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Design for Safety Review in Early Stages of Mandatory Implementation

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Abstract

Purpose: Prevention through design has been identified as a possible measure to prevent construction-related accidents. To operationalize this, Design for Safety (DfS) was introduced in Singapore as a legislatively mandated set of design review meeting with safety being the main focus. This study aims to investigate how DfS is practiced in the early stages of compulsory implementation.

Design: A case study approach was undertaken for this research with observations of two design stage DfS review meetings in one project. Thematic analysis was carried out.

Findings: Team members in the projects with newly established review processes were more reliant on external prompting by the team's leadership to carry out their due diligence. Relative priority placed on the review was higher in the team with an established process.

Limitations: Observations were made only during the projects' design stage. Thus, current work does not reflect lessons learnt and applied by project teams after carrying out the different stages of a project.

Originality: The impact of mandating a new safety review in construction projects is investigated. This contributes to the understanding of the competencies of project teams at different maturity levels of performing DfS review. This study provides insight to their conduct during the review meetings and provides insight to the coordination and cooperation requirements. Possible factors influencing the effectiveness of the DfS review process are identified.

Practical implications: This study is of significant use to those looking to implement or revise a DfS review process to prevent construction-related accidents. It provides insights on what to expect during early DfS adoption, allowing them to be cognizant of potential pitfalls.

Keywords: Prevention through Design, Design for Safety, Design for safety project team, Team processes.

Introduction

The construction industry is historically known to be a dangerous industry with disproportionately high contributions to recorded accidents worldwide, which results in dire social consequences impacting families, communities, and personal mental health of construction workers (Schulte et al., 2008). Therefore, controlling and minimizing hazards that lead to accidents is of paramount importance. Design for Safety (DfS) offers a promising way to address this problem, as it deals with designing out potential hazards and design risks of a facility (Goh and Chua, 2016; Toh et al., 2017). This aligns with Schulte et al. (2008), who notes that the approach to preventing hazards through design is the most effective means of preventing construction accidents. Due to its effectiveness, countries now require DfS or prevention through design (PtD) on construction projects (Larsen and Whyte, 2013). The European Union has mandated the implementation of prevention through design (PtD) through the Directive 92/57/EEC. Countries which adopted this directive earlier generally had lower accident rates as opposed to countries which implemented them later (Martínez Aires et al., 2010). The United Kingdom is one such early adopter, requiring PtD since 1995, which was subsequently updated in 2015 (HSE, 2015). Similar legislation is observed in Ireland (Health and Safety Authority, 2006), Australia (Australian Department of Consumer and Employment Protection, 2005), South Africa (South African Department of Labor, 2014), United States (Gambatese et al., 1997; NIOSH, 2013) and Singapore (Workplace Safety and Health Council, 2011, 2016).

However, implementation of DfS has not been completely smooth sailing and project stakeholders have faced difficulties in practicing DfS. In the UK, it has been reported that some designers feel that DfS has turned into a paperwork generation exercise; where designers fill out forms without meeting the purpose of the review process (Gambatese et al., 2009; Larsen and Whyte, 2013). Some reportedly perceive the problem of health and safety to be a problem of contractors to handle, even though the DfS regulations have been in place for a long time (Morrow et al., 2015, 2016). In Australia, even though attitude towards DfS is positive, it is reported that designers from small firms are less able to execute DfS (Behm and Culvenor, 2011). Even with policies for DfS in place, effectiveness is also dependent on the maturity of a particular countries' construction industry. Some developing countries have poor implementation of DfS as a result of low engagement in DfS by construction trade practitioners in those countries (Abueisheh et al., 2020; Manu et al., 2018, 2019).

In the context of Singapore, DfS was first introduced to the construction industry in 2008 as a voluntary initiative and subsequently mandated in 2015 as a regulation which has been operative since 2016 (Workplace Safety and Health Council, 2016). However, work on the effectiveness of this compulsory implementation is sparse. Therefore, the current study aims to investigate how DfS is practiced in the early stages of its compulsory implementation in Singapore. To this end, the objectives of this paper involves exploring how DfS review is practiced in the early stages of compulsory implementation through an exemplary case study; identifying areas of similarity and differences between DfS code of practice and the actual practice; and to identify potential underlying reasons for the observed differences.

