over 155,000 accidents and diseases from between 2003 and 2011 (Occupational Safety and Health Bureau, 2012). Available data from Eurostat also show that from 1998 to 2007, the construction sector across 16 European countries accounted for the highest number of fatal accidents (Eurostat, 2012). Aside the social costs of injuries and illnesses, their associated economic costs are eye watering. For example previous estimate from the USA based on 2002 national incidence data from the Bureau of Labor Statistics put the costs of non-fatal and fatal injuries in the construction industry (in 2002) at US$11.5 billion (Waehrer et al., 2007).

Generally, whilst occupational injuries and illnesses are ubiquitous, previous global estimates of occupational accidents by Hämäläinen, Takala & Saarela (2006) pointed out that in sub-Saharan Africa (SSA) the situation is much worse. As a rough illustration of this in respect of the construction sector, 162 fatalities were recorded in South Africa in 2007/2008 (South Africa Construction Industry Development Board, 2009), whilst in the UK 72 worker fatalities were recorded in 2007/2008 (Health and Safety Executive, 2016). Given reports of under-reporting/concealment of occupational incidences in countries in SSA (Ezenwa, 2001; Boakye, Fugar & Akomah, 2010; Umeokafor et al., 2014; Hämäläinen, Saarela. & Takala, 2009) the actual status of occupational health and safety (H&S) performance in construction is very much likely to be worse. Global construction output is expected to increase significantly by 2025 (Global Construction Perspectives and Oxford Economics, 2013) and in sub-Saharan Africa, governments have earmarked significant investments in construction to address infrastructure deficits (e.g. is the infrastructure investment in South Africa (South Africa's Presidential Infrastructure Coordinating Commission, 2012)). This could have dire implications for H&S and therefore a range of efforts are needed to safeguard the health, safety and well-being of construction workers. Amongst the mechanisms for addressing poor H&S performance in construction is design for safety (DfS) which involves designers seeking to eliminate or mitigate hazards during the design stage in order to cut down the probability of occurrence and severity of accidents, injuries and illnesses during construction and maintenance (Schulte et al., 2008). Limited insights about DfS practice in SSA however exist and this brings into question the viability of the concept in countries in this region, including Ghana. This research thus investigated the awareness and practice of DfS amongst architects in the Ghanaian construction industry.

In the sections that follow, a review of DfS and construction H&S in Ghana is presented to highlight the status of construction H&S in Ghana and to underscore the research gap pertaining to DfS studies in SSA. Subsequent to this, the research method adopted for the study, the results of data analysis, implications of results and conclusions are outlined in this paper.

2.0 Literature Review

Introducing improvements in H&S performance is vital for the construction industry. Design and planning are essential phases in every construction work. DfS concept, which is also known as "prevention through design", "safety in design", "safe design", and "design risk management", can be defined as *"The practice of anticipating and designing out potential occupational safety and health hazards and risks associated with new processes, structures, equipment, or tools, and organizing work, such that it takes into consideration the construction, maintenance, decommissioning, and disposal/recycling of waste material, and recognizing the business and social benefits of doing so*" (Schulte et al., 2008). Early research carried out on DfS in construction aimed to establish an empirical link between design and H&S outcomes by analysing the causes of accidents. In the early 2000s strong evidence linking the concept of DfS with construction accidents was found by a number of studies carried out in UK (Haslam, Hide, Gibb, Gyi, Pavitt, Atkinson & Duff, 2005; Gibb, Haslam, Gyi, Hide & Duff, 2006), in USA (Behm, 2005; Gambatese, Behm, & Rajendran, 2008) and in Australia (Cooke & Lingard, 2011). Furthermore, some countries seeking to entrench DfS practice in construction have introduced DfS legislation. Amongst these are the construction DfS-related legislations in several European countries (Aires et al., 2010).

There is a rapidly growing body of studies on DfS in construction, as shown in the Appendix. In response to this phenomenon, Öney-Yazıcı and Dulaimi (2015) commented that DfS publications have often focused on: (1) policies and regulations regarding DfS (e.g. Choudhry, Lingard & Blismas, 2009; Aires, Gamez & Gibb, 2010);

(2) the development of tools for use by designers (e.g. Hadikusumo & Rowlinson, 2004; Cooke, Lingard, Blismas & Stranieri, 2008); and (3) the integration of safety into the design process of construction works (e.g. Weinstein, Gambatese & Hecker, 2005). Aside these, there are also studies on issues regarding designers' H&S knowledge and education (e.g. Behm, Culvenor & Dixon, 2014; López-Arquillos et al., 2015).

