Exploring the knowledge of Prevention through Design (PtD) among Malaysian civil & structural designers

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Abstract. Devastating accidents in construction projects have elevated interests on providing early attention to safety hazards in design phase. Calls for changes in safety practice, through the Prevention through Design (PtD) concept has become increasingly vocal in various countries. In Malaysia, a Guidelines of Occupational Safety And Health in Construction Industry (Management) (OSHCI(M)), which stems from the PtD concept was launched to provide guidance for designers to enhance their PtD capability. This paper aims to explore the current PtD knowledge among C&S designers, in order to gauge the initial understanding towards OSHCI(M) implementation. Data were collected from 70 C&S designers in Malaysia through questionnaire survey and discussion conducted from four series of PtD workshops. The findings revealed that despite the current state of C&S designer’s knowledge still needs to be improved, majority of them have been very positive and supportive on the OSHCI(M) implementation. A number of recommendations towards improving the PtD knowledge have been highlighted; PtD early education; the use of pedagogical approach in PtD teaching; continuous training and establish integrated PtD educational resources. This study extends the PtD literature in construction context, in particular into the advancements towards improving the PtD knowledge among designers in the developing countries.

1. Introduction
In Malaysia, construction is the third most dangerous industry, with the highest rate of fatalities compared to other industries. Department of Occupational Safety and Health [1] reported that out of 247 occupational accidents reported in construction in the year 2016, 106 were fatal increase about 17 per cent from previous year. In 2017, the number of fatalities increased about 4.5 per cent, equivalent to 111 fatalities. The figures might have looked even worse considering the possibility of non-fatal accidents in the construction sector which goes unreported [2].

The increasing trend of the accident rate in the Malaysian construction industry is deviate from the National Occupational Safety and Health (NOSH) policy which is aimed at protecting workers’ rights to a safe, healthy and conducive work environment. In response to improve the occupational health and safety (OHS) performance of the industry, the Ministry of Human Resources, through the Department of Occupational Safety and Health (DOSH) has introduced the Guidelines on Occupational Safety and Health in Construction Industry (Management) (OSHCI(M)) in early 2017 in order to integrate the
Prevention through Design (PtD) principles as part of initiatives to address the capability of construction stakeholders in improving the OHS performance. The OSHCI(M) embraces the “from the cradle to the grave” concept (i.e. considers the total life span of a building or structure – from the initial concept, design, construction and usage until its demolition). This OSHCI(M) is deemed to be enforced in the coming years under the existing act of Occupational Safety and Health Act 1994. It is worth highlighting that the OSHCI(M) is mould based on the Construction Design and Management (CDM) in the UK and this concept has also been referred to in various ways, such as Prevention through Design in US, Design for Safety (DfS) in Singapore and Safe Design in Australia.

Despite this PtD concept have been acknowledged by many governments worldwide (e.g. in the UK, Singapore and Australia have legalise the PtD practices while in countries such as US, Hong Kong and Malaysia, PtD is at voluntary basis), research on PtD have indicated that the total diffusion of PtD is every nation is still growing due to the lack of safety knowledge among the designers [3]. In recent study by Karakhan and Gambatese [4], they found that limited knowledge is one the factors inhibit the diffusion of PtD in US. In another study by Tymvios [5], he found that majority of designers disagree that they should participate in implementing PtD. Manu et al. [6] in their study in Nigeria found that the barrier for enhancing the PtD knowledge may be related to designers’ attitudes, the adequacy and availability of PtD training courses. Moreover, other studies in different countries (e.g. Goh and Chua [7] in Singapore; Morrow et al. [8] in UK) have also acknowledged that the lack of PtD knowledge among designer might hinder the progress of PtD diffusion in the construction.

With the recent introduction of OSHCI(M), the need to explore the current PtD knowledge among the designer is significant. Efforts to understand the PtD capability of this professional cannot be ignored as they would contribute towards OSHCI(M)’s development and transition in the construction industry. With this in mind, this paper aims to explore the PtD knowledge among the civil and structural (C&S) designers. The role of C&S designer towards PtD is important as outlined in many ethical codes (e.g. Board of Engineers Malaysia (BEM) Code of Conduct), they should have the ability to fulfil their ethical duty to hold paramount the safety and health of human beings. This study is part of a wider study to understand the extent of OSHCI(M) implementation in Malaysia. Gaining an insight of how PtD knowledge can be enhanced will facilitate the government and authorities in the PtD diffusion across the country.