Literature Review

Implementation of Design for Safety

According to the hierarchy of control, it would be most effective, reliable, and cheaper to make changes to the design to address hazards at the source (Lingard et al., 2014; Manuele, 2008). The project team's ability to influence safety in a construction project and subsequently the completed building is the highest at the start (Weinstein et al., 2005). It is found that, to operationalize and implement DfS effectively, an explicit process is required (Toole et al., 2017). By involving designers for DfS right at the start of the project through such a process; it gives them the ability to make decisions which will reduce or eliminate identifiable risks before such risks occurs (Behm, 2005). Otherwise, as a project advances, it is subjected to greater resistance to change as the cost of changes to the project steadily increases, making it unfavourable for the developer (Szymberski, 1997).

Support from the developer is also of utmost importance to the success of the DfS implementation and in is most cases embedded into the regulatory requirements. For example, in the UK, developers are required to ensure there is no unreasonable safety and health risk to any person by hiring competent contractors and designers. The developers must also ensure relevant health and safety information is properly disseminated among project team members and sufficient resources are provided to fulfill their health and safety duties (HSE, 2015). Concurrently, Toole et al. (2017) empirically showed that high owner expectations and proactive leadership catalyses effective participation of project stakeholders in the DfS review process and subsequent successful implementation of DfS. Similarly, with the compulsory implementations of DfS, each project stakeholder, the designers and contractors, is given specific duties to ensure safer designs.

While adhering to the regulatory frameworks, actions undertaken at the design stage are able to influence how the building is constructed. Hence, risks can be eliminated or mitigated through proper analysis and assessment during this stage (Zou et al., 2008). During the pre-design phase, safety and risk management requirements are established. Roles and responsibilities of the involved parties are also assigned. Hazard identification is carried out at the conceptual and schematic design stage. When the design has developed with greater details and specifications, control measures of the hazards can be implemented. The hierarchy of control is adopted to control the hazards. Behm and Culvenor (2011) suggested that the use of hierarchy of control prompts the formation of more reliable solutions. In this process, subsequent redesign incorporating the control measures can be done when necessary.

Opportunities and challenges for Design for Safety implementation

Toole and Gambatese (2008) identify three distinct advantages of utilizing DfS to reduce construction hazards. Firstly, proactive identification and elimination of a risk is safer and cheaper than a reactive approach to managing risks. Secondly, building professionals with the most knowledge and experience with regard to common and critical hazards will consider site safety as a result of considering DfS. Thirdly, there is intrinsic symbolic value of project stakeholders being concerned with worker safety even from early design stages. This indicates a good safety culture within the construction organization. Further to this, removal of hazards have a direct relationship with reducing the total cost of a project (Toole and Gambatese, 2008). On top of this, Behm and Culvenor (2011) notes that a safer design increases workers’ safety and productivity, thereby enhancing project quality.

On the other hand, a perceived increase in design duration, cost and requirements for additional resources arising from the DfS process is observed from countries where DfS has been implemented (Behm and Culvenor, 2011; Gambatese et al., 2009). On top of that, barriers such as design professionals lacking sufficient expertise on construction safety (Gambatese et al., 1997; Hallowell and Hansen, 2016; Toole et al., 2017) and designers' concerns over legal liability have been shown to be detrimental to the effective implementation of DfS review to improve construction safety (Toole, 2005; Toole and Gambatese, 2008). This is in agreement with the findings of Gambatese et al. (2005) who found designer’s knowledge in DfS to be crucial for its effective implementation in practice. Yet, this is hindered by a lack of available and accessible knowledge compilations on DfS as identified by Goh and Chua (2016). Furthermore, as Schulte et al. (2008) note, for a compulsory national DfS implementation to be successful, it must be more than a mere improvement of designer's competencies. There should be buy-in from commercial decision makers such as developers and clients, who have the power to insist on backing projects and professionals with a good safety track record, thus increasing demand for safer designs to protect workers. Further research into the current state of practice is therefore crucial to understanding the shortfalls. This can aid in the development of policy and legislative reforms to compulsory implementations of DfS in the construction industry.

