Designer’s Confidence and Attitude towards Designing-for-Construction-Safety (DfCS) Implementation

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Abstract. The construction industry is known as a hazardous industry, which has been overwhelmed with accidents for a long time. One of the new strategies to reduce the number of accident in Malaysia is through emphasizing the safety responsibility on the parties involved during the design stage. This study investigated the confidence level of designing-for-construction-safety (DfCS) and the perceptions of the hindrance by focusing on the role of designers and its implementation among construction designers. The quantitative approach had been used, in which questionnaire survey forms were distributed via email and self-administered to forty (40) construction designers (i.e. civil and construction engineer, quantity surveyor, architect) in Johor. The findings have revealed that the respondents are confident of their ability to design for construction safety, though they are relatively less willing to implement the concept. This study demonstrates that significant effort is required to promote the benefits of DfCS in improving the safety performance of the construction industry so that it is widely accepted and implemented by the construction stakeholders.

1. Introduction
In many countries in the world, the construction industry is renowned as the most hazardous industry, despite its importance in contributing to the economic growth of the country. In many states, the fatality and incident rates of construction industry are noticeably higher than other sectors. Construction workers are exposed to many dangerous substances from the construction materials, unpleasant dust, unpredicted working environment and other physical hazards [1]. Therefore, construction industry stakeholders need to control safety and health risks at the construction site, and further its safety performance.

In Malaysia, the number of fatalities that occurred in the construction industry is the highest among other sectors, as proven by SOCSO and DOSH reports every year. One of the new strategies to reduce the number of accident in Malaysia is through emphasizing the safety responsibilities on the parties involved during the design stage. Cooke [2] and Gambatese et al. [3] suggested that the lousy safety performance of construction can be improved through preventing accidents and reducing uncertainty before it happens. This statement indicates that, in order to improve safety performance in the construction industry, designing-for-construction-safety or commonly known as DfCS, would be the best option. The influence of the design of construction accidents has been studied in decades. Trehewy et al. [4] argued that designers could directly affect safety and health outcomes through the selection of procurement systems, preparation of contract documentation, construction process sequencing, and
contract tenure decisions. It could also indirectly affect safety and health outcomes through the selection of frame types, material specifications and the design itself. Smallwood [5] interviewed general contractors in South Australia and revealed that half of them agreed that "design" is a significant factor that affects health and safety negatively. Majority of these contractors stated that there is a need for architect and design engineers to attend safety education subject at the university or technical college. Meanwhile, a 1991 European study found that about 60% of workplace accidents can be traced back to decisions made before construction work began [6]. More recent research on DfCS is focusing on integrating the concept of DfCS with the use of modern tool such as Building Information Modelling (BIM) [7-10].

In the UK, some rules emphasize the responsibility of designers during the design stage which is the Design and Construction Management (CDM) Regulations 1997 (now known as the CDM Regulations 2007 [11]). This rule requires the construction players, especially designers, to accept national laws to formalize a process to make sure that construction site safety is considered during the design process. However, according to Summerhayes [12], since the introduction of the legislation to construction design professionals in 1997, the designers are still doubtful to comply with the legislation.

In Malaysia, the Master Plan for Occupational Safety and Health in Construction Industry (MPOSHCI) 2005-2010 has introduced this concept as a positive recommendation to improve occupational health and safety performance of the construction industry [13]. A number of OHS-related positive actions related to ‘designing construction safety’ and incorporating education into the concept of OHS, and providing guidance to clients to conduct safety and health design examinations provided before construction [13-14]. Moreover, the Guidelines on Occupational Safety and Health in Construction Industry (Management) 2017 has been introduced, which assigning specific OHS obligations for construction design professionals [15]. However, it is doubtful that Malaysian construction designers adequately understand how to identify, assess and control OHS risks in their designs. This assumption is based on the 'nature of the job responsibility', in which designers are usually not involved in or responsible for OSH. Moreover, the number of studies that investigate the designer's perspective on the issue is minimal [16]. Although several studies have been conducted to reach the perspectives and insights of the designer's on DfCS concept [16-18], there are still weaknesses in resolving their perspectives on these issues in the Malaysian context. Therefore, this study attempts to contribute to filling this gap by investigating the designers' confidence and attitude towards DfCS concept implementation.

