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Design for Safety Implementation Factors: A Literature Review

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Abstract

Purpose: Decisions made during the design stage of construction works can significantly reduce the risk of occurrence of occupational accidents, injuries and illnesses. Moreover it has been established that design is one of the major contributors of accidents and injuries. Design for safety (DfS) studies within construction have highlighted factors affecting the implementation of DfS, amongst which are: designer attitude; DfS knowledge/awareness and education; availability of DfS tools including guidance; client's influence and motivation; and legislation. The main objective of this study is to carry out an in-depth literature review of DfS studies within construction to explore the extent to which existing DfS research have looked at the above listed DfS implementation factors.

Design/methodology/approach: A review of 164 journal articles related to design for safety in construction (published from 1990 to 2017) within built environment, engineering and multi-disciplinary safety journals was undertaken.

Findings: The findings indicate that around 60% of the journal articles reviewed address designer knowledge/awareness and education issues; about 27% looked at DfS implementation tools to assist designers to undertake DfS; about 23% studied client influence/motivation; about 16% studied designers attitudes towards DfS implementation; and approximately 16% looked at the role of legislation in DfS implementation. The literature points that client influence/motivation and legislation are very influential DfS implementation factors despite a limited number of studies in these areas.

Originality/value: Overall, the findings provide an indication of areas of DfS implementation, particularly client influence/motivation and legislation, where more research would be needed to promote DfS in construction in order to help mitigate the occurrence of accidents and injuries.

Keywords: Accident; construction; design for safety; prevention through design; safety in design.

Introduction

Despite improvements in occupational safety and health (OSH) in construction over the years in several countries, the rate of accidents, injuries and illnesses in the construction industry is still greater than that of other industries (Health and Safety Executive, 2014; Department of Occupational Health and Safety (DOSH), 2015; Bureau of Labor Statistic, 2016). Construction accident causation is rather a complex phenomenon and there are many factors that have to be taken into consideration. It has been established that hazards that lead to accidents, injuries and illnesses on construction sites could be avoided or mitigated through design decisions (Behm, 2005; Haslam et al., 2005; Cooke and Lingard, 2011). Hence implementing design for safety (DfS) (also known as “prevention through design”, “safety in design”, “safe design”, and “design risk management”) is considered to be one of the prominent ways of tackling the occurrence of occupational accidents, injuries, and illnesses in construction.

Studies on DfS have linked the viability of the concept of DfS in construction to DfS implementation factors (Gambatese et al., 2005; Tymvious and Gambatese, 2016;

Goh and Chua, 2016; Toh et al., 2016). Amongst the early DfS studies in this regard is the work by Gambatese et al. (2005) in which designer attitude, designer awareness/knowledge and education regarding DfS, availability of DfS tools, clients' influence/motivation, and legislation were highlighted as key factors affecting DfS implementation. Subsequently, the findings of other studies (e.g. Tymvious and Gambatese, 2016; Goh and Chua, 2016) have also corroborated the factors reported by Gambatese et al. (2005). For instance, Tymvious and Gambatese (2016) showed from a Delphi survey in the United States of America (USA) that client's involvement has the greatest influence to generate interest in DfS. A survey of construction industry stakeholders in Singapore by Toh et al. (2016) similarly revealed that the client/developer is perceived to have the greatest influence on DfS. Goh and Chua (2016) investigated the DfS knowledge, attitude and practice of civil and structural engineers in Singapore by the use of a survey and found that designers' mind-set towards safety and legislative force were perceived to be amongst the most important factors influencing the success of DfS. Over the years, whilst various studies have looked at these DfS implementation factors, within the extant DfS literature there is lacking an overall indication of the extent to which the factors have been explored so as to constitute an informed basis to forge appropriate research directions. The main objective of this study is thus to systematically review published research (journal articles) on DfS in construction in order to gauge the extent to which the existing studies have researched the aforementioned DfS implementation factors. Involving over 150 DfS articles in built environment, engineering and multi-disciplinary safety journals this review aims to provide directions for further empirical works.

Research Method

A review of existing international evidence on DfS was conducted using systematic evidence review techniques (search strategy, inclusion criteria, data extraction and synthesis). The review included searching academic databases as shown in Table 1 as well as other relevant journals (e.g. The Australasian Journal of Construction Economics and Building, and Journal of Construction in Developing Countries) that were not included in any of the highlighted databases. In particular the search looked at journal articles on DfS published from 1990 to mid-2017. After conducting preliminary searches to assess the effectiveness of different search terms, the following search strings were used: “design for safety”, “safety in design”, “prevention through design” and “design risk management”. The initial search was performed and subsequently the abstracts of the recorded journal articles were screened further for relevant subject areas and the duplicates found in different databases were removed. The selected journal articles were then screened again and classified according to the following DfS implementation factors: designer attitude; knowledge/awareness and education; DfS tools; clients’ influence/motivation; and legislation (Gambatese et al., 2005; Tymvious and Gambatese, 2016; Goh and Chua, 2016; Toh et al., 2016).