Despite the accumulating body of literature on DfS, the vast majority of the DfS research have focused on a few countries particularly in North America, Australia, and Europe. Only two DfS studies appear to have been reported from the SSA region based on a review of journal articles related to DfS (published from 1990 to 2016) within built environment, engineering and multi-disciplinary safety journals (refer to Appendix). Both studies, however, pertain to South Africa where there are no DfS-specific legislations (Smallwood, 2004; Emuze & Smallwood, 2012). Despite an acknowledgement of the importance of DfS by South African designers, Smallwood (2004) concluded that there is a need for more consideration to enable enhanced contribution of design to improve occupational H&S outcomes. There are no apparent DfS studies for the rest of the SSA region. An investigation of DfS in SSA is thus very important particularly given the reported poor status of H&S in this region (Hämäläinen et al., 2006, 2009; Takala et al., 2014). The urgency of this is further buttressed by the forecasted growth in global construction (Global Construction Perspectives and Oxford Economics, 2013) which could have dire H&S consequences for workers within the construction industries of countries in this region. It is on this ground that this study took interest in examining DfS in the Ghanaian construction industry.

Whilst the construction sector of Ghana is a vital sector for the nation's development (Ghana Statistical Services, 2014), its reputation is dented by poor H&S performance (Kheni, Dainty & Gibb, 2008). Whilst H&S statistics are difficult to come by in Ghana, in 2000, out of 902 accidents that occurred in construction, 56 were fatal resulting in a fatality rate of 77.6 per 100,000 workers (Labour Department, 2000). The poor outlook of H&S in Ghana's construction sector within the past 10-15 years has instigated studies in the area of construction H&S (e.g. Kheni, Gibb & Dainty, 2006; Kheni, Dainty & Gibb, 2007; Kheni, Dainty & Gibb, 2008; Kheni, 2009; Boakye et al., 2010; Laryea & Mensah, 2010; Danso, Badu, Ahadzie & Manu, 2015a, 2015b; Donkoh, Adinyira & Aboagye-Nimo, 2015). In the main, these studies have focused on onsite H&S management issues and the enforcement of legislation, with the exception of the work by Donkoh et al. (2015) which explored ways to improve construction H&S through public works procurement. However, there has been no inquiry into DfS (as shown by the Appendix) in spite of recognition by Donkoh et al. (2015) that H&S needs to be integrated into the various phases of construction procurement in Ghana, including the design phase. Whilst there are several H&S legislations which are meant to safeguard the health, safety and wellbeing of workers in the various industries in Ghana, including construction (e.g. Labour Act 651 (2003), Workmen's Compensation Law 187 (1987) and the Factories, Offices and Shops Act 1970), there is no construction specific H&S legislation in Ghana. Consequently, unlike a few countries like Singapore and UK where there are regulations which require DfS, there are none in place in Ghana. Regardless of a DfS legislation in Ghana, an inquiry into its awareness and practice is still worthwhile considering the established link between design, accident and injury occurrence in construction. This is reflected by the situation in countries such as USA and South Africa, where in spite of the non-existence of DfS legislation there has been research activity to help promote DfS practice.

3.0 Research Method

In view of the study's aim of obtaining a generic view of the awareness and practice of DfS by architects in Ghana, a quantitative research strategy, in particular a survey involving the use of a questionnaire, was adopted (Fellows & Liu, 2008; Creswell, 2009).

3.1 Questionnaire design

The questionnaire comprises two main parts.

Part 1: This requested for the following respondents' demographic information: role, experience in role, size of organisation (by number of employees); and professional body affiliation.

Part 2: This requested for responses regarding respondents' awareness of the DfS concept, their education and training relating to DfS, and their engagement in DfS practice. A preamble statement which described the DfS concept was included in the questionnaire. The statement was, *"The concept of design for safety can be described as the integration of hazard identification and risk assessment methods early in the design process to eliminate or minimise the risks of injury and ill health throughout the life of a building or structure being designed".* Based on this description of DfS, respondents were asked to respond to a question about their awareness of DfS prior to their participation in the study.

Concerning the practice of DfS, respondents were asked to indicate their frequency of engaging in several DfS practices that are related to prominent causes of occupational injuries and illnesses in construction such as *working at height, working in confined space, congestion on site, manual handling and the presence of substances hazardous to health* (Suraji, Duff & Peckitt, 2001; Haslam et al., 2005, Cooke & Lingard, 2011; Manu, Ankrah, Proverbs & Suresh, 2010, 2014). 5 practices were examined. The rationale for considering DfS practices that are related to the mitigation of prominent causes of accidents was that, whilst it would be impracticable to cover all DfS practices given that they can be numerous, the focus on the practices that are related to prominent causes of accidents would help to give a reasonable indication of the level of practicing DfS. A five-point Likert scale was used to assess the frequency of engagement in the 15 DfS practices (i.e. 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always).

