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DEVELOPMENT OF A DESIGN FOR OCCUPATIONAL SAFETY AND HEALTH CAPABILITY MATURITY MODEL

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Design for occupational safety and health (DfOSH) is growing in prominence in the construction sector. Consequently, designers (as individuals or organisations) are expected to mitigate occupational health and safety risks through design. In order for design firms to effectively do this, they need to have adequate capability in respect of DfOSH. However, there is limited empirical insight regarding DfOSH capability as well as robust mechanisms for ascertaning the DfOSH capability of design firms. Drawing on the capability maturity concept, this study through three iterations of expert focus group discussion presents a preliminary DfOSH capability maturity model. The preliminary model captures DfOSH capability attributes mapped unto five stages of capability maturation. The model is undergoing review and testing by industry experts to ensure its practical utility within industry. It is anticipated that through the testing of the preliminary model, the eventual DfOSH capability maturity model would be beneficial to several industry stakeholders, particularly design firms by way of self-assessing their capability in order to understand the areas of capability deficiency and strength. Clients who appoint design firms could also use the model as part of pre-qualification arrangements in selecting design firms with adequate DfOSH capability.

Keywords: design, design for occupational safety and health, prevention through design, safety in design, capability maturity model.

INTRODUCTION

The construction sector is one of the highest contributors to work-related accidents and illnesses. For instance, in the UK, the Health and Safety Executive (HSE) (2015) estimates that yearly about 3% of construction workers suffer from work-related illness, and about 3% sustain an occupational injury resulting in 1.7 million lost working days. The rate of fatal injuries to workers in the construction sector is about 3.5 times the average rate of fatal injuries to workers in all industries, and also the rate of non-fatal injuries in construction is about 1.5 the average rate in all industries. In terms of occupational illnesses, the prevalence rate of self-reported illness in construction is also higher than the average rate in all industries (HSE, 2015). One of the prominent initiatives to address the OSH situation in construction is design for occupational safety and health (DfOSH), also known as ‘prevention through design’, ‘design for safety’, and ‘safety in design’. While there is a growing body of research on DfOSH in construction, empirical work on DfOSH capability of design firms (or more broadly organisations with design responsibility) is sparse (Manu et al., 2017). This study thus examines DfOSH capability. In particular, it presents a maturation model for DfOSH capability. The next section presents a brief overview of DfOSH and capability maturity to provide the underpinning for the

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development of the DfOSH capability maturity model. The research method applied and a preliminary version of the model are subsequently presented. The implications stemming from the preliminary model and concluding remarks are finally presented.

LITERATURE REVIEW

DfOSH involves anticipating and eliminating or minimising OSH hazards and risks in the design process of a building or structure in order to eliminate or minimise the risks of occupational injury and illness to construction and maintenance workers (Schulte et al., 2008). The prominence of DfOSH is rooted in studies which have highlighted design as a contributory factor in the occurrence of construction accidents and injuries (e.g. Behm, 2005; Gibb et al., 2006; Manu et al., 2014). In the study by Behm (2005), undertaken in the USA, 42% of 224 construction fatality cases were linked to design. Research by Gibb et al. (2006) reported that up to 50% of a 100 construction accident cases that were studied could have been mitigated through choices in the design. From these studies, it is evident that design is an important factor in construction accident causation and has therefore resulted in the growing prominence of DfOSH as shown by the legislative support for its practice in some countries e.g. UK, Australia and Singapore (see the Work Health and Safety Acts and Regulations in Australia, the Construction (Design and Management) (CDM) Regulations 2015 in UK, and the Workplace Safety and Health (Design for Safety) Regulations 2015 in Singapore).