[Insert Table 1]

Main Results

As a result of the in-depth search, using the search protocol described in the research method section as well as snowballing in published DfS research, 198 journal articles were recorded, 34 of which were not relevant in the context of construction and DfS implementation factors. Consequently, 164 articles were used in the study. Review of the 164 articles showed that surveys, interviews and expert group technique are commonly employed methods in DfS research. Categorisation of the articles based on the DfS implementation factors they examined is shown by Table 2 where: *A - Designer attitude; B - Designer Awareness/knowledge and education; C – DfS tools; D - Clients influence/motivation; and E - Legislation*. A breakdown of the spread of the factors and articles over time, which is given by Table 3 shows a growing trend in DfS articles, with 2008 and the period of 2011-2015 recording the highest number of articles between 1900-2015. A further illustration of a percentage distribution of the DfS implementation factors within the 164 articles is given by Figure 1 as: *A - Designer attitude (15.85%); B - Designer Awareness/knowledge and education (60.37%); C – DfS tools (27.44%); D - Clients influence/motivation (22.56%); and E - Legislation (16.46%)*. The factors are discussed further in the following sections.

[Insert Figure 1]

[Insert Table 2]

[Insert Table 3]

Discussion

Designer attitude

This factor featured in less than a quarter of the reviewed articles (i.e. 15.85%). In 1992 a survey of design firms and contractors in the USA found that a one-third of the designers take into consideration the safety of construction workers in design (Hinze and Wiegand, 1992). The results from later studies on this topic confirmed that designers' attitude is an important factor influencing implementation of DfS in practice (Gambatese et al. 2005; Sacks et al. 2015; Öney-Yazıcı and Dulaimi, 2014; Toh et al., 2017). Moreover it has been shown that designers' interpretation of the term health and safety affects their response to the demands to consider it during design stage (Öney-Yazıcı and Dulaimi, 2014). In their work, Gambatese et al. (2005) evaluated designers' attitude towards DfS via interviews which suggested that most of the respondents have a positive or neutral attitude towards safety. Similarly, the majority of respondents in a survey conducted by Toh et al. (2017) in the Singapore construction industry demonstrated a positive attitude towards DfS. The level of DfS attitude was statistically significantly higher than the neutral level. Sacks et al. (2015) carried out a study to test designers' attitudes to construction safety hazards through virtual reality tools. The results obtained revealed that consultation and dialogue with an experienced construction professional could influence designers to consider safety issues when adapting design details. Although a number of studies within the articles reviewed seem to suggest that the majority of design professionals have a positive attitude towards DfS, there is also evidence that not every design professional/firm succeeds in demonstrating their commitment to DfS. This indicates that DfS practice is underdeveloped in the construction industry (Toh et al., 2017).

Designer Awareness/Knowledge and Education

Designer awareness/knowledge and education is often accompanied by designer attitude discussed in the subsection above. In general from the review of different studies it can be concluded that even though design professionals may be supportive of DfS and have awareness of DfS, the level of DfS knowledge and education needs to be continuously improved (López-Arquillos et al., 2015, Toh, et al., 2017, Goh and Chua, 2016, Gambatese et al., 2008, Hadikusumo and Rowlinson, 2004, Hallowell, 2012). The literature review showed that more than a half of the articles (i.e. 60.37%) have explored designer awareness/knowledge and education issues and consider it crucial for DfS implementation (Gambatese et al. 2005; Öney-Yazıcı and Dulaimi, 2014, Toh et al., 2017). Toole (2005) identified designers' lack of understanding of construction processes as a substantial barrier that would prevent designers from contributing to worker safety. A survey conducted by Behm et al. (2014) showed that an educational intervention changed students' perceptions of accident causality and prevention to favour safe design thinking. However, an insufficient emphasis on DfS in design and construction courses has been reported in Spain (López-Arquillos et al., 2015). López-Arquillos et al. (2015) argued that industry stakeholders ought to launch initiatives to promote DfS in university degrees as improved knowledge on safety issues would be beneficial for construction. Apart from offering design professionals appropriate courses and training, it is also very important that organisations have an effective safety-knowledge management (KM) process in place. The work of Hallowell (2012) discusses through a number of case studies knowledge management strategies employed in USA construction industry whilst Hadikusumo and Rowlinson (2004) present a tool to capture safety knowledge from safety engineers about construction safety hazards and the safety measures required.