Due to difficulty in obtaining information records about architects in Ghana, which could have been used as a sampling frame, a pragmatic approach for questionnaire administration involving the use of snow balling was adopted. Hämäläinen et al. (2006) also recounted the difficulty in obtaining accessible information records to facilitate research work especially in developing countries. Overall, 132 completed questionnaires were received out of 350 questionnaires that were distributed. Two questionnaires were discarded due to the respondents not being architects. The effective sample size was thus 130.

3.2 Data analysis

The questionnaire data was initially inputted in Microsoft Excel 2016 to enable screening of the data. Subsequently, the data was exported to IBM SPSS Statistic version 23, which was used to run descriptive statistics including mean, standard deviation and frequencies, as well as inferential statistics, particularly one-sample *t*-test, independent samples *t*-test, and one-way analysis of variance (ANOVA).

Since design can influence workers' H&S significantly, DfS practice should be inherently part of design process. This study expected that, the DfS practices scrutinized should at least be commonly practised by architects due to the association of the practices with the prevention of prominent accident and illness causal factors in construction as previously mentioned. The one-sample *t*-test was therefore conducted to explore whether the frequencies of implementing the DfS practices by the architects could be considered as being at least "often". DfS practices with mean scores that are statistically significantly greater than the test value of 3.5 were thus deemed to be practiced at least often (Ahadzie, Proverbs & Olomolaiye, 2008). The ANOVA and independent samples *t*-tests were conducted to ascertain differences in the frequency of implementing DfS practices by various group comparisons. The groupings used for comparison were based on literature that suggests that issues such as experience, training, educational and professional background can affect DfS awareness, knowledge and skills of construction practitioners. The groupings are as follows: (a) DfS training and (b) receipt of DfS lessons as part of their formal education (Hadikusumo and Rowlinson, 2004; Behm et al., 2014; López-Arquillos, Rubio-Romero & Martinez-Aires, 2015; Goh & Chua, 2016; Toh, Goh & Guo, 2017; Hayne, Kumar & Hare, 2017); (c) membership of professional body (Royal Academy of Engineering, 2011; Sacks et al., 2015); and (d) experience in role (Smallwood, 2004; Sacks et al., 2015; Hayne et al., 2017). The size of respondent's firm was also considered in view of research evidence regarding the relationship between firm size and implementation of H&S practices (Kheni et al. 2008; Manu et al., 2018).

4.0 Results

The results of the data analyses are given below under three main sections: respondents' background information; awareness of DfS, DfS professional development training and education; and engagement in DfS practices.

4.1 Respondents' background information

Table 1 shows the respondents' demographic information. From the table, all the respondents are architects. 51.5% and 48.5% of the respondents have up to 5 years and over 5 years of experience in their role respectively. The mean experience in role is 6.03 years (Standard Dev. = 3.464). 43.1% of the respondents are members of a professional body/bodies. The professional bodies to which the respondents are affiliated to are the Ghana Institute of Architects and the Ghana Engineers and Architects Association. In terms of size of the respondents' organisation, the majority are employed by small firms.

4.2 DfS awareness, education and professional development training

Table 2 gives the results of the respondents' DfS awareness, education and professional development training. From the table, a vast majority (98.5%) of the respondents indicated an awareness of the DfS concept and 83.1% have received DfS related lessons as part of their formal education. However, a much lower proportion of the respondents have received DfS professional development training, although 92.3% of the respondents indicated interest in undertaking DfS training. Regarding preferred method of DfS training, very similar proportions of the respondents indicated preference for attending seminars/workshops and online courses/studies.

[Insert Table 1 approximately here]

[Insert Table 2 approximately here]

4.3 Engaging in DfS practice

The frequency of implementing DfS, based on an examination of the 15 practices, is shown by Table 3. For 13 out of the 15 DfS practices, less than 50% of the respondents implement them often or always. The only two for which 50%+ of the respondents undertake at least often are: designing to take into account safe movement of site workers, plants, & equipment on a project site during construction; and designing to mitigate possible adverse impact a project could have on safe movement of the general public during construction. Overall, the results signal low engagement in DfS practice.

[Insert Table 3 approximately here]

One-Sample t-test for engagement in DfS practice

One-sample *t*-test based on a test value of 3.5 was conducted to explore whether the mean frequencies of implementing the DfS practices by the respondents can be considered as being at least "often". For the sake of brevity only the significant outcomes (i.e. where $p \leq 0.050$) are reported. From the test, only one out of the 15 practices (i.e. *DfS.8* [$t\ (129) = 8.93$, $p < 0.001$]) can be considered as being implemented at least often by the respondents. The results underscore the results shown by Table 3 regarding the low engagement in DfS practice. Thus, apart from designing to eliminate potential negative impact of a project on the safety of the general public during construction, all the other practices are not implemented often or always. These include: *designing to minimise or eliminate the need for workers to work in confined space; designing to minimise or eliminate the need to work at height; designing to avoid construction operations that create hazardous fumes, vapour and dust; specifying materials that are easier to handle; specifying materials that require less frequent maintenance or replacement; and following a structured/systematic procedure for undertaking design health and safety risk assessment.*

