Key Design Issues in the Construction Project: Conceptual and Detailed Design Review Phases

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Abstract. The Malaysian construction industry is among the highest ranked industries that contributes to accident and fatality rates. The Guidelines on Occupational Safety and Health in Construction Industry (Management) (OSHCIM) has introduced guidelines for design risk reduction in the construction industry. It involves determining root causes and mitigating the risk by control of the causation of accidents. The objective of this study is to identify the key design issues during the conceptual and detailed design review phases in the construction project. Although some of the design considerations have already been proposed by the OSHCIM guidelines, however, further implementation need to be diverse and versatile by considering the current design practices that are already being practiced by the industry practitioners. The methodology of this research involves document reviews, and a questionnaire survey that was used to collect answers from respondents in the construction industry. According to the results, the key design issues in the conceptual phase involve the site condition, environmental influences, ground or ground water condition, existing structure, demolition, services, adjacent to major infrastructure, traffic disruption, access for works, adjacent to other properties and projects, and site restriction. Moreover, those found in the detailed phase involve the mechanized construction system, installation of prefabrication components, ease of process, structural opening, edge line, fall hazard, accident prevention, layout optimization, ease of activities, permanent safety features, provision of access, and fall hazard. However, it is the duty of the construction industry practitioners to make sure that all other design issues are also included into their construction project risk analysis. As proposed by the OSHCIM guidelines, the review of design risks in the construction project should consider safety in all the stages: during construction, operation, maintenance, modification, and demolition.

1. Introduction

Due to the diverse and competitive nature of the construction industry, the implementation of occupational safety and health continues to be challenging [1]. Besides, safety concerns at sites are becoming the priority for any construction project planned, as the construction industry involves difficult and complex activities [2]. The authority and other key players have employed many campaigns and approaches in the construction industry, which include enhancing safety knowledge, improving work procedures, and surveying the effectiveness of the current safety practices [3]. The frequent spate of accidents related to the construction industry is a matter of concern to all. Steps must
be taken to address this issue of public confidence over occupational safety and health issues at worksites.

Statistics from the Social Security Organization (SOCSO) indicates that 8,841 accidents were reported in the construction industry in 2019, as compared to 4,330 cases in 2011 [4]. In line with the SOCSO report, the Department of Occupational Safety and Health (DOSH) reported 144 deaths in the year 2019, as compared to 183 deaths in 2017, as shown in figure 1 [5]. In particular, fatal accidents in the construction industry decreased by 16% (11.28 per 100,000 workers), as compared to 13.44 per 100,000 workers in 2018. This made the construction industry come second in place after the manufacturing industry, which contributes to the highest fatality rates. However, the total number of accidents in the construction industry has increased quite significantly, by 18% (3.81 per 1,000 workers, with the total number of accidents reported as 4,863), as compared to 3.11 per 1,000 workers, with a total number of accidents reported as 3,911 in the previous year, 2018, as shown in figure 2.

While numerous approaches have been employed to reduce accidents, the number of accidents in the construction industry in Malaysia has kept increasing. Concerned with the trend, DOSH, in collaboration with the Construction Industry Development Board (CIDB), has issued a Guideline on Occupational Safety and Health in Construction Industry (Management) (OSHCIM) in 2017. The guideline had proposed three important stages to reduce risks related to design issues in construction projects. The stages include conceptual, detailed, and pre-construction design reviews. The idea of OSHCIM is to use the higher hierarchy of control methods, such as risk elimination, substitution, and engineering control, during project design stages, so that only residual risks will need to be controlled during and after construction stages. This article focuses on key design issues that the designers need to give priority upon during the conceptual and detailed design stages.

![Figure 1](image1.png)

**Figure 1.** Statistics on fatalities in Malaysia [5].

![Figure 2](image2.png)

**Figure 2.** Statistics on accidents in Malaysia [5].
2. Literature Review

Accidents in the job are common in the construction industry, and they can result in permanent disability and a high rate of death [6]. This is evident from comparable estimates of fatal and non-fatal accidents that occur in various industries, including manufacturing. Accident statistics in the construction industry show that there is still a high rate of accidents in the Malaysian construction industry, implying that the industry is one of the key sectors that require a significant and rapid overhaul of current site safety practices. However, when basic information for mapping effective interventions, such as statistics on incidents, source of injury or death, occurrences of different types of accidents, possible causative factors, and mitigation strategy are only insufficiently available, ensuring safety becomes extremely difficult [7].