DfS Tools

This factor recorded the second highest proportion of articles (i.e. 27.44%). Articles on DfS tools started to emerge after 1995 as shown by Table 3. One of the first computer-based DfS implementation tools "Design for Construction Safety ToolBox" was developed by Gambatese et al. (1997). The purpose of the tool was to assist designers in recognising project-specific hazards and implementing the design suggestions into a project's design by linking the design and construction phase. The advances in computer-aided design technology later in the 2000s allowed the implementation of sophisticated tools and methodologies for integrating OSH in early stages of construction and providing decision support (Hadikusumo and Rowlinson, 2004, 2012; Cameron and Hare, 2008; Cooke et al., 2008; Nussbaum et al., 2009). Just a few worth mentioning examples include: a methodology to facilitate designers in comparing construction techniques and systems during the design phase and determining the corresponding level of safety risk (Gangolells et al., 2010); a decision support system (DSS) to allow early assessment of ergonomic risks by designers (Nussbaum et al., 2009); a safety indicator proposed for safety level assessment at the earliest design stages (Sadeghi et al., 2015); and more recently a proposed web-based DfS organisational capability maturity indicator tool (Manu et al., 2017).

Clients' influence/motivation

Construction clients being the initiators and/or funders of construction works can play a central role in encouraging the implementation of OSH practices in a project (Toole, et al. 2017). The importance of the client in motivating DfS implementation and OSH management in construction has been highlighted in the literature (Huang and Hinze, 2006; Atkinson and Westall, 2010; Lingard et al., 2013; Tymvious and Gambatese, 2016; Goh and Chua, 2016; Toh et al., 2017; Toole et al., 2017). The results of a recent survey by Goh and Chua (2016) investigating practices of DfS indicated that clients' motivation for DfS in Singapore could be the key to improving designers' DfS knowledge, attitude and practice. The survey results show that engineers consider clients as having the greatest influence on safety. Safety performance model introduced by Huang and Hinze (2006) analysed data gathered from 59 projects and showed that owner's and/or clients' involvement can improve project safety performance by setting safety objectives, selecting competent contractors, and participating in safety management during construction. These results agree with the Delphi study conducted by Tymvious and Gambatese (2016) which showed that owners' involvement has the greatest influence to generate interest in DfS in USA. Despite the evidence from different studies that suggests that clients' influence/motivation is probably the most important DfS implementation factor, there are fewer published articles on this factor (i.e. 22.56%) as shown by Figure 1. The dearth of articles on clients' influence/motivation is also accentuated by the lack of articles examining this factor for over an entire decade within 1990 and 2001 (see Table 3). More research regarding how client's influence/motivation can be leveraged to promote DfS implementation in construction would therefore be useful.

Legislation

The established connection between design and construction accidents instigated several countries to introduce legislation to encourage and/or require designer participation in construction worker safety. The literature review showed that there is only a small amount of research investigating legislation issues regarding DfS implementation (i.e. 16.46%) and that the studies observed concern legislation in developed countries such as Singapore (i.e. the Workplace Safety and Health (Design for Safety) Regulations 2015), Australia (i.e. the Work Health and Safety Acts and Regulations), UK (i.e. the Construction Design and Management Regulations 2015) and EU countries (adaptations of European Framework Directive 92/57/EEC). It is worth mentioning that currently USA has no DfS legislation in place despite an observed high number of DfS articles based on the USA context. In the survey conducted by Tymvios and Gambatese (2016) in USA, architects and engineers recognized obstacles for DfS implementation in three key areas: legal, economic, and contractual. Within the USA construction industry designers are deterred from assuming the additional responsibility of considering construction worker safety in their designs. A survey of design engineers in Australia concluded that the regulations and codes of practice have a positive impact on construction worker safety (Behm and Culvenor, 2011). In terms of influence of regulations on OSH in design stage, Aires et al. (2010, 2016) in their work explored the impact of European Framework Directive 92/57/EEC on DfS with particular focus on Spain and UK construction industry. They identified that in Spain DfS is practiced less frequently. Similar to client influence/motivation, whilst legislation is recognised within the literature as an important driver of DfS implementation, very few studies have focussed on DfS legislation (see Figure 1). In view of this, effective ways by which DfS legislation can be introduced and enforced in various national contexts could be explored by research.