DfOSH requires that designers (as individual professionals or organisations) take into consideration the OSH implications of their design decisions during the design stages of built assets. The UK CDM regulations, now in its third iteration (i.e. CDM 2015) after previous versions (i.e. CDM 1994 and CDM 2007) require that designers reduce foreseeable risk as much as possible through their decisions when preparing or modifying designs. The CDM 2015 has also introduced a new requirement in respect of the organisational capability of construction organisations to undertake their operations in a manner that protects workers from OSH injuries and illnesses. Regarding design firms, this can be considered in terms of their capability to implement DfOSH on projects. However, regardless of legislative requirement for DfOSH organisational capability, the contribution of design to the occurrence of occupational incidents in construction makes it imperative for design firms to have adequate capability to implement DfOSH on projects. However, lacking in the growing body of DfOSH academic literature is empirical work into DfOSH organisational capability (Manu et al., 2017). Aligned to this, Toole and Gambatese (2017) presented a theoretical piece on the levels of implementation of prevention through design (PtD) on projects, in which they suggested organisational characteristics and project processes that will enable adoption of PtD. There is thus lacking empirical research to shed light on the constituents of DfOSH organisational capability and mechanisms by which it can be reliably assessed.

Regarding organisational capability assessment, in the construction sector and other sectors, whilst there are various approaches for assessing performance (e.g. key performance indicators (KPIs), balanced score card, and excellence models), one of the prominent approaches for assessing organisational capability in a domain as part of process improvement is the capability maturity model (CMM) (Paulk et al., 1993; Strutt, et al., 2006; Succar 2009). Although originally developed for the domain of software development by the Software Engineering Institute at Carnegie Mellon University, the CMM represents a generic framework for continuous process improvement and hence, has been applied in several areas in construction including: change management; project, programme and portfolio management; asset management; building information modelling; and supply chain management (see Succar 2009; Mahamadu et al., 2017). In OSH, CMM has also been applied although not specifically to DfOSH e.g. the safety culture model by HSE (2000). The application of CMM in several areas in construction including OSH as a robust process improvement tool thus supports its application to DfOSH to produce a DfOSH capability maturity model.

RESEARCH METHOD

In order to develop a DfOSH capability maturity model, it is important to establish: (1) the key process areas (i.e. the DfOSH capability attributes); and (2) the maturity levels (Maier et al., 2012). The following subsections presents the steps undertaken to address both.

Determining the DfOSH Capability Attributes

The key process areas of a CMM can be derived from: (1) the originator's experience and reference to established knowledge in the relevant domain; and (2) a panel of experts in the domain, especially where there is limited prior literature about the domain (Maier et al., 2012). This study used a panel of construction industry experts due to the limited empirical work regarding DfOSH capability. Three iterations of expert focus group discussions (FGDs) were held in order to identify the attributes that determine DfOSH capability of organisations. In order to select suitably qualified and experienced experts in the domain of DfOSH, the guidance of Hallowell and Gambatese (2010) regarding the criteria for selecting experts (e.g. a professional with expertise in the subject of inquiry, and a minimum of five years of experience) was followed. In line with that, a total of eight experts were engaged in the three FGDs. The three FGDs mainly involved the experts engaging in brainstorming and reviews which were aimed at identifying the capability attributes and refining the attributes. Each FGD session took about two hours and they span over a 10 month duration. From the brainstorming excercies, the views of the experts regarding capability attributes were recorded, collated and synthesised through re-reading and thematic analysis. The iterative nature of the FGD sessions enabled elicited attributes to be reviewed and refined by the experts in subsequent FGD sessions in order to ensure appropriateness and clarity of the attributes. Through the review and refinement, the experts agreed on the DfOSH capability attributes at the third FGD session, and afterwards the maturity levels were formulated as discussed below.

Formulating the Maturity Levels

Capability maturity models commonly use five maturity levels (Maier et al., 2012) in line with the original CMM by Paulk et al. (1993). Similarly, in this study, five maturity levels was adopted, with level 1 being the lowest maturity level and level 5 being the highest maturity level. The concept of the capability maturity model is such that progression to, or attaintment of a higher maturity level is pre-conditioned on the attainment of lower maturity levels, so for instance, in order for an organisation to be at maturity level 5 in a capability attribute it should have already met the requirements for the lower levels.