To avoid incidents at construction sites, the root causes of accidents must be investigated. Efficient and appropriate preventive action against injuries can only be taken by recognizing and determining the root causes of accidents. Many accidents are preventable and most, if not all construction accidents at the site, should be treated as a failure of management [8]. Awareness of the causes of accidents would also promote the development of a better, healthier, and more favourable working condition at construction sites. In general, there are several effective accident prevention strategies that may be used by employers and employees to reduce injury rates in the construction site, as reported by Abdul Rahim et al. [9]. These include engineering control and safety training. However, they are still lacking in suitability and practicality. In order to propose preventive approaches to mitigate the accident rate at construction sites, the preventive measure must be suitable and in line with the cause of the accident. This was solved by the Guidelines on Occupational Safety and Health in Construction Industry (Management), which proposed five key elements, as shown in figure 3.

There are three main risk review stages involved in OSHCIM. They are related to design issues that may occur before the design is being realized into the construction phase. During every phase, all types of personnel involved (e.g. consultants, clients, and contractors) need to review design issues that will involve the proposed project. The conceptual stage involves the risks that are associated with geotechnical, existing infrastructure, traffic management, site surroundings, security, and hazardous material. Meanwhile, the detailed design stage need to involve design risks related to prefabrication, heavy lifting, confined space, falling from heights, temporary works, layout, access for maintenance, health hazard, weather, emergency route, and others. Lastly, the last stage of the risk review is related to minimizing the design risk, based on approaches such as temporary work, specialist design, weather, and others. Undoubtedly, the overall design risk review focuses on the life cycle of the structure, which includes construction, operation, maintenance, modification, and demolition.

![Figure 3. Key elements for risk reduction [10].](image-url)
Practitioners have long ago already considered the design risks highlighted by OSHCIM. Civil and structural engineers play an important role in designing the structure so that it is stable, robust and strong. Meanwhile, mechanical and electrical engineers play their role in ensuring that services and utilities are designed suitably and safely. Moreover, the contractor and client also play their role in supporting the design proposed by the designers. All other parties such as architect, quantity surveyor and land surveyor also play their role to ensure the success of a project. OSHCIM was introduced to guide the practitioners in a more systematic and feasible design risks analysis. It will help to ensure that all possible risks are mitigated effectively, so that only minimum residual risks exist in the future. However, since this guideline is still new, it is lacking in terms of its implementation and exemplars. Therefore, this study, by considering the key design issues, intended to assist the practitioners to start considering to apply the OSHCIM guideline into their construction project. By considering key design issues, it will give them an idea to more possible design risks that may be existing due to their proposed design.

3. Methodology
The research methodology of this study is outlined in figure 4. A document search was conducted, based on the Malaysian Department of Occupational Safety and Health, Malaysian Social Security Organization, published reports and journal papers. Based on a critical review of the literature, a questionnaire was designed in accordance with the design issues. A validation process was conducted to the survey questionnaire before distributing it to the respondents in the pilot survey phase and the actual survey program. The data that were collected were then analysed and reported in this article.

The questionnaire was designed to capture the main factors that have contributed to the increasing number of accidents that have occurred in the Malaysian construction industry. The questions were organized into two thematic parts. The first part included the respondent’s demographic information. The second part involved design issues that have caused accidents. The details on the design issues that have caused accidents have been focused according to the scopes.