Conclusion

DfS is a rapidly growing research area in construction. The in-depth literature review undertaken in this study recorded 164 articles published in built environment, engineering and multi-disciplinary safety journals. A great amount of research has been carried out on DfS in the context of designer awareness/knowledge and education. However whilst client influence/motivation and legislation have been suggested to probably be the most influential drivers of DfS implementation, fewer studies have focussed on these. To rectify this ‘imbalance’, further research would be needed to particularly explore ways by which client influence/motivation could be leveraged to stimulate greater interest and implementation of DfS amongst designers. Aligned to this, ways by which DfS legislation can be introduced and effectively enforced in different national contexts ought to be explored by research. Given the alluded significance of client influence and legislation, research in these directions could yield insights that could consequently engender greater positive designer attitude to DfS.

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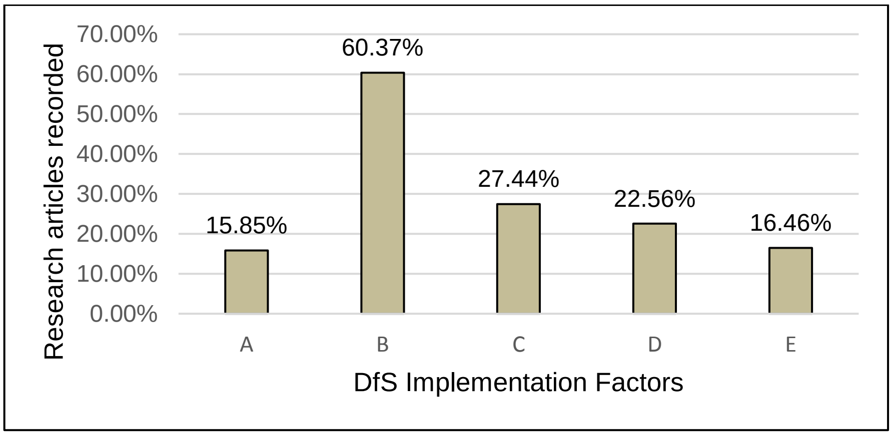

Figure 1: Percentage distribution of DfS implementation factors

of academic database search strings and results

Database	Search String	No. after initial search	No. after screening abstracts
Science Direct	pub-date ≥ 1990 and TITLE-ABSTR-KEY("design for safety") or TITLE-ABSTR-KEY("safety in design") or TITLE-ABSTR-KEY("prevention through design") or TITLE-ABSTR-KEY("design risk management").	76	64
Taylor & Francis	“design for safety” or “safety in design” or “prevention through design” or “design risk management”	143	28
Emerald Insight	“design for safety” or “safety in design” or “prevention through design” or “design risk management”	39	17
American Society of Civil Engineers (ASCE)	“design for safety” or “safety in design” or “prevention through design” or “design risk management”	163	45
EBSCO	“design for safety” or “safety in design” or “prevention through design” or “design risk management”	51	32
ICE (Institution of Civil Engineers) Virtual Library	“design for safety” or “safety in design” or “prevention through design” or “design risk management”	26	9
Other Sources	“design for safety” or “safety in design” or “prevention through design” or “design risk management”	3	3
		Total = 501	Total = 198

Table 2: Thematic categorisation of DfS articles based on DfS implementation factors

Author	Year	Journal	Vol.	Issue	Pages	DfS implementation factor
P.Manu, L. Mahdjoubi, A.Gibb, M. Behm	2017	PICE-CE	170	2	55-55	C
G. Hayne, B. Kumar, B. Hare	2017	PICE-MPL	170	2	85-94	B, C
Y. Z. Toh, Y. M. Goh, B. H. W. Guo	2017	JCEM	143	5	4016131	A, B, D
T. Toole, J. Gambatese, D. Abovitz	2017	JPIEEP	143	1	1-9	D
L. F. Alarcón, D. Acuna, S. Diethelm, E. Pellicer	2016	AAP	94		107-118	B
J. Wang, P. X.W. Zoua, P. P. Li	2016	AAP	93		267-279	A, B
Y. M. Goh, S. Chua	2016	AAP	93		260-266	A, B, D
R. Edirisinghe, A. Stranieri, N. Blismas	2016	AEDM	12	4	296-310	A, D
J. Teizer	2016	CI	16	3	253-280	C
S. Morrow, B. Hare, I. Cameron	2016	ECAM	23	1	40-59	A
N. Tymvios, J. A. Gambatese	2016	JCEM	142	8	4016024	D
N. Tymvios, J. A. Gambatese	2016	JCEM	142	2	4015078	D, E
I. Shiue	2016	JEDT	14	1	104-114	B
B. H. W. Guo, T. W. Yiu	2016	JME	32	1	4015016	B
D. M. Aires, M. C. Rubio, A. G. F. Gibb	2016	JPAR	53	1	189-191	E
M. Z. Abidin, R. Rusli, A. M. Shariff	2016	PE	148		1043–1050	C
Y.-W. Zhang	2016	PE	135		537–543	C
A. Karakhan	2016	DEPS	NA	NA	NA	B, D
A. Karakhan	2016	PS	61	4	53-58	B, E
R. Sacks, J. Whyte, D. Swissa, G. Raviv, W. Zhou, A. Shapira	2015	CME	33	1	55-72	A, B
A. Law	2015	FSJ	80		89-94	B
S. Bong, R. Rameezdeen, J. Zuo, R. Y. M. Li, G. Ye	2015	IJCM	15	4	276-287	D
V. Dharmapalan, J. A. Gambatese, J. Fradella, A. M. Vahed	2015	JCEM	141	4	4014090	B, C
L. Sadeghi, L. Mathieu, N. Tricot, L. Al Bassit	2015	SS	80		252–263	C