Independent samples t-test for engagement in DfS practice

Independent samples *t*-tests were conducted to ascertain differences in the frequency of implementing DfS practices by three categories of groups: (1) receipt of DfS lessons as part of their formal education; (2) membership of professional body; and (3) attendance of DfS training course. The analyses revealed no significant difference in the frequency of application of 15 DfS practices when those who have received DfS lesson as part of their formal design education are compared with those who have not. Similarly, there was no significant difference in the frequency of engagement in the 15 DfS practices when those who are members of a professional body are compared with those who are not. Only *DfS.6* came close to being significant with the *t*-test results as follows: Members of professional body ($M = 2.79$, SD = 0.967); Non-members of professional body (*M* = 3.12, SD = 0.979); t (128) = -1.948, *p* = 0.054. Concerning group comparison by engagement in DfS training (i.e. those who have undertaken DfS training and those who have not), there was significant difference in the mean frequency of implementing only one DfS practice (i.e. DfS.3) out of the 15 practices as shown in Table 4.

[Insert Table 4 approximately here]

ANOVA for engagement in DfS practice

One-way ANOVA was conducted to ascertain differences in the frequency of implementing DfS practices by two categories of groups: (1) experience in role (clustered as 1-5 years; 6-10 years; and over 10 years); and (2) size of organisation (clustered as 0-10 employees; 11-50 employees; and over 50 employees). There were no statistically significant differences between group means as determined by one-way ANOVA for years of experience in role and size of firm. Regarding experience in role, the only practice that was close to statistical significance was *DfS.4* (F (2,127) = 2.372, *p* = 0 .097). Regarding the ANOVA results for firm size, only *DfS.1* came close to statistical significance: F (2,127) = 2.372, *p* = 0 .097.

5.0 Discussion

The discussion compares the results with the findings of previous studies relating to DfS and H&S in general. Overall, the frequency of implementing DfS practices, which is shown by Table 3, and the one-sample *t*-test result, which is shown by Table 4, depicts a low level of involvement in DfS practice amongst the architects. This is an expected result considering the status of construction H&S in Ghana (previously discussed) and the status of occupational H&S in sub-Saharan Africa (Hämäläinen et al., 2006; 2009). The low level of implementing DfS practices is, however, out of sync with the overwhelmingly high level of awareness of the concept of DfS (i.e. 98.5%) amongst the respondents. Whilst Gambatese, Behm & Hinze (2005) reported that awareness of the concept of DfS is important for its implementation, the findings of this study do not reflect this. Although this does not suggest that awareness of the concept is not important for implementation, it however shows that awareness does not necessarily result in actual engagement in DfS practice as was also reported by Goh and Chua (2016) and Toh et al. (2017) in their assessment of the knowledge, attitude and practice of DfS by construction professionals in Singapore. This could be indicative of the existence of more potent obstacles to implementation of DfS or that key drivers for DfS implementation may be non-existent or ineffective within the Ghanaian context. Within the extant literature where designers' knowledge about DfS, designers' attitude towards the concept, and limited or no construction experience by designers amongst others have been identified as DfS barriers (Gambatese et al., 2005; Goh & Chua, 2016), DfS legislation and enforcement as well as clients' role in respect of DfS have been identified as very influential drivers of DfS implementation (Huang and Hinze, 2006; Goh and Chua, 2016; Tymvios and Gambatese, 2016). The gap between the level of awareness of DfS and the involvement in DfS practices could thus be due to the presence of some barriers or the absence of some critical stimuli such as legislation which has been reported as a factor affecting uptake of H&S practices, particularly in the SSA context (Smallwood, 2004; Kheni et al. 2008).

Overall, the independent samples *t*-tests and ANOVA also revealed interesting results. Whilst it was reasonable to expect that there would be significant differences in the means for the various group comparisons, the independent samples *t*-tests and ANOVA results largely did not reflect this expectation. Based on the importance of DfS knowledge, education and training to the practice of DfS (Gambatese et al., 2005; Behm et al., 2014; López-Arquillos et al., 2015; Goh & Chua, 2016, Toh et al., 2017), it was expected that respondents who have received DfS lessons, and also those who have attended DfS related training would show high level of engagement in DfS practice than those who have not. Additionally, based on the premise that professional bodies commonly promote best practices amongst their members, which in the case of design professional bodies should include the promotion of DfS amongst members (Royal Academy of Engineering, 2011; McAleenan & Oloke, 2015), it was expected that respondents who are members of a professional body (i.e. the Ghana Institute of Architects and the Ghana Engineers and Architects Association) would engage in DfS practice more frequently than those who are not. This expectation was, however, not supported by the results of the independent samples *t*-tests.