2. DfCS Concept
Traditionally, the parties responsible for preventing injury to workers are contractors and subcontractors. However, the current trend in the construction industry is now focusing on the duty of all construction participants, including owners, designers, contractors, and safety practitioners, to create a safe work environment. In the designing for safety concept, designers assess the identified risks of their designs to the workers on construction sites and eliminate or modify the design to eliminate hazards or minimize the impact of the risks.

The design phase of a new construction project is important since decisions taken in this phase tend to have a significant impact on the construction execution. The degree of uncertainty about the future to be encountered is considered high at this phase. In response to this situation, risk management executed in this phase can play a vital role to avoid uncertainty and risk before the construction phase takes place. Szymberski [19] postulated that by incorporating safety earlier in the project schedule, more considerable influence could be exerted (figure 1). By including construction site safety as a consideration (along with production, quality, project scope, etc.) early in the project’s life cycle, one has a more exceptional ability to influence construction site safety positively. Therefore, changes to the design process are needed to enable identification and proper management of decisions with the potential to create a risk to workers on the construction site. Designers are increasingly being pressured to assess the occupational safety and health risk their designs create for the construction worker, and consequently to eliminate or reduce these within their plans.
2.1 Designer’s role in influencing safety through design

There are many design solution suggestions proffered by researchers for better safety performance in construction. Behm [20] gives an example of how the features of the permanent facility can influence the safety of the constructors:

“When the height of parapet walls is designed to be 42”, the parapet acts as a guardrail and enhances safety. However, when roof perimeters do not contain permanently designed-in fall protection features (i.e. anchorage points and guardrails), worker safety is compromised.”

Gambatese et al. [21] suggested the factors that will affect the implementation of designing for safety. The factors include designer’s knowledge and acceptance on the concept, designer education and training, designer motivation to implement the concept, ease of implementation of the concept, availability of implementation tools and resources, competing for design/project objectives and design criteria/physical characteristics. The designers may benefit from the implementation of the concept in many ways and that the implementation of this concept may also have positive impacts on construction safety.

3. Methods

3.1 Procedure

This study employed a questionnaire survey method to attain participants’ (in particular, the designers) insights on DfCS concepts. The questionnaire form consisted of 3 parts, which are: i) Part 1 – questions concerning the participants’ background and awareness on DfCS; ii) Part 2 – designer’s confidence in implementing DfCS; and iii) designer’s attitude towards DfCS. This study adopted Yacizi and Dulaimi’s [16] instrument in developing the questionnaire. For general knowledge questions (Part 1), participants were required to answer the questions in either ‘Yes’ or ‘No’ for Part 2 and 3, the questionnaire used the following scales to attain designer’s answers on their confidence and attitude towards DfCS: 1 (strongly disagree), 2 (disagree), 3 (neutral), 4 (agree) and 5 (strongly agree).

Before distributing the original questionnaire forms, a pilot study was conducted to validate the questionnaire instrument by sending out the questionnaire to 3 panels of the expert. The experts were
among those who had more than 15 years of experience in design activities. All panels agreed with the questionnaire instrument, which denotes that the adopted questionnaire is suitable to be used in the Malaysian environment.

Next, the actual questionnaire form had been distributed to the participants in the form of a self-administered questionnaire. The participated designers were group into architects, civil and structural (C&S) engineers, and quantity surveyors who were currently engaged in design activities for construction projects in Johor. The total number of participants was 40, and the summary of the participants is depicted in Table 1. These surveys were done during working hours, and each respondent took not more than 15 minutes.