Based on a review of several CMMs, Maier et al. (2012) noted that formulating maturity levels involves: (1) using a top-down or bottom-up approach; (2) consideration of the information source; and (3) consideration of the formulation mechanism. In the bottom-up approach, measures of maturity are determined first, before definitions are written to reflect the measures (Maier et al., 2012). In the top-down approach, the emphasis is first on what represents maturity, before how it can be measured (Maier et al., 2012). This approach is most appropriate if the field is relatively new (Maier et al., 2012). This approach was mainly used given the limited empirical work on DfOSH capability. Regarding what represents maturity in each key process area, it is important to establish the underlying notion of maturity and to do that several information sources can be useful e.g. existing literature relating to the key process areas (Maier et al., 2012). Existing CMMs and best practice guides on subjects that are related to the DfOSH capability attributes (e.g. the risk management maturity model (RM3) by the Office of Road and Rail and Health and Safety Laboratory (2017)) were reviewed in addition to maturity indicators (explained in the results section) suggested by the FGD experts in order to obtain an understanding of what represents maturity in each of the DfOSH capability attributes. This understanding informed the underlying notion of maturity which was then used in formulating the maturity level descriptors for each of the DfOSH capability attributes. Regarding the formulation mechanism for the maturity level descriptors, in line with the suggestion by Maier et al. (2012), in the first instance, the descriptors for the maturity levels at the extreme ends (i.e. level 1, being the lowest level, and level 5, being the highest) were formulated (based on the underlying notion) such that level 1 represented no or very low maturity and level 5 represented the highest level of maturity which is also depicted by regular reviews within the capability attribute in order to ensure continuous improvement. Secondly, the mid range maturity level descriptors (i.e. from level 2 to level 4) were deduced from the underlying notion and formulated accordingly. For the purpose of illustration, excerpts from the eventual DfOSH capability maturity model are presented in the results section.

RESULTS AND DISCUSSION

The FGD experts are: a senior design manager; an architect; two occupational health and safety professionals; a civil/structural engineer; a health and safety consultant and civil engineer; a senior quantity surveyor; and a project manager. Each expert is affiliated to at least one professional body, which includes the Association for Project Management, Association for Project Safety, Chartered Institute of Building, Institution of Civil Engineers, Institution of Occupational Safety and Health, Institution of Structural Engineers, Royal Institute of British Architects, and the Royal Institution of Chartered Surveyors. The minimum years of experience in professional role and the minimum years of experience in construction are 10 and 15 respectively. In the main, the experts are suitable for the study as their roles and experience relate to design, OSH management, DfOSH, and selection of project organisations, which under CDM 2015 requires consideration of organisational capability in respect of OSH.

From the FGD brainstorming and reviews, 18 DfOSH capability attributes were identified. Additionally, the FGD experts suggested examples of maturity indicators (i.e. items, activities or practices that could evidence maturity) for the DfOSH capability attributes. The 18 DfOSH capability attributes elicited from the FGDs are: (1) skills of design staff in relation to DfOSH; (2) knowledge of design staff in relation to DfOSH; (3) experience of design staff in relation to DfOSH; (4) access of design staff to competent advice; (5) role definition for design staff and the recruitment of design staff into roles; (6) design staff training in relation to DfOSH; (7) DfOSH policy; (8) top management commitment to DfOSH; (9) DfOSH research and innovation; (10) corporate experience in implementing DfOSH on projects; (11) organisation's design quality management systems/processes; (12) organisation's design risk management systems/processes; (13) organisation's project review systems/processes for learning DfOSH lessons; (14) systems/processes for management of outsourced/subcontracted designers; (15) organisation's physical work resources; (16) organisation's ICT resources; (17) intra-organisational collaboration in implementing DfOSH; and (18) inter-organisational collaboration in implementing DfOSH.