Furthermore, based on the logic that more experienced design professionals would be more knowledgeable of DfS than younger professionals, it was expected from the ANOVA that years of experience would be associated with frequency of implementing DfS practice. Also, based on evidence in literature that smaller organisations are less likely to implement H&S practices as reported by Kheni et al. (2008), Bonafede et al. (2016) and Manu et al. (2018), it was expected from the ANOVA that the size of respondents' organisation would be associated with frequency of involvement in DfS practice by the respondents. On the contrary, the ANOVA did not reflect either of both expectations.

Significantly, the independent samples *t*-test and ANOVA results, when taken together, suggest that, within the Ghanaian context, DfS training and education, design professional body membership, years of professional experience and the size of firm do not seem to have a significant influence on architects' engagement in DfS practice. Whilst this does not mean that DfS training and education, design professional body membership, experience and organisation of work are not relevant for DfS practice in Ghana, the results are rather indicative of the existence of some other more potent drivers for DfS practice in Ghana which may well be related to the attitude of designers and other industry stakeholders (e.g. clients) towards the importance of DfS. This line of thinking aligns with the study by Goh and Chua (2016) in Singapore, which found designers' mind-set towards DfS to be the most critical factor to the success of DfS practice. Tymvious and Gambatese (2016) based a DfS inquiry in the USA have also reported that clients are the greatest influence for promoting involvement in DfS. The observed keen interest in undertaking DfS training (i.e. 92.3% of respondents) compared with the low participation in DfS professional development training (i.e. 24.6% of respondents) strongly gives hints of barriers to the acquisition of DfS knowledge amongst architects in Ghanaian construction sector. Such barriers may be aligned to designers' attitude towards DfS practices, the suitability and accessibility of DfS training, or other individual or organisational constraints (e.g. organisational support for DfS related professional development).

6.0 Study implications

Important implications emanating from the findings are presented below.

The poor outlook of engagement in DfS practice could be detrimental to the improvement of construction H&S in Ghana and therefore it is important for the profile of DfS to be raised amongst industry stakeholders including architects, clients and the design professional bodies. Clients, being the parties that initiate and finance construction works, wield significant influence which can be leveraged to drive DfS practice on projects. The Ghana government in particular, as the major construction client can play an instrumental role in raising the profile of DfS across the construction sector.

In this study the observed architects have shown strong interest and enthusiasm to receive DfS training. This is expected to be fostered by the design professional bodies (e.g. The Ghana Institute of Architects) and other industry associations by designing and providing adequate training courses which are aligned to the preferred DfS training methods of designers. Close partnerships between the professional bodies and higher education institutions for design/architecture studies could be useful in designing and delivering both online and face-to-face DfS training/education courses and modules.

The study observed a gap between the DfS knowledge related factors (i.e. training and education) and the actual involvement in DfS, a gap between interest in DfS training and the actual attendance of DfS training, which combined with the results obtained from the independent samples *t*-test and ANOVA constitutes a ground for future research to better understand the critical success indicators/obstacles to DfS knowledge exchange and DfS practice in Ghana.

7.0 Conclusions

The construction sector worldwide is notorious for accounting for a high number of occupational injuries and illnesses. The Ghanaian construction sector like others in Sub-Saharan Africa is no exception. Whilst DfS is one of the outstanding ways of reducing the occurrence of injuries and illnesses in construction, very limited empirical insights about DfS exist in sub-Saharan Africa in general and more specifically within the Ghanaian construction context. This research through a survey of architects in Ghana has contributed towards addressing this gap within the extant DfS literature. The research has shown that DfS practice amongst architects is rather low despite a high awareness of the concept of DfS. Furthermore, architects' engagement in DfS training is low despite high interest by architects. Significantly, the findings are suggestive of the existence of some influential inhibitors to DfS practice and knowledge acquisition for which further empirical work would be worthwhile. Joined-up efforts by multiple industry stakeholders, particularly the design professional bodies, educational institutions, clients, design firms and individual designers would be needed to encourage the application of DfS principles beyond mere awareness to actual implementation.

There are two main study limitations that require mentioning. Firstly, the study has focussed on architects and therefore may not reflect the situation within other designer groups in Ghana e.g. civil/structural engineers and building services engineers. Secondly, the findings are based on the Ghanaian context and therefore attempts to draw inferences for other countries within the SSA region should be done with caution. Whilst the empirical examination of DfS awareness and practice focused on the

Ghanaian construction context, the approach used in this study to investigate DfS awareness and practice, particularly the DfS practices that were examined, could provide a useful reference point for the empirical assessment of DfS awareness and practice in other countries in SSA. In view of the significant dearth of DfS research in SSA, more studies on DfS within this region are required in order to provide a clear picture of the status of DfS practice and to also explore ways of increasing interest in DfS amongst industry stakeholders.