2. Overview of PtD framework in construction

It is well documented that there is relation between accidents with design-related factors that contribute towards the deaths, injuries and illnesses in the construction sector. Global construction studies (e.g. Behm [9]; Haslam et al. [10]) linking between 27 percent and 60 percent of workplace fatalities to design-related factors. Considerable evidences on the linkages have influence many governments to changes their safety regulatory framework and legislations. For example, in the UK, the Construction Design and Management (CDM) Regulations were first introduced in 1994 and have been revised twice in 2007 and 2015. Similarly, in the US, PtD practices has started to gain momentum through the establishment of Institute for Safety through Design in 1995 and he application of PtD was advanced in 2012 through the national standard on PtD, ‘Prevention through Design: Guidelines for Addressing Occupational Hazards and Risks in Design and Redesign Processes’ [11]. In Australia, the enforcement has been embedded under section 22 in the Work Health and Safety (WHS) Act (since 2012). New Zealand followed the efforts made by their neighbouring country through the enactment of Health and Safety at Work Act 2015, which came into effect in April 2016. In South Africa, designers liable for the impact of design on construction health and safety and ergonomics under Section 10 of the OHS Act 85/93. In Singapore, the PtD practices, also known as Design for safety (DfS), was initially introduced as a voluntary scheme in 2008. However, the rise of fatal injury rate has led the Ministry of Manpower to enact the DfS regulation in July 2015 and was enforced in August 2016 [7].

In Malaysia, the Occupational Safety and Health Act 1994 (OSHA) and Factories and Machinery Act (FMA) 1967 is known to be the legislative framework for the construction industry. However, the poor safety performance (i.e. 696 workers were killed at construction sites, between years 2011 and
2017 (Department of Occupational Safety and Health (DOSH), 2018)) represents a significant threat to the industry’s social and human resource’s sustainability as well as the business value to construction organisations. Despite the established guidelines related to safety practices (e.g. Guidelines for Public Safety and Health at Construction Sites, 2007, Guidelines for the Prevention of Falls at Workplaces, 2007), the need to have new initiatives on safety practices, in particular the OSHCI(M), is crucial to enhance the standards of safety in the construction industry. There is a need to have specific regulations made for construction under the Occupational Safety and Health Act (OSHA) 1994, as the current legislations were found to have shortcomings in managing construction safety and health at work due to the lack of provisions that provides specific duties or obligations of the duty holders involved in construction [12]. Consequently, based on the CDM framework, OSHCI(M) has been introduced and would add value to the existing OSHA 1994 in securing and reducing the discrepancy of responsibility and accountability in compliance to safety guidelines between construction stakeholders. The guideline serves as a guide for people with legal duties under sections 15 (General duties of employers and self-employed persons to their employees) and 17 (General duties of employers and self-employed persons to persons other than their employees) of the OSHA 1994 and further defines their role in compliance with the law.

Overall, while some governments have mandated the use of PtD in their workplace safety legislations, implementation of the recently established OSHCI(M) guideline in Malaysia is based on voluntary approach (similar to the US and Hong Kong) and is deemed to be enforced in coming years. This would provide ample of opportunities for design professionals in the construction industry to prime themselves with the new requirements and at the same time, acquire knowledge in hazard analysis and risk assessment for early stages of construction.

3. Research method

A pragmatic methodological approach through mixed method, in particular questionnaire survey and discussion forum through workshop was adopted. In line with the study’s objective in exploring the PtD knowledge among C&S designers in Malaysia, the pragmatic approach is believed is the most suitable as having a direct discussion and interaction with designers could produce results that can be translated into practical ends (e.g. capturing the current state of PtD knowledge and provide recommendations to enhance the PtD implementation).