Method

A case study approach was undertaken for this research. As the regulations were new and practice hence different from current practice, it would be difficult to anticipate how practice would carried out. The choice of the case study method gave the researchers a full and broad picture of the DfS practice without prior constraints applied to the observations.

One project was observed in detail. The project observed was a new 26 storey residential building, built on empty land. Residential buildings represented typical buildings built in Singapore. Observations were carried out twice, once in the conceptual design stage, and the second time during the detailed design stage. At early stages in the design, it would be difficult to visualize the unique features of the design, as items have not been designed yet. Later in the design, many items in the design would already have been finalized and changes difficult to make. It was anticipated that observations of this project that were still in the early stages of the DfS review process would be most productive.

Notes were taken during the meetings of the items presented, behaviours displayed, and the general flow of the meeting. The two observations were analysed using thematic analysis. Common themes that were observed between the two meetings were compiled.

Results

Background on DfS guidelines

The DfS regulations implemented in Singapore imposes statutory duties on the developer, contractor, designer, registered proprietor, and Design for Safety Professional (DfSP). The DfSP serves as the facilitator of the DfS review process. Other mandatory obligations include the developer convening the DfS review meeting and maintaining the DfS risk register. These tasks may be delegated to the DfSP. The DfS risk register is a compilation of the design risks identified in the project and the mitigation measures that should be undertaken to address them. Prescribed statutory duties are explained in the DfS guidelines. The enforcement and prescription of penalties for any lapses in implementation are based on the regulations *Workplace Safety and Health (Design for Safety) Regulations* (2015).

Published as an accompaniment to the regulations by the Workplace Safety and Health Council (2016), the DfS guidelines are a non-mandatory code of practice for DfS, suggesting a specific structure for the review process to take. They are not legally binding, and hence, projects do not have to follow the prescribed structure. However, most projects try to adhere to the structure. In event of enforcement, they may use their compliance with the guidelines as a form of protection against penalties. The suggested structure is known as the GUIDE process. During a GUIDE process, the stakeholders are to be gathered, understand the design concept, identify the risks, design around them, and to record all relevant information. It is also suggested that meetings take place at three distinct stages: concept design, detailed design, and pre-construction. These are known respectively as GUIDE-1, GUIDE-2, and GUIDE-3.

Other recommendations given in the DfS guidelines help to scaffold the design review process. A list of common design considerations that may pose risk are given. Suggestions are also given for: the design changes that are under a designer's control, the use of annotations in the designs to further convey the risk to the appropriate recipients, and the production of a maintenance strategy report to bring maintenance concerns into focus for the project team.

Results in the following sections are reported in the order of observed proceedings of the review meeting, comparing with the DfS guidelines, and finally, the elicited underlying themes.

Project observations

Attendance

Two meetings were observed. In the first meeting, the attendees comprised of; the developer's representative, the architect, the civil and structural engineer, the mechanical and electrical engineer, and the project coordinator. The architect also served as the DfSP of the project. In the second meeting, the civil and structural engineer was unable to attend. This practice is in contrast to what is provided in the DfS guidelines, which states that the developer should ensure that all the relevant parties, designers and contractors (if on-board the project) should attend the meeting.

Focus of meeting

In the first meeting observed, the stated intent of the meeting was to aid the project team in understanding how to carry out the GUIDE processes. The representative of the developer conducted this meeting as the DfSP was not considered to be satisfactorily conducting review meetings. Each item on the DfS risk register was discussed among the project team, the DfSP, and the designers. While going through each item, the developer's representative guided the team and provided opinions and advice on how to carry out GUIDE-1. During the meeting, the designers discussed the items on the risk assessment using the site map and the DfSP recorded all the amendments. The items discussed were more general as the emphasis was on familarising the project team members with the conceptual thinking of performing the DfS review, rather than specifically tackling the project's design risks. The DfS guidelines do not mention any introductory briefings, or trainings to be given to the team members. However, these are useful to clarify expectations for the team members.