Declaration of Interest Statement
The authors have no conflict of interest to declare.

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[Insert Appendix approximately here]

Table 1: Respondent background information

	Frequency	**Percentage**
Professional role		
Architect	130	100

Years of experience in professional role		
1-5 years	67	51.5
6-10 years	52	40.0
Over 10 years	11	8.5
Mean = 6.03. Standard Dev. = 3.464		
Size of organisation by number of employees		
0-10 Employees (Micro firm)	39	30.0
11-50 Employees (Small firm)	82	63.1
Over 50 Employees (Medium - Large firm)	9	6.9
Professional body affiliation		
Yes	56	43.1
No	74	56.9

Table 2: Design for safety awareness, education and training

	Frequency	**Percentage**
Awareness of design for safety (DfS) concept		
Yes	128	98.5
No	2	1.5

Receipt of DfS lessons as part of formal education		
Yes	108	83.1
No	22	16.9
Engagement in DfS professional development training		
Yes	32	24.6
No	98	75.4
Interest in undertaking DfS training		
Yes	120	92.3
No	10	7.7
Preferred DfS training method[a]		
Online course/study	75	57.7
Attending seminar/workshop	76	58.5
Other preference	2	1.5

[a]Note: The total percentage is greater than 100 percent due to multiple preferences by some respondents.

Table 3: Extent of engagement in design for safety practices

	DfS Practices	Frequency of engaging in design for safety practice

DfS Practice Code		Never (%)	Rarely (%)	Sometimes (%)	Often (%)	Always (%)	Often & Always (%)
[a]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).	4.6	14.6	38.5	32.3	8.5	40.8
[a]DfS.2	I specify materials that require less frequent maintenance or replacement.	0	36.9	42.3	6.9	12.3	19.2
[a]DfS.3	I specify materials that are easier to handle such e.g. light-weight blocks.	0	13.8	55.4	15.4	14.6	30
DfS.4	I design to take into account safe movement of site workers, plants, & equipment on a project site during construction.	0	11.5	26.2	51.5	9.2	60.7
[a]DfS.5	I specify materials that have less hazardous chemical constituents.	3.8	14.6	49.2	24.6	6.9	31.5
[a]DfS.6	I eliminate materials that could create a significant fire risk during construction.	0	49.2	3.8	46.2	0	46.2
[a]DfS.7	I design to position buildings/structures to minimise risks from buried services and overhead cables.	15.4	18.5	40	10	15.4	25.4
DfS.8	I design to mitigate possible adverse impact a project could have on safe movement of the general public during construction.	3.1	0	6.2	63.8	24.6	88.4
[a]DfS.9	I design elements (e.g. walls, floors, etc.) so that they can be prefabricated offsite.	18.5	18.5	55.4	0.8	6.2	7
[a]DfS.10	I design to minimize or eliminate the need to work at height.	0	26.9	52.3	19.2	0	19.2
[a]DfS.11	I design to minimize or eliminate the need for workers to work in confined space.	0	0	49.2	46.2	3.1	49.3
DfS.12	I highlight unusual construction considerations that have safety implications to the contractor e.g. key sequence of erecting/construction	0	24.6	20.8	40	12.3	52.3
[a]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.	17.7	18.5	43.8	0	18.5	18.5
[a]DfS.14	I produce designs that enable ease of building/constructing	3.1	18.5	36.9	24.6	15.4	40
[a]DfS.15	I prepare hazard identification drawings that show significant hazards that may not be obvious to a contractor.	0	21.5	30.8	39.2	6.2	45.4

Note: As a result of some missing responses, the total % may not be 100% for some DfS practices.

[a]DfS practices for which less than 50% of the respondents undertake often or always.

Table 4: Independent samples t-test for differences in engaging in DfS practices - by engagement in DfS training

DfS Practice Code	DfS training	N	Mean	Std. Dev.	Std. Error Mean	t	df	Sig. (2-tailed)	Mean Diff.	Std. Error Diff.	95% Confidence Interval of the Difference	
											Lower	Upper
DfS.3	Yes	32	3.59	.946	.167	2.128	128	.035	.379	.178	.027	.732
	No	98	3.21	.853	.086							

Appendix: Design for Safety Studies in Construction (published in journals since 1990s)