Four series of PtD workshops (were held on 25th April; 8th and 25th August 2018; and 18 - 19 February 2019) with a total of 70 C&S engineers (on average of 17 participants per workshop) were conducted as a platform to gather data. It is worth highlighting that the PtD workshop is believed to be one of the first PtD workshop with C&S designers organised in the industry (since the introduction of OSHCI(M)), and was conducted in collaboration with the regulatory bodies (i.e. DOSH and CIDB). The purposive sampling of C&S engineer was adopted in this study as the focus of the PtD engagement with industry is with the dominant designer in the local construction industry. From the 70 participants, 81% (57) is male and the remaining 19% (13) is female. As for their designation, 58% of them described their job functions as engineer and senior engineer, followed by associate director (17%), director (16%) and engineer / OSH practitioner (with certified safety officer) (9%). It is worth noting that 75% of the participant were registered as Civil and Structural Professional Engineer under the Board of Engineers Malaysia (BEM) and The Institute of Engineers Malaysia (IEM). In terms of years of experience in the construction industry, the majority of participants had experience between 11 to 20 years (39%). Thirty-four per cent (34%) of participants claimed to have experience of at least 10 years. This is followed by respondents (17%) who had experience between 21 and 30 years; and ten per cent (10%) of the participants had more than 31 years of experience in the industry.

3.1. Questionnaire survey

A questionnaire survey on PtD has been administered to the participants in each of the workshops. The key elements of this survey was developed based on the study by Goh and Chua [7], complemented with previous PtD literatures in construction. The questionnaire survey consists of specific section addressing
the PtD knowledge of C&S designers. Questions were asked in relation to their first knowledge on PtD, source of knowledge, understanding of PtD and familiarity with the hierarchy of safety controls for various hazards.

3.2. Group discussion
The group discussion was conducted at the end of the each workshop (last session) and lasted about an hour with specific theme of ‘shaping the future of PtD practices in the construction industry’ in order to capture the C&S designers’ opinion on what it takes to enhance the PtD knowledge among the C&S designers.

4. Result and analysis
There are four questions concerning PtD knowledge in the questionnaire. The respondents were first asked the time when they first heard about the PtD concept and their means of knowing about the concept. From the analysis, majority of respondents (45.7%) claimed that they never knew about PtD until now. The remaining 22 respondents have mentioned that they have heard of PtD prior to year 2017 (before the introduction of OSHCI (M)), while sixteen respondents (22.9%) have acknowledged about PtD on or after the official introduction of OSHCI(M). As for the means of learning about the concept, majority of the respondents (i.e. who do not know PtD till now) claimed that their first encounter with PtD is through the workshop. In contrast, others who have mentioned their knowledge on PtD got to know about PtD through their company (24.3%) and tertiary education (10%). The remaining respondents have indicated that they have learned about PtD through other mediums, such as communication and information related to OHS. It is also worth highlighting that out of the seventeen respondents that have indicated their first knowledge on PtD was from the workplace, twelve of them had more than 10 years of experience. This result suggests that companies (through experienced people) were the main and important source of information on PtD for C&S designers. In addition, only seven respondents indicated they acquire about PtD knowledge from their tertiary education, in particular from master degree. This indicated that there is a lack of PtD education at undergraduate level in civil engineering programme in Malaysian higher education.

Table 1. Cross-tabulation on the effect of PtD training on the level of understanding and familiarity.

| Attended PtD training | Understand the concept | Level of understanding ≤ “Quite Well” | Level of understanding ≥ “Well” | Total |
|-----------------------|------------------------|--------------------------------------|---------------------------------|-------|
| Yes                   | 6                      | 2                                    | 8                               | 8     |
| No                    | 51                     | 11                                   | 62                              |       |
| p = 0.624 > 0.05     |                        |                                      |                                 |       |
| Familiar with PtD    | Level of Familiarity ≤ “Quite Well” |                            |                                 |       |
| Yes                   | 8                      | 0                                    | 8                               | 8     |
| No                    | 53                     | 9                                    | 62                              |       |
| p = 0.559 > 0.05     |                        |                                      |                                 |       |

It is noted that only eight respondents had experience attending training courses related to PtD, while the other respondents have not attended any PtD training. In reference to table 1, 51 out of 70 respondents who have not attended PtD training (prior to this workshop) indicated that they understood the concept of PtD “quite well” or less, in contrast to the other 11 remaining respondents, who felt that they understood PtD “well” or “very well”. Similar to the level of familiarity of PtD during the concept, detailed and pre-construction design stages, more than half of the respondents who have not attended
any training had an understanding level of “quite well” or less, while the other nine respondents have indicated that they are familiar with the concept “well” or “very well”.