A. López-Arquillos, J.C. Rubio-Romero, M.D. Martinez-Aires	2015	SS	73		Aug-14	B
M. R. Hallowell, D. Hansen	2015	SS	82		254-263	A, B
A. López-Arquillos, J.C. Rubio-Romero	2015	RC	14		58-64	B, C
J. W. Mroszczyk	2015	PS	60	6	55-68	C, D
C. White	2015	PS	60	6	69-73	B, D
J. Weidman, D. Dickerson, C. Koebel	2015	W	52	4	865-876	C, D
S. Zhang, K. Sulankivi, M. Kiviniemi, I. Romo, C. M. Eastman, J. Teizer	2015	SS	72		31-45	B, C
M. Kasirossafar, F. Shahbodaghlou	2015	PS	60	8	42-46	B
D. W. Wilbanks	2015	PS	60	4	46-51	B, C, E
E. Öney-Yazıcı, M. F. Dulaimi	2014	AEDM	11	5	325-337	A, B
S. Morrow, I. Cameron, B. Hare	2014	AEDM	11	5	338-359	A
R. Simanaviciene, R. Liaudanskiene, L. Ustinovichius	2014	AC	39		47-58	A
H. Park, B. J. Meacham, N. A. Dembsey, M. Goulthorpe	2014	BRI	42	6	696-709	C
H. Park, B. J. Meacham, N. A. Dembsey, M. Goulthorpe	2014	BRI	42	6	696-709	B, C
J. Qi, R. R. A. Issa, S. Olbina, J. Hinze	2014	JCCE	28	5	A4014008	C
K. Terwel, S. Jansen	2014	JPCF	29	3	4014068	B, D
S. Mahmoudi, F. Ghasemi, I. Mohammadfam, E. Soleimani	2014	SHW	5	3	125-130	C
E. Diniz Fonseca, F. P.A. Lima, F. Duarte	2014	SS	70		406–418	B
P. X.W. Zou, R. Y. Sunindijo, A. R.J. Dainty	2014	SS	70		316–326	B
T. Horberry	2014	TIES	15	3	293-304	A, B, D
M. Behm, J. Culvenor, G. Dixon	2014	SS	63		01-Jul	B
D. Walline	2014	PS	59	11	43-49	A, B
D. Young-Corbett	2014	JCEM	140	9	6014007	B
W. Azmi, M. S. Misnan	2014	IJSCH	2	4	232-237	A, B, E