For the second meeting observed, this took the form of a typical DfS review meeting, where specific design items were discussed to identify hazards and mitigate them. This meeting was considered to be part of the GUIDE-2 stage in the design review process. The timing of the meeting as appropriate as it was conducted before the design was close to finalization. This can help the designer to review the structure progressively as it develops.

Hazard identification and mitigation

One of the main processes in the DfS review is hazard identification. For the review process to be effective, it is critical that hazards are specifically identified. This allows for appropriate mitigation measures to be taken. During the first meeting, the developer's representative set out to clarify what the appropriate hazards to be identified and documented were. There must be considerations of the hazards and risks in the long term perspective, i.e. during the maintenance stage. Possible hazards and risks that may affect the site and/or surrounding environment must be brainstormed during the meeting.

Hazards identified should be recorded in the DfS risk register. Completing the DfS risk register was challenging for the project team. There were items in the DfS risk register that were similar to each other. The DfS risk register included risks that were resolved prior to the first meeting, even though the intent of the DfS risk register was to record residual risk at that specific point in the project. The contents in the DfS risk register were recorded with abbreviations instead of being spelled out in full.

The first meeting observed was aimed at introducing the project team to the ideas behind DfS and how to perform the review procedure. For the second review meeting, the focus was less on the specifics of recording items in the DfS risk register and more towards identifying hazards. The project team was prompted by the developer's representative to think about the hazards posed in all stages of the project's life cycle including maintenance. The team was also prompted by the developer's representative to consult the main contractor for expertise on construction related issues like deep excavation. Other hazards discussed included the potential traffic flow around the construction site, and the measures needed to account for that. One mitigation measure that was implemented was moving a generator away from residential areas, thereby eliminating the hazard.

Recording the hazards was still an area of confusion in the second design review meeting. There was confusion over among the team whether there would still be residual risk if the stated mitigation measures were applied. For items where there were residual risks, the designers would make a note of it in the drawings. Despite the instruction from the previous meeting, risk recorded in the DfS risk register were still inadequate. For example, items recorded did not have a stated hazard and the proposed control measure did not address the problem.

In the DfS guidelines, hazard identification should take place at each stage of the design process. The team implemented the DfS review process at each stage of the project, as necessary, to review the design while it is ongoing. It is also critical in the DfS review process to identify hazards posed in the construction and maintenance stages, which the project team did upon prompting from the developer's representative. A checklist of common design considerations is provided in the DfS guidelines, which the team used to scaffold their thinking. These were used to identify potential and specific areas of the project that needed further improvement. Brainstorming, as mentioned by the developer's representative, is also a suggested method for identifying design risk.

The DfS guidelines state that the DfS risk register is to be used to record the risks, mitigation measures chosen, and subsequent residual risk. The completed document is to be handed over to future management of the building. The team adopted a measure suggested in the annexes, which was to mark out residual risks in the drawings. Overall, the developer's representative's identification of the issues of the DfS risk register aligned with the intent of the DfS guidelines. One common issue faced herein was the lack of specificity with the identified hazards. There is no direct statement in the guidelines of how specifically a hazard should be identified. However, when keeping in mind the intent of being able to mitigate design risk hazards, the necessity of the clear identification of the design hazards becomes apparent. Other examples include adjusting for the intent of being able to keep the DfS risk register as a live document, which could be handed down to future building managers. The use of full names for items rather than abbreviations would help to make the register comprehensible to future readers of the manual.