**Table 1. Number of participants**

| Type of participant | Number or participant |
|---------------------|-----------------------|
| Architect           | 13                    |
| C&S engineer        | 16                    |
| QS                  | 11                    |
| **Total**           | **40**                |

3.2 Measures for data analysis

In order to analyze the questionnaire questions for Part 2 and Part 3, this study applied the Average Index method, which provides means to ascertain respondents’ validation of a criterion [22]. The average or the mean index of a criterion is evaluated using the following Equation:

\[
Average \ or \ Mean \ Index = \sum aiXi/\sum Xi
\]  

Where,  
\( a = \) constant, weighing factor for \( i \), \( \{i = 1, 2, 3,... n\} \);  
\( X_i = \) frequency of respondent

4. Results

4.1 Background and awareness on DfCS of participants

The survey form was distributed to the participants, as depicted in Table 1. The summary of the participants’ background is shown in figure 2. As can be seen in the figure, the majority of participants possessed a bachelor’s degree and had between 3 to 10 years working experience.

![Figure 2. (a) Level of education, (b) working experience (years)](image)

With regards to awareness on DfCs, majority of total participants are aware of the concept and implement DfCS in their work, as shown in figure 3. However, the selected participants from architects seemed to be less aware of DfCS and did not implement the concept in their work.
4.2 Designer’s confidence on DfCS concept

In attaining the confidence on DfCS among construction designers, the designers were required to rate their level of confidence based on the 5-point Likert scales given. The results of the designers’ answers are shown in Table 2.

Table 2. Average index analysis of respondents’ answers on their confidence towards DfCS concept

| No. | Statement                                                                 | Architect | C&S engineer | QS       | Average for all group |
|-----|---------------------------------------------------------------------------|-----------|--------------|----------|-----------------------|
| 1.  | Influence on end user’s safety                                            | 4.615*    | 4.438        | 4.272    | 4.442                 |
|     | I believe that decisions at the design stage of a project influence end-users’ safety and health |           |              |          |                       |
| 2.  | Influence on workers safety                                              | 4.538*    | 4.563*       | 4.182    | 4.427                 |
|     | I believe that decisions at the design stage of projects can influence workers’ safety & health on construction sites |           |              |          |                       |
| 3.  | Familiarity with the concept                                              | 3.538     | 4.313*       | 4.000*   | 3.950                 |
|     | I am familiar with the concept of designing to enhance construction worker safety & health |           |              |          |                       |
| 4.  | Capability of identifying hazardous design                                | 3.769     | 4.688*       | 4.636*   | 4.364                 |
|     | I am capable of identifying potentially hazardous design solutions        |           |              |          |                       |
| 5.  | Awareness on safe design solutions                                        | 3.923     | 4.563*       | 4.273*   | 4.253                 |
|     | I am aware of design solutions that could be used to address construction workers safety & health |           |              |          |                       |
| 6.  | Safe design development skills                                            | 3.923     | 4.188*       | 3.909    | 4.006                 |
|     | I am skilled at developing design solutions that can help to avoid hazardous situations on construction sites |           |              |          |                       |
| 7.  | Awareness on OSH legislation                                               | 3.923     | 4.313*       | 3.818    | 4.018                 |
|     | I fully understand the relevant legislation regarding construction safety in the Malaysia |           |              |          |                       |
| 8.  | Awareness on safe design tools                                            | 3.846     | 4.600*       | 4.182    | 4.422                 |
|     | I am aware of design tools that could be used to address construction workers safety & health |           |              |          |                       |
| 9.  | Formal education and training on the DfCS concept                         | 3.769     | 4.750*       | 4.545*   | 4.355                 |
|     | Addressing construction workers safety & health was included in my formal education and training |           |              |          |                       |

*Indicates higher mean value scored than mean
In general, the participants have high confidence in the DfCS concept. From the data obtained, it could be seen that the top 3 of the designers’ confidence in DfCS scored by selected participants are questions number 1, 4, and 9. The lowest scored value is question number 3. It is interesting to note that the C&S engineers possessed higher confidence in implementing DfCS concept, in which they scored the highest value for almost all questions. This is followed by QS. Even though there was no question scored by them as the highest value, most of their scores are higher than the total mean value for all participants. The results are in-line with the awareness of DfCS questions (see Fig. 2) where most selected participants from C&S engineers and QS are aware of the concept and implementing the DfCS in the works. Architects seemed to possess the lowest confidence level in implementing DfCS concept. The majority of the selected architect participants were not aware and not implementing the concept. The results provide evidence that civil and structural engineer were more informed about DfCS concept. C&S engineer is more related to the concept as they do the designing, assessing, and inspecting structures in the construction field, which they know how to prevent the accident from happening. However, there were also several questions in which designers somehow agreed to each other. For example, they believe that the decision at the design stage of a project influences the end user’s (questions 1) and the workers’ health and safety (question 2). This is in agreement with Dulaimi & Yazici’s [16] finding which stated that construction designers are aware of the workers’ health and safety.