For the sake of brevity, Table 1 presents excerpts of the DfOSH capability maturity grip. It shows five capability attributes mapped unto the five maturity levels. It also shows the underlying notion that informed the formulation of the maturity level descriptors for each of the five capability attributes. From Table 1 it can be seen how the underlying notion for each of the capability attributes was used to deduce descriptors depicting increasing maturation in the capability attributes.

Table 1: Extracts from DfOSH Capability Maturity Model

Capability Attribute	Underlying Notion of Maturity	**Maturity Levels**				
		Level 1	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Inter-organisational collaboration	Higher maturity levels would be characterised by developing and maintaining long-term relationship and strategic relationship planning, while lower maturity levels would be characterised by lack of shared vision.	Company/ design office (DO) shows no commitment to the shared OSH vision of projects they are involved in.	Company/DO shows limited commitment to the shared OSH vision of projects they are involved in.	Collaboration by company/DO with other project team members is usually only reactive.	Collaboration by company/DO with other project team members is usually proactive in order to ensure effective delivery of OSH and other project objectives.	Company/DO continuously develops and sustains long-term collaborative working relationships with other organisations in order to harness and continuously improve collective expertise relevant for DfOSH or construction OSH in general.
DfOSH policy	As maturity increases, company DfOSH policy becomes clearer, well-communicated within the organisation, and interpreted and applied consistently by all managers/supervisors and staff.	No policy on DfOSH.	Vaguely worded policy statement or out-of-date policy statement on DfOSH. Policy has not been communicated within the organisation.	Clear company/DO policy on DfOSH setting out the intention(s) on DfOSH. The policy is communicated within management and staff, but managers/supervisors and staff have inconsistent interpretations and applications of the policy.	Clear company/DO policy on DfOSH setting out the intention(s) on DfOSH. The policy is well-communicated within the organisation and to external stakeholders. The policy is consistently interpreted and applied the same way by all managers/supervisors and staff.	Clear company/DO policy on DfOSH setting out the intention(s) on DfOSH and recognising that DfOSH is not a separate/add-on task but an integral part of a design work flow, productivity and competitiveness. Policy is consistent with other best-performing organisations' policies. Policy is reviewed regularly to drive continuous improvement that is in line with the best-performing organisations.
Organisation's ICT resources	Higher maturity levels would be characterised by exploitation of cutting edge computing and information technology facilities that support DfOSH.	No or very little ICT resources (including software and hardware) to support DfOSH.	ICT resources that support design function (including DfOSH) are available but not standardised across company/DO. Specifications of ICT resources are	ICT resources that support design function (including DfOSH) are available and standardised across company/DO. Specifications of ICT resources are just adequate	ICT resources that support design function (including DfOSH) are widely available, standardised and managed according to a resource plan. Specifications of ICT resources are	Cutting-edge ICT resources that support design function (including DfOSH) are available, standardised and considered as a core measure of operational excellence. Specifications of ICT resources are the most up to date

			basic and not consistent.	and standardised.	advanced and of a high standard.	and of the highest standards. ICT resources are regularly reviewed for their up-to-date suitability to ensure continuous improvement in the use of digital technologies for design function (including DfOSH).
Design staff continuous professional development (CPD) in relation to DfOSH	As maturity increases, there would be regular provision of DfOSH related CPD training for design staff. In addition, design staff would regularly undergo performance and development review, which informs their CPD training.	No provision of DfOSH related CPD training for design staff. No structured performance and development review (PDR) for design staff to ascertain staff performance and training needs.	Rare provision of DfOSH related CPD training for design staff. Design staff PDR is rarely undertaken.	Occasional provision of DfOSH related CPD training for design staff. CPD training is usually reactive. Design staff PDR is sometimes undertaken.	Regular provision of DfOSH related CPD training for design staff. CPD training is usually proactive. Design staff regularly undergo PDR.	Design staff CPD training and PDR are integral to the organisation's human resource development strategy/plan and they are embedded within the organisation's human resource development practices. PDR procedures and organisational human resource development strategy/plan are reviewed to ensure their up-to-date suitability and continuous improvement.