![Figure 4. Flow chart of research methodology.](image-url)
Table 1 shows the details of the design issues with respect to the review stages which was considered as a scope in this study. The questionnaire included multiple-choice questions with predefined answers, offering respondents the possibility to choose and rank from several options or the possibility to grade on a “1” to “5” scale. In this scale, 1 represented “no effect”, 2 represented “slightly effect”, 3 represented “significantly effect”, 4 represented “very significant effect” and 5 represented “extremely significant effect”.

| No. | Conceptual stage         | Detailed design stage          |
|-----|--------------------------|--------------------------------|
| 1   | Geotechnical             | Prefabrication                 |
| 2   | Existing infrastructure  | Falling from heights           |
| 3   | Traffic management       | Layout                          |
| 4   | Site surroundings        | Access for maintenance         |

After a verification of the survey questions, a pilot-test was conducted on a small sample of respondents, to ensure the questionnaire’s clarity and comprehensibility, as well as its ease of completion. The pilot test included eight construction practitioners with extensive experience; five designers and three site engineers were among the respondents. Meanwhile, a total of 100 professionals were selected for the actual survey program, including safety officers, designers, project managers, site engineers and quantity surveyors. After the completion of the questionnaire survey, Microsoft Excel software was used to record the data by category. An analysis of questionnaire data was then finally carried out to meet the research objectives.

4. Results and Discussion

4.1. Design issues related to construction industry accidents

In general, there are many design issues in the construction industry since the structure itself is a complex model made from a design sketch. The results of the present review showed that there are a few standard risks that can be related to design considerations. According to the analysis, the causes of construction accidents were primarily related to the method of implementation (23.1%), which included issues such as incorrect work procedures, lack of knowledge, and failure to follow work procedures. The second most important factor was management (19.1%), which was due to a lack of work supervision, lack of technique guides, lack of communication, lack of teamwork, lack of information flow, no significant knowledge provided to the workers, no warning system, noncompliance with safety regulations, and an inadequate safety policy.

Design complexity came third in place (18.4%), because of its complexity, not being constructible, incomplete and inconsistency of design, safety not considered during design, and lack of safety by eliminating or avoiding design (lack of safety control in design). The unique nature of construction (16.3 %) came next, which includes issues related to working operation, working at height, limited working space, working in variable hazards, and transient workforce, indicating that this industry is more dangerous than others. Moreover, factors such as site condition (6.8%) and issues that are material related (5.4%), equipment related (7.5%), and external related (3.4%) all play a role in the cause of accidents in construction sites. Figure 5 and figure 6 mapped the issues in relation to its respective design considerations. The figures take account of the guidelines proposed by OSHCIM, and are also aligned with the previous literatures and statistical data from DOSH and SOCSO.
4.2. Demographic information

The survey responses involved 58 male respondents and 42 female respondents. The respondents were from various age categories: 18 – 25 years (1%), 26 – 35 years (48%), 36 – 45 years (34%) and 46 – 55 years (17%). Meanwhile, the greatest portion of the respondents were designers or consultants at 36%, followed by safety officers at 27%, site engineers at 22%, project managers at 11% and others at 4%. Lastly, the largest category of respondents had a working experience of less than 5 years (45%),
followed by 40% of the respondents having 5 – 10 years of working experience, and 15% of the respondents having working experience of more than 5 years.

4.2. Key design issues

4.3.1. Conceptual stage

The contribution of all three factors from the geotechnical aspect (stability of soil, soil condition or classification, and susceptibility to flooding due to ground water condition) on design related accidents in the construction site were ranked by a majority of respondents (54-67%) at four (very significant effect). Meanwhile, 40-44% ranked them at five (extremely significant effect), and only 2-5% ranked them at three (significant effect). The ranked results show that most of the problems encountered in construction projects are due to unforeseen ground conditions that could have been avoided if suitable precautions had been carried out. The results further indicate that all these factors should therefore be taken seriously during design risk analysis.

The existing infrastructure aspect is also as important as the geotechnical aspect. This is shown by the results of the analysis, which indicated that all the factors (existing structure, demolition process and services) were ranked at five by a large number of respondents (39-46%), at four by the majority (47-53%), and at three by a small percentage of respondents (3-9%). Designers thus need to identify and consider all these factors before the beginning of the construction phase. This is to ensure that they can provide a safe environment during the construction stage. Designers need to eliminate all the foreseeable risks, and if that is not possible, they need to modify the designs or provide a less risky option. In addition, they must ensure that appropriate information, on the reasonably practicable steps they have taken to reduce or control those risks, is included in the safety and health file.