H. Lingard, T. Cooke, N. Blismas, R. Wakefield	2013	BEPAM	3	1	Jul-23	D
G. D. Larsen, J. Whyte	2013	CME	31	6	675-690	B
C. Salter, G. Ramachandran, S. Emmitt, N. Bouchlaghem	2013	FSJ	62	Part C	256–263	C
C. Lopez Del Puerto, K. Strong , M. Miller	2013	IJCER	9	4	307-316	D
T. Toole, Carpenter G.	2013	JAE	19	3	168-173	B
H. Lingard, R. Wakefield	2013	PICE-MPL	166	5	240-248	B, C
T. M. Toole, H. Pamela, H. Matthew	2013	PS	58	1	41-47	E
T. Toole, P. Heckel, M. Hallowell	2013	PS	58	1	41-47	E
E. Biddle	2013	PS	58	3	56-64	D
A. Lamba	2013	PS	58	1	34-40	B, D
F. M. Renshaw	2013	PS	58	3	50-55	B, C, E
N. Tymvios, J. A. Gambatese	2013	EDF	23	1	31-37	B
S. Zhang, J. Teizer, J.-K. Lee, C. M. Eastman, M. Venugopal	2013	ACE	29		183-195	C
Z. Zhou, J. Irizarry, Q. Li	2013	CME	31	6	606-622	B
J. Hinze, R. Godfrey, J. Sullivan	2013	JCEM	139	6	594-600	B, E
G. Popov, L. Blunt, J. McGlothlin	2013	PS	58	3	44-49	B
J. Gambatese, M. Hallowell, F. Renshaw, M. Quinn, P. Heckel	2013	PS	58	1	48-54	D
B.H.W. Hadikusumo, S. Rowlinson	2012	AC	11	5	501-509	C
W. Zhou, J. Whyte, R. Sacks	2012	AC	22		102-111	C
C. K. Chun, H. Li, Martin Skitmore	2012	CI	12	1	29-42	C
K. S. Dewlaney, M. Hallowell	2012	CME	30	2	165-177	B, C
M. Behm	2012	JCEM	138	8	999-1003	B
M. I. Mohamad, M. A. Nekooie, A. B. S. Al-Harthy	2012	JCDC	17	2	23-44	B, C
N. Chileshe, E. Dzisi	2012	JEDT	10	2	276-298	A, B
M. Hallowell	2012	JME	28	2	203-211	B
M. A. Qianlia, G. Wei	2012	PE	45		685–689	C

F. Emuze, J. J. Smallwood	2012	PICE-MPL	165	1	27-34	E
L. Almén, T. J. Larsson, E.-V. Thunqvist	2012	SSM	16	1	02-Jul	D
M. Behm, P. Hock	2012	SSBE	1	2	186-205	B
H. Yanga, D. A.S. Chewb, W. Wuc, Z. Zhouc, Q. Li	2011	AAP	48		193-203	B, C
S. Al-Jibouri, G. Ogink	2011	AEDM	5	4	179-192	B
R. Valdes-Vasquez, L. Klotz	2011	JPIEEP	137	4	189-197	B
A. Pinto, I. L. Nunes, R. A. Ribeiro	2011	SS	49	5	616–624	B
T. M. Toole	2011	LME	11	2	197-207	B
J. Pérez-Alonso, Á. Carreño-Ortega, Á. J. Callejón-Ferre, F. J. Vázquez-Cabrera	2011	SS	49	2	345-354	B
M. Behm, J. Culvenor	2011	JHSRP	3	1	Sep-32	A, E
S. Hecker, J. A. Gambatese	2010	AOEH	18	5	339-342	B
R. Rwamamara, H. Norberg, T. Olofsson, O. Lagerqvist	2010	CI	10	3	248-266	C
A. R. Atkinson, R. Westall	2010	CME	28	9	1007-1017	D
R. Lopez, P. E. D. Love, D. J. Edwards, P. R. Davis	2010	JPCF	24	4	399-408	A, B
M. Gangolells, M. Casals, N. Forcada, X. Roca, A. Fuertes	2010	JSR	41	2	107-122	B, C
D.M. Aires, C. R. Gamez, A. G. F. Gibb	2010	SS	48	2	248–258	E
H. L. Floyd	2010	IAM	16	3	14-16	B, D
H. L. Floyd, D. P. Liggett	2010	IAM	16	3	17-22	B
S. Rajendran, J. A. Gambatese, M. G. Behm	2009	JCEM	135	10	1058-1066	B
M. A. Nussbaum, J. P. Shewchuk, S. Kim, H. Seol, C. Guo	2009	E	52	1	87-103	B, C
J. P. Scopes	2009	PICE-CE	162	2	76-86	B
I. Cameron, B. Hare	2008	CME	26	9	899-909	C
T. Cooke, H. Lingard, N. Blismas, A. Stranieri	2008	ECAM	15	4	336-351	C
W. Creaser	2008	JSR	39	2	131-134	D, E
J. Adin Mann	2008	JSR	39	2	165-170	B