Author	Year	[a]Journal	Volume	Issue	Pages	[b]Location of Study	[c]Region
Hinze & Wiegand	1992	JCEM	118	4	677-684	USA	NAM
Heger	1996	PPSDC	1	4	113-118	USA	NAM
Gambatese et al.	1997	JAE	3	1	32-41	USA	NAM
Gambatese	1998	JAE	4	3	107-112	USA	NAM
Gambatese & Hinze	1999	AC	8	6	643-649	USA	NAM
Arditi & Nawakorawit	1999	JAE	5	4	107-116	USA	NAM
Coble & Blatter	1999	JAE	5	2	44-48	n/a	n/a
Baxendale & Jones	2000	IJPM	18	1	33-40	UK	EUR
Hadikusumo & Rowlinson	2002	AC	11	5	501-509	Hong Kong	AS
Toole & Gambatese	2002	PPSDC	7	2	56-60	USA	NAM
Hinze	2002	PPSDC	7	2	81-84	USA	NAM
Anderson	2003	PICEME	156	3	175-178	UK	EUR
Hecker & Gambatese	2003	AOEH	18	5	339-342	USA	NAM
Hadikusumo & Rowlinson	2004	JCEM	130	2	281-289	Hong Kong	AS
Al-Homoud et al.	2004	BRI	32	6	538-543	Saudi Arabia	MENA
Smallwood	2004	JSAICE	46	1		South Africa	SSA
Gambatese et al.	2005	JCEM	131	9	1029-1036	USA	NAM
Weinstein et al.	2005	JCEM	131	10	1125-1134	USA	NAM
Hare et al.	2006	ECAM	13	5	438-450	UK	EUR
Huang & Hinze	2006	JCEM	132	2	174-181	USA	NAM
Toole et al.	2006	MSC	46	6	55-59	USA	NAM
Greenwood	2007	TAJCEB	7	1	37-44	Australia	AUS
Gibb et al.	2007	CIQ	9	3	113-123	UK	EUR
van Gorp	2007	DS	28	2	117-131	Netherlands	EUR
Cooke et al.	2008	ECAM	15	4	336-351	Australia	AUS
Creaser	2008	JSR	39	2	131-134	Australia	AUS
Slater & Radford	2008	TAJCEB	8	1	23-33	Australia	AUS
Cameron & Hare	2008	CME	26	9	899-909	UK	EUR
Evans	2008	PICECE	161	5	16-20	UK	EUR
Frijters & Swuste	2008	SS	46	2	272-281.	Netherlands	EUR
Mann	2008	JSR	39	2	165-170	USA	NAM
Schulte et al.	2008	JSR	39	2	115-121	USA	NAM

Howe	2008	JSR	39	2	161-163	USA	NAM
Lin	2008	JSR	39	2	157-159	USA	NAM
Manuele	2008	JSR	39	2	127-130	USA	NAM
Gambatese	2008	JSR	39	2	153-156	USA	NAM
Toole & Gambatese	2008	JSR	39	2	225-230	USA	NAM
Behm	2008	JSR	39	2	175-178	USA	NAM
Khudeira	2008	PPSDC	13	3	109-110	USA	NAM
Gambatese et al.	2008	SS	46	4	675–691	USA	NAM
Al-Jibouri & Ogink	2009	AEDM	5	4	179-192	Netherlands	EUR
Hallowell & Gambatese	2009	JCEM	135	12	1316-1323	USA	NAM
Rajendran et al.	2009	JCEM	135	10	1058-1066	USA	NAM
Megri	2009	PPSDC	14	4	181-189	USA	NAM
Atkinson & Westall	2010	CME	28	9	1007-1017	UK	EUR
Gangolells et al.	2010	JSR	41	2	107-122	Spain	EUR
Martinez-Aires et al.	2010	SS	48	2	248–258	EU	EUR
Rwamamara et al.	2010	CI	10	3	248-266	Sweden	EUR
Christensen	2010	PS	55	4	32-39	USA	NAM
Lopez et al.	2010	JPCF	24	4	399-408	n/a	n/a
Pinto et al.	2011	SS	49	5	616–624	Portugal	EUR
Pérez-Alonso et al.	2011	SS	49	2	345-354	Spain	EUR
Valdes-Vasquez & Klotz	2011	JPIEEP	137	4	189-197	USA	NAM
Chun et al.	2012	CI	12	1	29-42	Hong Kong	AS
Yang et al.	2012	AAP	48		193-203	China/USA	AS/NAM
Lingard et al.	2012	CME	30	5	367-382	Australia	AUS
Chileshe & Dzisi	2012	JEDT	10	2	276-298	UK	EUR
Aneziris et al.	2012	RESS	105		36-46	Greece/Netherlands	EUR
Zhou et al.	2012	AC	22		102-111	UK-Israel	EUR/MENA
Dewlaney & Hallowell	2012	CME	30	2	165-177	USA	NAM
Behm	2012	JCEM	138	8	999-1003	USA	NAM
Emuze & Smallwood	2012	PICEMPL	165	1	27-34	South Africa	SSA
Lingard et al.	2013	BEPAM	3	1	7-23	Australia	AUS