Upon further analysis, a Fisher’s exact test was conducted (due to one of the cell in table 1 is less than 5) to assess the statistical significance of attending PtD training with the level of understanding and familiarity of the PtD concept. The Fisher’s exact test revealed that the level of understanding and familiarity of PtD is not significantly different between respondents who have or have not attended prior PtD training (p > 0.05). Nevertheless, further investigation of the results indicated that individuals who had vast experience (more than 20 years) are well understood and familiar with the PtD concept without attending the training. This shows that the older generation might perceive safety as a norm practice in design (based on their experience), as compared to the younger engineers.

As for C&S designers’ understanding on the types of hazard known to them, they were requested to rate their familiarity with the type of controls for common hazards found at construction sites. From the findings (shown in table 2), the ‘falls from working at height’ (mean = 3.71) was ranked as the hazard that most respondents are familiar with (in terms of it controls). The ‘inhalation of dust’ and ‘loud noise’ ranked second and third with a mean of 3.61 and 3.57 respectively. On the other hand, the least familiar hazard control indicated by the respondents was ‘exposure to radiation’ (mean = 2.3).

Table 2. Familiarity with the type of controls for common construction hazards.

| No. | Hazard                                                                 | Mean  | Standard Deviation |
|-----|------------------------------------------------------------------------|-------|--------------------|
| 1   | Exposure to radiation                                                  | 2.3286| 1.17611            |
| 2   | Working near, in, or over water                                       | 3.2143| .96147             |
| 3   | Exposure to dangerous substances                                       | 2.8857| 1.24578            |
|     | (chemical and biological substances or material)                      |       |                    |
| 4   | Being struck or crushed by a workplace vehicle                        | 3.2714| 1.10232            |
| 5   | Vibration from tools or vibrating machinery                            | 3.3429| .93073             |
| 6   | Handling of rough materials                                            | 3.3429| .89904             |
| 7   | Emergency evacuation                                                   | 3.2286| 1.03799            |
| 8   | Bad working postures, often in confined spaces                        | 3.1143| 1.13626            |
| 9   | Struck by falling objects                                             | 3.4714| 1.12574            |
| 10  | Crush injuries in excavation work                                      | 3.3571| 1.12978            |
| 11  | Injuries due to hand tools                                             | 3.4286| 1.02958            |
| 12  | Loud noise                                                             | 3.5714| .95662             |
| 13  | Moving heavy loads                                                     | 3.4286| .98645             |
| 14  | Inhalation of dust                                                     | 3.6143| .93705             |
| 15  | Slips and trips                                                        | 3.4286| 1.00103            |
| 16  | Falls from working at height                                           | 3.7143| 1.10523            |

In addition to that, respondents have also been asked to select the most effective hierarchy of control measures to manage hazards at construction sites. From the analysis, it was found that ‘Elimination of hazards’ received the highest percentage with 61.4 per cent. This is followed by ‘Administrative controls’ and the ‘Use of Personal Protective Equipment’ with 22.9 per cent and 12.9 per cent, respectively. The ‘Engineering controls’ received 10.0 per cent and ‘Substitution of hazards’ received two votes from the respondents. Upon further analysis using ANOVA, it was found that there is no significant difference (p > 0.05) in regards to years of experience towards the choice of controls to manage hazards. This indicates that replacing the hazards would be the least effective of all control
measures by the C&S designers. They preferred for the hazards to be either controlled or eliminated in order to ensure protection of the workers involved in construction projects.