P. A. Schulte, R. Rinehart, A. Okun, C. L. Geraci, D. S. Heidel	2008	JSR	39	2	115-121	B, E
J. Howe	2008	JSR	39	2	161-163	E
J. A. Gambatese	2008	JSR	39	2	153-156	B
T. M. Toole, J. A. Gambatese	2008	JSR	39	2	225-230	B
J. A. Gambatese, M. Behm, S. Rajendran	2008	SS	46	4	675–691	A, B
R. Slater, A. Radford	2008	TAJCEB	8	1	23-33	B, D
F. A. Manuele	2008	PS	53	10	28-40	A, B
T. Braun	2008	JSR	39	2	137-139	B,D
M. Behm	2008	JSR	39	2	175-178	B, D, E
A. Frijters, P. Swuste	2008	SS	46	2	272-281	C
P. G. Kovalchik, R. J. Matetic, A. K. Smith, S. B. Bealko	2008	JSR	39	2	251-254	C
J. Seo, H. Choi	2008	JCEM	134	1	72-81	B, C
T. Zagres, B. Giles	2008	JSR	39	2	123-126	B
P. Zou, S. Redman, S. Windon	2008	AEDM	4	03-Apr	221-238	B
T. R. Driscoll, J. E. Harrison, C, Bradley, R. S. Newson	2008	JSR	39	2	209-214	B
C. Ozmen, A. Unay	2007	BE	42	3	1406-1416	B
M. S. Al-Homoud , A. A. Abdou, M. M. Khan	2007	BRI	32	6	538-543	E
A.G.F. Gibb, R. A. Haslam, T. C. Pavitt, K. A. Horne	2007	CIQ	9	3	113-123	B, D
A. van Gorp	2007	DS	28	2	117-131	A, E
T. M. Toole	2007	JPIEEP	133	2	126-131	B
J. P. Greenwood	2007	TAJCEB	7	1	37-44	D
F. A. Manuele	2007	DEPS	NA	NA	NA	B
A. Beal	2007	PICE-CE	160	2	82-88	E
W. C. Christensen	2007	PS	52	5	36-44	B, D
K. Imriyas, L. S. Pheng, T, Ai Lin	2007	ASR	50	2	149-162	C
X. Huang, J. Hinze	2006	JCEM	132	2	174-181	D
T. M. Toole, N. Hervol, M. Hallowell	2006	MSC	46	6	55-59	B
R. M. Choudhry, D, Fang, S. Mohamed	2006	SS	45	10	993–1012	D
E. Fadier, C. De la Garza	2006	SS	44	1	55-73	A, B, D
D. V. MacCollum	2006	PS	51	5	26-33	C

J. W. Mroszczyk	2006	ASSE-B	5	3	01-Apr	D
X. Huang, J. Hinze	2006	JCEM	132	2	164-173	D
P. Lam, F. Wong, A. Chan	2006	DS	27	4	457-479	A, B
R. Navon, O. Kolton	2006	JCEM	132	7	733-740	C
J. A. Gambatese, M. Behm, J. W. Hinze	2005	JCEM	131	9	1029-1036	A, B, D
T. M. Toole	2005	JPIEEP	131	3	199-207	A, B
M. Behm	2005	SS	43	8	589-611	B, C
S. Hecker, J. Gambatese, M. Weinstein	2005	PS	50	9	32-44	D
M. C. Rubio, A. Menendez, J. C. Rubio, G. Martinez	2005	JPIEEP	131	1	70-75	B, E
E.W.L. Cheng, H. Li, D.P. Fang, F. Xie	2004	CI	4	4	229-241	A, B
B. H. W. Hadikusumo, S. Rowlinson	2004	JCEM	130	2	281-289	B, C
W. R. Wildman, T. H. Castelli	2004	JPIEEP	130	4	306-310	E
J.J. Smallwood	2004	JSAICE	46	1	02-Aug	A, B
J. Culvenor	2003	SA	25	3	19-27	B
J. Gambatese	2003	IeJC	NA	NA	NA	B
T. Kletz	2003	PSEP	81	6	401-405	B
T. M. Toole, J. A. Gambatese	2002	PPSDC	7	2	56-60	B, E
R. N. Andres	2002	PS	47	1	20-26	E
T. Toole, J. Gambatese	2002	PPSDC	7	2	56-60	E
T. M. Toole	2002	JCEM	128	3	203-210	B, D
B. W. Main	2002	PS	47	1	27-33	D
J. Gupta, D. Edwards	2002	PSEP	80	3	115-125	B
A. Griffith, N. Phillips	2001	CME	19	5	533-540	E
T. Baxendale, O. Jones	2000	IJPM	18	1	33-40	E
J. Gambatese	2000	CE	70	6	56-59	B
M. D. Hansen	2000	PS	45	1	20-25	B, C
J. Gupta	2000	JLPPI	13	1	63-66	B
J. Gambatese, J. Hinze	1999	AC	8	6	643-649	B, C
D. Arditi, M. Nawakorawit	1999	JAE	5	4	107-116	B
M. A. Hassanain	1998	StS	26	1	55-62	C
J. A. Gambatese, J. Hinze, C. Haas	1997	JAE	3	1	32-41	C
S. E. Magnusson, H. Frantzich, K. Harada	1996	FSJ	27	4	305–334	C
T. Kletz	1996	PSP	15	1	05-Aug	B