Tender preparation

During the first meeting, the developer's representative highlighted to the project team members that the information they were creating was key to the preparing the tender documents. The information currently available was judged to be insufficient. It was highlighted to the DfSP that they would have to gather as much information as possible to place into the tender so that the contractor can appropriately price for the residual risk that they would have to address. Questions about future tender preparation were also present in the second review meeting. For example, if hoarding at the site was needed, the quantity and specific locations were all necessary so that the contractor would be able to price in the control measure.

There is no explicit mention of the link between the tender process and the DfS review in the DfS guidelines. However, there exists a duty for the developer to manage the project such that all designers and contractors have sufficient project resources to perform their duties. Placing the project specifications in the tender helps to define the necessary resources to be used for each mitigation measure.

Developer role

In both meetings, the developer's representative was observed to be a key player. They provided specific guidance to the project team, continually prompting them where necessary to better align their work with the spirit of the DfS guidelines. For example, the project team members were repeatedly asked to be more specific with identifying the hazard. By leading the meeting, the developer would be keeping to their duties of ensuring that all 'foreseeable design risks are eliminated' or 'reduced to as low as reasonably practicable'. The developer's representative in this study took a hands-on approach towards this duty by directly overseeing and getting involved in the process. The developer also helped to ensure that necessary resources were provided, by asking for them to be listed in the tender.

DfSP role

In the meetings, it was observed that the DfSP took a majority of their direction from the developer's representative in the project. While they tried to facilitate the meeting by asking probing questions of the designers, this role was mostly carried out by the developer's representative. Although they improved between the first and second meeting. Even so, the second meeting was still largely run by the developer's representative. From the DfS guidelines, it is stated that the developer may delegate the task of convening the DfS review meeting to the DfSP. Hence, the DfSP role is to serve as the facilitator of the meeting. Yet in practice, for this specific project, the meeting was facilitated by the developer's representative.

Designers

Consultants were observed to contribute actively to the meeting by providing details and information on the design features when prompted. They were knowledgeable and ready to provide information on their areas of expertise. For areas that may not be under their responsibilities, they would also offer their opinions and feedback. In the second review meeting, the mechanical and electrical consultant was clear on his work, so they were able to provide information readily whenever asked. The DfS guidelines ask that the designers provide the relevant information, and to prepare design plans that eliminate or reduce as far as reasonably practicable design risks. By participating in the meeting, identifying the risks, they are partially fulfilling their duties to do so.

Discussion

During the implementation of new regulations, knowledge about the newly imposed statutory duties must be transferred to the practitioners whom it affects. A method of doing so is through the publication of the code of practice. This serves as a formal statement of the regulator's interpretation of the guidelines, even if the enforcement would be based strictly on the text of the regulations. It is not known how many of the participants at the observed meetings had read the guidelines. However, formalized methods of training for the DfS review process will derive their information from the DfS guidelines.

Training and leadership

While the DfS guidelines providing information to the designers on their duties were published before the observed meetings, designers and the DfSP did not refer to the published guidelines. Rather, they received training in how to act from the meeting. This was done by the developer's representative as they pointed out what they felt was correct or incorrect, such as the appropriate way to identify risks, implement mitigation measures, and subsequently record this process. By doing so, the developer had fulfilled their statutory duties to 'ensure that all foreseeable design risks were eliminated or reduced to as low as reasonably practicable'. The developer's representative's advice closely matched that which was given or could be implied from the advice of the given in the guide. However, this calls into question the utility of the DfSP. Of all the positions in the DfS review, only the DfSP is required to have a minimum qualification and receive mandatory training in DfSP. It is not expected that this would make the DfSP the most familiar with the procedures. However, it was observed that the DfSP was inexperienced, and had to be guided by the developer's representative instead. This calls into question the efficacy of the mandatory training undergone by the DfSP.

The designers and team were receptive to this informal training, as they were all cooperative and actively contributed to reviews of the design. This could have been because the training was undertaken by the developer's representative. The developer's representative serves as the leader of the team. They control the resources and payment in the project, which gives them power over the other members. This power could make the team more receptive to their suggestions and instruction. The findings are in line with previous research on the importance of developer support for implementation of DfS (Toole et al., 2017).