For example, for DfOSH policy, whereas at Level 1 there is no company policy regarding DfOSH, at level 5 there is a clear policy that is regularly reviewed and updated. Between these two extremes, there is progressing and distinct maturation as the DfOSH policy improves from being vaguely worded and not communicated (at Level 2) to being clear, communicated, but inconsistently interpreted and applied (at Level 3), and then being clear, communicated, and consistently interpreted and applied (at Level 4).

The emergent DfOSH capability attributes have resemblance to some of the key process areas used in existing capability maturity grids. For example, Strutt et al.'s (2006) design safety capability maturity model for the offshore sector proposed attributes such as education and training, research and development, organisational learning, and managing of safety in the supply chain. The safety culture maturity model by HSE (2000) also included attributes including 'training', 'management commitment and visibility', 'learning organisation', and 'safety resources'. Outside the area of safety, Succar (2009) proposed a building information modelling maturity matrix which composed of capability attributes labelled as 'BIM competency sets'. These attributes included leadership, human resources (encompassing competencies, roles and experience), physical infrastructure, hardware and software.

The DfOSH capability attributes (e.g. DfOSH CPD training, DfOSH research and innovation, organisation's project review systems/processes for learning DfOSH lessons, systems/processes for management of outsourced/subcontracted designers, top management commitment to DfOSH, ICT reseaources and physical resources) share similarities with the above mentioned atributes in the models by HSE (2000), Strutt et al.'s (2006) and Succar (2009), although the DfOSH capability attributes have specific relevance or focus on the implementation of DfOSH by construction organisations with design responsibilities (e.g. architectual design consultancy firms, engineering design consultancy firms, and design and build contractors). In broad terms, the DfOSH capibility attributes also reflect the categorisation/classification of attributes used in existing capability maturity grids such as 'technology', 'process' and 'policy' (Succar, 2009).

Overall, the study has shown that the capbility maturity concept, as applied to several subjects in construction and in other disciplines, can be applied to DfOSH capability. Within topical areas of construction such as building information modelling (BIM), there has been a proliferation of maturity models including those used by industry stakeholders for organisational BIM capability assessment (see Sebastian and Berlo, 2010). For instance, Sebastian and van Berlo (2010) BIM capability tool is used in the Netherlands for benchmarking the BIM performance of design, engineering and construction firms. These generally attest to the practical utility of capability maturity tools. Similarly, the DfOSH capability maturity model could therefore be beneficial to several construction sector stakeholders including: construction clients (and their representatives) who commission construction projects and appoint firms with design responsibilities; and design firms (e.g. civil/structural engineering, architectural and building services engineering) who have design responsibilities on projects. However, the DfOSH capability maturity model in its present form is preliminary and therefore requires further review and testing by industry professionals in order to ascertain its practical utility. Further development and subsequent expert evaluation of the preliminary DfOSH capability maturity model is currently underway.

CONCLUSIONS

DfOSH is increasingly gaining ground in the global construction sector of several countries. It entails firms in design roles producing designs that are safer for workers to build and maintain. Such firms therefore need to have the appropriate level of capability in terms of DfOSH. Design firms would have varying DfOSH capability and it is important that they understand their current capability so that they are able to improve. Likewise it is imperative that construction clients, their representatives or entities engaging the services of design organisations are also able to ascertain the DfOSH capability of those organisations. This ongoing study is addressing a signficant research gap regarding DfOSH capability by presenting empirical work which is leading to the development of a DfOSH capability maturity model. The model shows five distinct levels of maturation in distinct DfOSH capability attributes drawn from focus group disucssions with a panel of industry experts. To ensure its practical utility, the model is at a stage of review and evaluation by industry experts. It is anticipated that through the review and expert evaluation, vaulable feedback would be obtained to futher improve the model. It is also expected that the eventual maturity model would be beneficial to industry stakeholders including, clients by way of assessing the capability of design firms they appoint, and also to design firms by way of undertaking self-assessment of their DfOSH capability in order to improve.

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