According to the results obtained for the traffic management aspect, all the factors (adjacent to major infrastructure, traffic disruption and access for works) were ranked at five by 41-56% of the respondents, at four by 43-52% and at three by a small portion of 1-7%. Practitioners in the construction industry generally already know the massive impact of neglecting or ignoring this aspect. Current practice, a designer needing to provide a Traffic Management Plan (TMP) to ensure effective traffic management implementation at work zones. But, considering the issue early during the design phase will help to promotes better planning and design for the on-site implementation teams, ensuring proper traffic management.

The results related to the site surroundings aspect (adjacent to other property, restriction and adjacent to other projects) show that the majority of the respondents ranked it at five (43-56%) while the others ranked it at four (42-48%). This shows that all the factors of this aspect have such a huge influence in the contribution to an accident or failure on the construction site. The client thus need to provide a brief on the necessary prior information (relevant to the planning, management and monitoring of the construction phase and the coordination of health and safety matters during the construction phase) to the principal designer and contractor. Table 2 summarize the priority for the associated key design issues.

| Issues          | Priority | Key design issues                  | Remarks                                                                 |
|-----------------|----------|------------------------------------|-------------------------------------------------------------------------|
| Geotechnical    | 1        | Site condition                     | Soil is among the hardest properties to predict and therefore a systematic technical consideration should be carried out during the design stage. |
|                 | 2        | Environmental influence            | A construction project can caused impact to the environments and therefore risks involved need to be minimized even as early as during the design stage. |
Ground/ground water condition

There are issues related to the ground water including water penetration through capillary which caused dampness and water ponding at ground floor level. Besides, a ground water issue if not properly catered will caused blockage. All of these should be avoided as early as during the design stage.

Existing infrastructure

1. Existing assets/infrastructure
   An existing asset onsite should be identified as early as during the design stage so that any important decision such as a protection can be planned accordingly.

2. Demolition process
   When carrying out a new development it may involves a demolition process to the existing structure, this process need to be identified with its associated risks as it will affect the infrastructure that may be existed adjacent to the site.

3. Services/utilities
   The existing services or utilities (especially those overhead and buried underground) need to be identified even as early as during the design stage to avoid disruption and failure if it is found later during the construction stage.

Traffic

1. Adjacent to major infrastructure
   Design should consider avoiding a traffic jam from happen and the machineries road is diverted from any adjacent major infrastructure ways such as airport, school and religion buildings.

2. Traffic disruption
   When a new development is planned especially at busy and compact area, it will cause a traffic disruption especially due to the massive construction activities. It is the duty of the designers to make sure the disruption should be minimized if not to be avoided.

3. Access for works
   Access for works are important especially for a safety and security purposes. The access should be safe and secure so that any unauthorized vehicles or persons will no mistakenly entering the area.

Site surroundings

1. Adjacent to other property
   Design should consider risks involves when the new development is to be constructed adjacent to other property. An example is the construction activities involves from the design project may cause failure or defect to the adjacent property.

2. Site restriction
   Restrictions from the site surrounding area need to identified in early design stage, so that it can be minimized and if not, a better management will be planned for the future.

3. Adjacent to other projects
   Design should consider risks involves when the new development is to be constructed adjacent to other project. The examples of risks are impact to the environment due to an intolerable projects.

4.3.2. Detailed design stage

The use of a prefabrication system in a construction project can benefit the practitioners in several ways. These include project quality, better monitoring, and speed of construction. However, the use of the system, if not properly monitored and planned, will initiate design risk issues. The risks can come during the process and installation. Besides, since it involves the use of a heavy machine and mechanized system, further risks will be introduced. Most of the respondents agreed that all the proposed considerations related to prefabrication in this study (mechanized construction system, installation of component and ease of process), are indeed key design issues related to prefabrication.