5. Way forward to enhance the PtD knowledge among C&S designers

In general, the feedback provided by respondents during the four PtD workshops on improving the PtD knowledge were largely consistent from many aspects. The first driver identified was the PtD education itself. The lack of early PtD education in Malaysian higher education in significant. In fact, majority of the participants indicated that not only PtD, subject such as construction OHS should also be incorporated in the undergraduate programme. Despite majority of the participants indicated that although they may have learned the related knowledge on the PtD concept (mainly through their lesson learned and experiences), arrangements to include the subject of OSH in general and PtD concept (e.g. risk, constructability) should be made during the early professional education i.e. bachelor degree in related civil engineering and built environment courses. Creating a new subject focusing on PtD is desirable by embedding topics such as concept, processes, tools and resources, challenges, and active learning exercises involving hazard recognition and design mitigation. In addition, diverse topic on PtD such as ethics, social sustainability, integrated design and construction, lifecycle analysis, and public policy could also be introduced as part of multifaceted teaching opportunity in PtD knowledge [13]. The delivering of the PtD knowledge could be made through the use of different modes of teaching, for example, the use of pedagogical approach; serious gaming and simulations; massive open online courses (MOOC) and based on lesson learned from real case studies. It is worth highlighting that the Engineering Accreditation Council (EAC) in Malaysia dictates that all civil engineering degree programs must demonstrate the graduates meet the 12 specific program outcomes (POs) where two of the outcomes (PO 3: Design/Development of Solutions and PO6: The Engineer and Society) explicitly includes the term ‘safety’. Nevertheless, based on feedback from participants (professional engineers who experienced as a panel by EAC) who have been involved with the accreditation process indicated that the incorporation of safety as a standalone subject is remain elusive. If there is any, the safety subject is mostly incorporated as a sub topic in a subject such as engineers in society, construction law and only covering the generic context of safety legislation and organisational safety management. This is supported by van Dijk et al. [14] who found that the inclusion of OHS and risk management subject across Malaysia’s tertiary education is lacking. In fact, Misnan et al. [15] found that none of local and private universities in Malaysia include safety by design in their curricular for both architectural and civil engineering programme.

Considering the lack of PtD knowledge as well as the awareness of the OSHCI(M), there is a need for more wider reaching programmes in order to reach-out to the C&S communities. With encouraging interest of acceptance among the participants, continuous PtD training (start with clear, simple and practical modules) across all key designers is desirable, as an avenue for practical guidance towards enhancing the PtD knowledge and practice (e.g. role and responsibilities, risk management, communication techniques, hazards control, safety tool and file, etc). Some of the participants recommended that for a start, introductory video should be introduced as part of the initiative to increase PtD awareness and understanding among the designers. In addition, a growing dialogue between clients, constructors and designers on PtD is also preferable (e.g. enhancement of PtD community) as it could offer benefits to all stakeholders on the understanding and improvement of relationship towards PtD practices over time. This is to create a stimulating environment that creates a momentum for a paradigm shift (especially on cultural and behaviour) in the current industry, towards the adoption of PtD, subsequently the OSHCI (M).

Another driver that has been proposed by the participants is to have open educational resources (preferable online) to be accessed by all construction stakeholder. Ability to have one integrated platform (e.g. digital library, digital repository, or digital collection) on PtD would allow continuous and life long learning. Accessibility on resources such as PtD modules, standard or guidelines (local and international) and research publications on PtD would help engineers develop their capacity and
cognitive skills to meet their OHS responsibilities as well as their professional engineering competencies.

6. Conclusions
Based on the four series of PtD workshops with C&S designers, it can be concluded that the current PtD knowledge among C&S designers need to be improved significantly in order to ensure the successful implementation of OSHCI(M). Despite the evidence of positive support on PtD, more efforts need to be initiated over time in order to ensure the C&S designers possess different cognitive skills from those involved in business as usual. Focusing on continuous improvement and best practices will help to enhance the landscape of PtD practices among the C&S designers. This study also shed some light on recommendations, notably the integration of PtD subject in higher education; the use of pedagogical approach in PtD teaching; continuous training and PtD educational resources that could be exercised to facilitate the diffusion of PtD in the construction industry. The regulatory bodies, construction organisations and educational institutions could focus on these recommendations as an effort to embrace and correct the fundamentals of PtD knowledge, not only for future C&S engineers but also for all professionals. Ability to enhance the PtD knowledge will contribute to the capacity building of C&S designers on improving safety performance and conforms with the Construction Industry Transformation Programme (CITP) 2016-2020 under the Quality, Safety and Professionalism thrust: “Initiative Q2b: Improve level of occupational safety and health at construction site” that emphasises on securing health and safety performance in construction projects.

Finally, this study was limited to the views and perceptions of C&S designers in the Malaysian construction industry. Consequently, the findings of this study may not represent the views of the entire construction industry. As the PtD implementation in Malaysia gathers its pace, future efforts can be made to seek views and expand the findings with large-scale and diverse samples (e.g. clients, architects, developer, contractors), for comparative purposes as well as to gauge the real practice, attitude and knowledge of PtD in the industry. In addition, the future work could also focus on how to make design criteria considerate PtD elements in order to ensure effective PtD implementation in the industry.

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