Lingard & Wakefield	2013	PICEMPL	166	5	240-248	Australia	AUS
Larsen & Whyte	2013	CME	31	6	675-690	UK	EUR
Spillane & Oyedele	2013	TAJCEB	13	4	50-64	UK	EUR
Zhang et al.	2013	AC	29		183-195	USA	NAM
del Puerto et al.	2013	IJCER	9	4	307-316	USA	NAM
Toole & Carpenter	2013	JAE	19	3	168-173	USA	NAM
Kaskutas et al.	2013	JSR	44		111-118	USA	NAM
Rajendran & Gambatese	2013	PPSDC	18	1	67-72	USA	NAM
Toole et al.	2013	PS	58	1	41-47	USA	NAM
Popov et al.	2013	PS	58	3	44-49	USA	NAM
Gibb et al.	2014	CME	32	5	446-459	Australia/UK/USA	AUS/EUR/NAM
Almén et al.	2014	BEPAM	4	3	251-263	Sweden	EUR
Mahmoudi et al.	2014	SHW	5	3	125-130	Iran	MENA
Qi et al.	2014	JCCE	28	5	A4014008	USA	NAM
Behm et al.	2014	SS	63		43282	USA	NAM
Simanaviciene et al.	2014	AC	39		47-58	n/a	n/a
Forsythe	2014	PICEMPL	167	5	242-252	n/a	n/a
Zou et al.	2014	SS	70		316–326	n/a	n/a
Fonseca et al.	2014	SS	70		406–418	Brazil	SAM
Bong et al.	2015	IJCM	15	4	276-287	Australia	AUS
Sadeghi et al.	2015	SS	80		252–263	France	EUR
López-Arquillos et al.	2015	SS	73		8-14	Spain	EUR
Zhang et al.	2015	SS	72		31-45	Finland	EUR
Morrow et al.	2015	AEDM	11	5	338-359	UK	EUR
Ganah & John	2015	SHW	6	1	39-45	UK	EUR
Öney-Yazıcı & Dulaimi	2015	AEDM	11	5	325-337	UAE	MENA
Kasirossafar & Shahbodaghlou	2015	PS	60	8	42-46	Iran	MENA
Sacks et al.	2015	CME	33	1	55-72	Israel/UK	MENA/EUR

Dharmapalan et al.	2015	JCEM	141	4	4014090	USA	NAM
Hallowell & Hansen	2015	SS	82		254-263	USA	NAM
Wilbanks	2015	PS	60	4	46-51	USA	NAM
Wang et al.	2016	AAP	93		267-279	China	AS
Goh & Chua	2016	AAP	93		260-266	Singapore	AS
Edirisinghe et al.	2016	AEDM	12	4	296-310	Australia	AUS
Teizer	2016	CI	16	3	253-280	Germany	EUR
Morrow et al.	2016	ECAM	23	1	40-59	UK	EUR
Martínez-Aires et al.	2016	W	53	1	189-191	UK/Spain	EUR
Tymvios & Gambatese	2016	JCEM	142	8	4016024	USA	NAM
Tymvios & Gambatese	2016	JCEM	142	2	4015078	USA	NAM
Hallowell & Hansen	2016	SS	82		254-263	USA	NAM
Alarcón et al.	2016	AAP	94		107-118	Chile	SAM

Notes

[a]AAP = Accident Analysis and Prevention, AC = Automation in Construction, AEDM = Architectural Engineering and Design Management, AOEH = Applied Occupational and Environmental Hygiene, BEPAM = Built Environment Project and Asset Management, BRI = Building Research and Information, CI = Construction Innovation, CIQ = Construction Information Quarterly, CME = Construction Management and Economics, DS = Design Studies, ECAM = Engineering, Construction and Architectural Management, IJCER = International Journal of Construction Education and Research, IJCM = International Journal of Construction Management, IJPM = International Journal of Project Management, JAE = Journal of Architectural Engineering, JCCE = Journal of Computing in Civil Engineering, JCEM = Journal of Construction Engineering and Management, JEDT = Journal of Engineering, Design and Technology, JPCF = Journal of Performance of Constructed Facilities, JPIEEP = Journal of Professional Issues in Engineering Education and Practice, JSAICE = Journal of the South African Institution of Civil Engineering, JSR = Journal of Safety Research, MSC = Modern Steel Construction, PICECE = Proceedings of ICE Civil Engineering, PICEME = Proceedings of ICE Municipal Engineer, PICEMPL = Proceedings of ICE Management, Procurement and Law, PPSDC = Practice Periodical on Structural Design and Construction, PS = Professional Safety, RESS = Reliability Engineering and System Safety, SHW = Safety and Health at Work, SS = Safety Science, TAJCEB = The Australian Journal of Construction Economics and Building, W = Work.
[b]EU = European Union, n/a = not available, UAE = United Arab Emirates, UK = United Kingdom, USA = United States of America.

[c]AS = Asia, AUS = Australia, EUR = Europe, MENA = Middle East and North Africa, n/a = not available, NAM = North America, SAM = South America; SSA = Sub-Saharan Africa.