According to results on the falling from heights aspect, all the factors (structural opening, edge protection and fall protection) were ranked at five by more than half of the respondents (56-59%). Meanwhile, 40-43% of the respondents ranked it at four. These results show the high level of importance that need to be put under consideration during the pre-construction and construction phase. The designers need to reduce floor openings in their structures, to prevent falls from heights. The
project need a safe access designed and planned prior to the construction, to avoid falls when working at a height. When this is discovered early, any accidents can be avoided and prevented.

The layout considerations for material, equipment, pedestrian and traffic flow (related to accident prevention, site arrangement optimization and ease of construction activities) during the construction stage was ranked at four by the majority (maximum of 56%). Meanwhile, they were ranked at five by maximum of 33% of the respondents, whilst they were ranked at three by maximum of 11%. This indicates that the factors are very important to ensure the smoothness of workflow in the construction phase, while providing a safe environment in the construction site.

Finally, for the access for maintenance (permanent safety features, provision of access and fall arrest), the results show that most of the respondents rank it at four and five. It is known as the maintenance activities include inspection, testing, measurement, replacement, adjustment, repair, upkeep, fault detection, replacement of parts, servicing, lubrication and cleaning. All these activities need safe access and sufficiency for the maintenance worker to work on it, in order to avoid accidents from occurring. Table 3 summarize the priority for the associated key design issues.

**Table 3.** Ranking of key design issues for detailed design stage.

| Issues                      | Priority | Key design issues                        | Remarks                                                                                                                                                                                                 |
|-----------------------------|----------|------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Prefabrication              | 1        | Mechanized construction system           | When prefabrication components to be used, risks will exist due to its mechanized system which used heavy equipment and machineries. The risks involves should be identified and measured.                |
|                             | 2        | Installation                             | The use of prefabrication components will need an installation at their prescribed locations. The risk such as those related to drop material can occurred and therefore should be identified and evaluated.     |
| Falling from height         | 1        | Structural opening                       | Any high risk opening within a structure for a new development should be minimized if cannot be avoided. This is especially apply for a floor opening to prevent falling from height.                   |
|                             | 2        | Edge protection                          | Any structural edge should be protect to prevent falling from height.                                                                                                                                 |
|                             | 3        | Fall protection                          | If any structural opening or structural edge cannot be avoided from being constructed, a possibility of designing a fall protection should be considered during the design stage.                     |
| Layout                      | 1        | Accident prevention                      | The site and structural layout should be designed with accident prevention.                                                                                                                                  |
|                             | 2        | Optimization                            | The site and structural layout should be designed to promote smooth traffic and assist the asset life cycle activities.                                                                                     |
|                             | 3        | Ease of activities                       | The site and structural layout should be designed so that the asset life cycle activities can be optimized and facilitated.                                                                                |
| Access for maintenance      | 1        | Permanent safety features                | Safety features can be designed as a permanent component to facilitate the maintenance activities such as air-conditioner ledge and roof system.                                                       |
|                             | 2        | Provision of access                      | The access for maintenance works should be safe enough to prevent accidents.                                                                                                                              |
|                             | 3        | Fall arrest/protection                   | Fall protection can be designed as a part of building feature or permanent components to facilitate the maintenance works.                                                                                 |
5. Conclusion
Growing at a rapid pace, Malaysia's construction industry continues to contribute to the country's economy. Due to the nature of the complex activities involved in the construction industry, this industry is regarded as among the dangerous in terms of its risks and needs for occupational safety and health. The Guideline of Occupational Safety and Health in Construction Industry (Management) has been issued by DOSH to decrease the risks involved in the construction industry. The approach of the guideline is to mitigate design risks involved during the conceptual, design and pre-construction stages to ensure that only residual risks exist during the life cycle of the building or structure. The guideline has highlighted several design considerations. However, more specific design considerations should also be taken from the perspectives of the practitioners (such as designers and contractors). In order to start with the risk analysis for the respective design considerations, this study has reported the key design criteria. Nevertheless, the risk analysis should not stop at the key design criteria only, as the practitioners should also include other design risks that will potentially be foreseeable along the life cycle of the building or structure. In this way, it is believed that accidents in the construction site can be prevented, or if not, then at least minimized. This will promote safety and security priority, and will benefit the practitioners directly, and the community indirectly.

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