Hazard identification

It was observed that the project team faced great difficulty with the process of hazard identification. Knowledge of DfS by the designers is both crucial and not currently sufficiently widespread for implementation to be effective (Gambatese et al., 2005; Goh and Chua, 2016). Items listed in the DfS risk register were not specific enough to truly understand what the hazard was; and what subsequent mitigation measures were needed. The DfS risk register lists common design considerations that might result in hazards. However, for the process to be truly effective, there is a need to consider the unique risks arising from the site and to clearly state the risk. The mitigation measure would be easy to derive from there. The team members also had difficulties understanding what should be included in the DfS risk register. It is not made explicit in the DfS guidelines as to what risks should be recorded. For example, if they have already considered the problem and addressed it in the design. The DfS guidelines focused on instructions for the process, and less so on the documentation required.

Implications of findings

In the early stages of implementation of a DfS review process, it is expected that project team members will be uncertain of how to carry out the process. Instruction is needed. This study shows that non-mandatory codes of practices may not be followed. Nevertheless, guidelines should still be published as it gives people an understanding of how the DfS regulations can be implemented in practice. The practical implication of the results show that this cannot be the only method in which information is spread about newly introduced guidelines. In particular, the observations made in this study suggest that a critical method in which project team members learn about newly implemented procedures is through lived experience. One or more of the senior team members serves as a guide for the team. This suggests that it is critical to have widespread DfS training targeted at all major roles in the DfS review process. Redundancies in the expertise of the review process can help to ensure that all project teams can receive guidance for a newly implemented review process.

This study also calls into question the position of the DfSP. If guidance for DfS review in the project team can come from the core team, which existed before the implementation of the regulations that created the position of the DfSP, there may not be a need for a DfSP. When the process is more familiar to practitioners, the utility of the DfSP role should be reconsidered. This would be in line with removal of a similarly designated facilitation role in the UK regulations (Carr, 2014).

To address the problem of the difficulty in identifying hazards, it would be useful to compile a sample of a potential DfS risk register. This would assist project team members in performing DfS review.

Conclusions

The objective of this study was to investigate how DfS is practiced in the early stages of compulsory implementation. In this study, observed behavior of participants in the DfS review process was compared to what was written in the DfS guidelines and regulations that implemented the DfS review process. The impact of mandating a new safety review in construction projects is investigated. This study provides insight to project team members' conduct during the review meetings. The differing roles of each project team member was also studied. This provided insight as to the importance of factors such as leadership for the project team. Possible factors influencing the effectiveness of the DfS review process were identified, such as the training each of the project team members received to prepare them to carry out DfS. The themes identified in this research may be used to identify key themes and components to study the climate within a DfS review process.

This study is of significant use to those looking to implement or revise a DfS review process to prevent construction-related accidents. Behaviour observed during DfS review practice is remarked, allowing future adopters of DfS to be aware of potential pitfalls that they might face. For example, the lack of understanding on the part of the design team for performance of the task.

This case study studied one project, from which it would be difficult to capture a sense of the overall practice in Singapore. Observations were made only during the projects' design stage. It is unknown how project teams would take to DfS review in the later stages of the process. Since this meeting was observed at the early stages of the design process, further research should be done on the later stages of the design process. In particular, how the contractor and the design team review the design work. Although DfS is to account for the design of temporary structures that are used in construction, in practice, it is felt that these structures are the scope of the contractor's work. Designers may be more reluctant to review any such work. Further research can be conducted on this, as the present study did not account for the role of the contractor.

This research focused on the practice of DfS review in the early stages of mandatory implementation. Further research could explore process maturity as the regulation becomes more firmly entrenched in the local practice. Process maturity could differentiate between projects that are implementing DfS review only for compliance, and those who are practicing it to actively improve the design and reduce risk inherent in the design. In addition, identifying the differences in practice and attitude of team members between mandated review processes and those that were voluntarily implemented could prove to useful for regulators seeking to regulate the practice.

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