T. Hetherington	1995	StS	13	1	05-Jun	E
J. Hinze, F. Wiegand	1992	JCEM	118	4	677-684	A, B

Notes

DfS Implementation Factors: A - Designer attitude; B – Designer Knowledge/Awareness and Education; C – DfS tools; D – Clients' influence/motivation; E - Legislation

Journals: AAP - Accident Analysis and Prevention; AOEH - Applied Occupational and Environmental Hygiene; AEDM - Architectural Engineering and Design Management; AC - Automation in Construction; ASR - Architectural Science Review; ASSE-B - ASSE Blueprints; BE - Building and Environment; BRI - Building Research & Information; BEPAM - Built Environment Project and Asset Management; CE - Civil Engineering; CIQ - Construction Information Quarterly; CI - Construction Innovation; CME - Construction Management and Economics; DEPS – By Design, Engineering Practice Specialty, ASSE; DS - Design Studies; E – Ergonomics; ECAM - Engineering, Construction and Architectural Management; FSJ - Fire Safety Journal; IeJC - International e-Journal of Construction; IJCER - International Journal of Construction Education and Research; IJCM - International Journal of Construction Management; IJPM - International Journal of Project Management; IJSCH; International Journal of Science Commerce and Humanities; JAE - Journal of Architectural Engineering; JCCE - Journal of Computing in Civil Engineering; JCEM - Journal of Construction Engineering and Management; JCDC - Journal of Construction in Developing Countries; JEDT - Journal of Engineering, Design and Technology; JHSRP - Journal of Health & Safety Research & Practice; JLPPI - Journal of Loss Prevention in the Process Industries; JME - Journal of Management in Engineering; JPCF - Journal of Performance of Constructed Facilities; JPAR - Journal of Prevention, Assessment & Rehabilitation; JPIEEP - Journal of Professional Issues in Engineering Education and Practice; JSR - Journal of Safety Research; JSAICE - Journal of the South African Institution of Civil Engineering; LME - Leadership and Management in Engineering; MSC - Modern Steel Construction; PPSDC - Practice Periodical on Structural Design and Construction; PE - Procedia Engineering; PICE-CE - Proceedings of ICE Civil Engineering; PICE-MPL- Proceedings of ICE Management, Procurement and Law; PS - Professional Safety; RC - Revista de la construcción; SA - Safety in Australia; SHW - Safety and Health at Work; SS - Safety Science; SSM - Safety Science Monitor; SSBE - Smart and Sustainable Built Environment; StS - Structural Survey; TAJCEB - The Australian Journal of Construction Economics and Building; TIES - Theoretical Issues in Ergonomics Science; W - Work.

Other Acronyms: NA – Not available

Table 3: Distribution of DfS articles over time

Year	Number of Papers within DfS Implementation Factors					Total papers in year	Durational Band	Total Papers within Durational Band
	A	B	C	D	E			
1990	0	0	0	0	0	0	1990-1995	2
1991	0	0	0	0	0	0		
1992	1	1	0	0	0	1		
1993	0	0	0	0	0	0		
1994	0	0	0	0	0	0		
1995	0	0	0	0	1	1		
1996	0	1	1	0	0	2	1996-2000	11
1997	0	0	1	0	0	1		
1998	0	0	1	0	0	1		
1999	0	2	1	0	0	2		
2000	0	3	1	0	1	4		
2001	0	0	0	0	1	1	2001-2005	23
2002	0	3	0	2	3	6		
2003	0	3	0	0	0	3		
2004	2	3	1	0	1	4		
2005	2	4	1	2	1	5		
2006	2	3	2	5	0	9	2006-2010	54
2007	1	5	1	3	3	10		
2008	2	13	5	4	4	19		
2009	0	3	1	0	0	3		
2010	1	5	2	2	1	8		
2011	1	6	1	0	1	7	2011-2015	73
2012	1	6	6	1	1	12		
2013	0	9	4	5	4	17		
2014	6	10	4	2	1	15		
2015	2	10	7	4	1	14		
2016	4	7	3	5	3	15	2016-2017	19
2017	1	2	2	2	0	4		

Notes: Period is up to June 2017.
DfS Implementation Factors: A - Designer attitude; B – Designer Knowledge/Awareness and Education; C – DfS tools; D – Clients' influence/motivation; E - Legislation