4.3 Designer’s attitude towards DfCS concept
Meanwhile, in obtaining the construction designers’ attitude towards DfCS, the designers were required to rate their perceptions on DfCS concept based on ten questions. The results of the designers’ answers are shown in Table 3.

| No. | Question                                                                 | Architect | C&S engineer | QS       | Average for all group |
|-----|---------------------------------------------------------------------------|-----------|--------------|----------|-----------------------|
| 1   | I believe that to design safety & health would limit my creativity as a designer. | 3.154     | 3.125        | 2.909    | 3.062                 |
| 2   | Addressing construction worker safety & health at the design phase will increase my liability exposure. | 3.385     | 3.25         | 3.091    | 3.242                 |
| 3   | I – as a designer- lack motivating forces (legal, contractual, or regulatory) to adopt design for health and safety methods | 3.077     | 3.063        | 3.091    | 3.35                  |
| 4   | I believe that designing for safety & health will increase project cost. | 3.038     | 3.75         | 3.818    | 3.535                 |
| 5   | I believe that designing for safety & health will increase project duration. | 3.769     | 3.875        | 3.909    | 3.851                 |
| 6   | I believe that designing for safety will decrease number of accidents on site. | 3.692     | 4.125        | 4.091    | 3.969                 |
| 7   | I believe that designing for safety will enhance project performance | 3.769     | 3.688        | 4.812    | 4.090                 |
| 8   | The traditional contractual relationship between the designer and contractor impedes me from formally addressing construction worker safety & health in the design phase. | 3.462     | 3.4          | 3.636    | 3.499                 |
| 9   | OSH policies and procedures mean little to me when it comes to get tasks completed. | 3.077     | 1.938        | 2.455    | 2.49                  |
| 10  | As a designer I am not expected to take OSH into consideration when designing a project. | 2.846     | 2            | 2.364    | 2.403                 |

From Table 3, it could be seen that in general, the respondents’ attitude towards implementing DfCS concept were varied. In some questions, they showed high commitment towards achieving the concept, such as questions number 6 and 7. In these questions, the respondents agreed that the DfCS concept
could impact project safety performance as a whole. Besides, they also showed positive commitment towards considering DfCS in their designs, as shown in questions number 9 and 10. However, some impediments might hinder the designers from implementing the DfCS concept in their projects, in the aspects of project-specific (increase in project cost and duration), industry-specific (traditional contractual relations), and country-specific (lack of supportive legal). This is in agreement with Yacizi & Dulami’s [16] findings. They indicated that there should be a means to overcome the perceived barriers so that the DfCS concept can be accepted and practiced extensively by all designers. Besides that, the results showed high scores for ‘limitation on the creativity; and ‘increased liability,’ which might hinder the designers from implementing the DfCS concept. Consistently with Yacizi & Dulami’s (2015) finding, the respondents showed their disagreement on their roles to implement the concept in current practices.

5. Discussion and Conclusion
This study aims to investigate the confidence and attitude of designers towards the DfCS concept implementation. In general, the results show that the respondents are confident of their ability to design for construction safety. However, they are relatively less willing to implement the concept. It is also worth noting that the respondents’ confidence and attitude were varies depending on their professional background. This study provides evidence that an enormous effort is needed to promote the benefits of DfCS in improving the safety performance of the construction industry. This will ensure that it is widely accepted and implemented by the construction stakeholders.

The results of this study may be limited by the number of respondents for each group of professionalism. Thus, further research is needed to increase the number of respondents for each professional group so that the results can be generalized. Moreover, it is also worthwhile to extend the study to involve respondents in other states or regions within Malaysia.

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