Themes and Factors of Construction Safety Management for System Dynamic Model Interactions: A Systematic Review

Nur Azalini Jasni¹, Rumaizah Mohd Nordin¹, Zulhabri Ismail¹ and Nurul Ayuni Abdul Aziz¹.
¹Centre of Studies of Post Graduate, Faculty of Architecture, Planning and Surveying, Universiti Teknologi MARA (UiTM), Shah Alam, 40450 Selangor, Malaysia

Email: drumaizah@uitm.edu.my

Abstract. The construction industry has always been regarded as a dangerous industry to work in, and the Malaysian construction industry is not exempted. Most safety and health studies conducted in this industry only view the overall factors contributing to the accidents or focus only on the main factor such as human behaviour. However, accidents actually happen based on the interaction between all the factors of the accidents at a construction site, and thus this study is conducted to identify the factors contributing to the accidents happening at construction sites and to classify them into their themes by using a systematic review method. This method is used to gather the empirical evidence regarding construction safety management by assessing academic journals mostly searched using keywords ‘construction safety management’, ‘themes of accidents’, ‘factors of accidents’ and ‘System Dynamic’ on academic journal databases known as ‘Google Scholar’, ‘Science Direct’ and ‘Academia’. The findings of this study identified 18 factors that contribute to the accidents and are classified into four (4) main themes which are human factors, management factors, technical factors and also environmental factors. The themes and factors identified in this study would contribute to develop a construction safety management system using System Dynamic model that will show the complex interactions between all the factors according to their themes.

1. Introduction
The construction industry in Malaysia noted a high number of total accidents with 95 cases reported by June in 2018 alone, and 52 of the cases that ended in casualties [1]. As a complex industry involving many personnel for each project where [2] stated to be inclusive of clients or employers of the project, professionals, contractors, sub-contractors, producers and suppliers, providers and installers, and many other parties or organisations which are relevant in the industry, it is bound to cause several problems, and the main concentration of the industry measures the success rate of a project according to cost, time and quality has led to low regards in safety [3].

Therefore, the government of Malaysia introduced several acts such as Occupational Safety and Health Acts (OSHA), 1994 that implements regulations on safety as well as health aspects [4] and Construction Industry Development Board (CIDB) which was developed to focus on the construction industry quality and health in order to achieve the global competitiveness level [5]. However, to this day, hardly any system developed has been able to handle and reduce the number of accidents reported from all the industries in this country [6].

With that information, many researchers conducted studies regarding the safety in the construction industry to come out with the factors that contribute to the accidents that happen, but many end up focusing on the behaviour of the workers as it is the main factor causing most of the accidents with the highest percentage [7]. As there are not many researches done on the connection of all the factors causing the accidents [8], it is important for this research to be conducted to identify the relations of the factors in order to introduce the best corrective actions to reduce the number of accidents at construction sites.
Hence, System Dynamic (SD) model has been identified as one of the best model to study and understand for a complex system by showing the interrelation between all of its variables [9], is chosen to be developed. To properly come out with the variables for the model, a comprehensive review of previous researches done on the factors of accidents and classification of factors into their themes need to be systematically done using the systematic review methodology.

2. Background
The focus on cost, time and quality as the main driving keys to determine the success rate of a project in the construction industry, especially in Malaysia, has been the reason that the safety and health aspects have been neglected and seen as a taboo subject in the industry [3], the root cause of the accidents that happened need to be identified in order for the effective remedial measures can be applied to prevent such accidents from happening in the future.

Supporting the statement, several theories created by some of the theorists and researchers known as Accidents Causation Model (ACM) explained that every accident happened due to a cause. Heinrich (1959) comes out with the first phase of ACM with the “Domino Theory” which stated that there are five (5) sequential factors that affect any management, creating a domino effect starting with the ancestry or physical environment, followed by fault of a person (carefulness), unsafe act or mechanical or physical condition, which will then cause accidents and lastly, will result in injury [10]. Updating the theory, Reason (2000) comes out with the “Swiss Cheese” model [11], and the latest update on ACM which is the Functional Resonance Accident Model or FRAM by Hollnagel in 2005 explained the several components causing accidents followed by the information have to be identified to prevent accidents in the future [12].

Looking at the construction industry scene, the factors of the accidents studied have identified many factors causing accidents at construction worksites which were categorised by [13] into two groups which are immediate factors and contributing factors with a total of 11 factors extracted. Meanwhile, [14] categorised the factors into unsafe equipment, job site condition, unique nature of the industry, unsafe method, human element, and also management. As there are many factors that can be categorised into different themes, a systematic review is deemed necessary to be conducted. Hence, identifying the factors and themes to further study the interaction between each and every one of the factors is the main focus of this study.

3. Methodology
To properly come out with enough variables to create a System Dynamic (SD) model, systematic review has been adopted in this study where it is a methodological approach to identify, select and appraise literatures agreed to a certain level of quality which are relevant to this study’s questions [15].

To start with the review, questions from the objectives of this study are generated, where two questions are identified as follows:
1. What are the factors that cause accidents at a construction site?
2. What are the themes that categorise all the identified factors causing accidents at a construction site?

From the questions, the keywords for the review are identified, which are ‘safety management’, ‘themes of accidents’, ‘factors of accidents’ and also ‘System Dynamic’ to search for academic journals. Following the keywords generated, the second step includes searching for data via vast databases which are ‘Google Scholar’, ‘Science Direct’ and ‘Academia’ where academic journals that fall under the keywords identified are selected.

The outcome of searching for journals in the databases resulted in a total of 49 journals that consist of researches that mention the factors of accidents at construction sites. From the 49 journals, seven (7) journals are selected which discussed the different factors that contributed to the accidents. The data from the journals selected were then extracted and synthesised as discussed in the Finding. All the steps mentioned will lead to creating the variables to be used to create a System Dynamic model in future research. The steps adapted to create the review for this research is put together into Figure 1 as shown below:
4. Finding
Based on the systematic review conducted, seven (7) journals are thoroughly analysed and 18 factors of accidents are identified which are lack of training, unsafe method of handling materials/equipment/operations, fatigue by workers due to overwork, lack of compliance to safety regulation, unsafe behaviour, poor safety awareness among workers/managers, lack of experienced project managers/skilled workers, lack of concern for safety by management, lack of personal protective equipment, defective/poor/unsafe equipment, unsafe condition of workplace, insufficient/lack of housekeeping program, poor site management, poor quality control system, poor illumination, excessive noise, pressure between contractors, procurement & contract problem, nature of the industry and lastly, unforeseen circumstances.

The factors collected from the journals were put into tables and sorted according to the frequencies of each factors mentioned are counted and noted in Table 1 below:
Table 1. Frequencies of the factors mentioned.

| Factors                                           | Frequencies |
|---------------------------------------------------|-------------|
| Unsafe behaviour                                  | 6           |
| Defective /poor/unsafe equipment                  | 5           |
| Unsafe condition of workplace                     | 5           |
| Lack of personal protective equipment             | 4           |
| Unsafe method of handling materials/equipment/operations | 4       |
| Lack of concern for safety by management          | 4           |
| Lack of compliance to safety regulation           | 4           |
| Lack of training                                  | 3           |
| Poor site management                              | 3           |
| Poor safety awareness among workers/managers      | 2           |
| Insufficient/lack/housekeeping program            | 2           |
| Excessive noise                                   | 2           |
| Procurement & contract problem                    | 2           |
| Nature of the industry                            | 2           |
| Lack of experienced project managers/skilled workers | 1      |
| Fatigue by workers due to overwork                | 1           |
| Poor illumination                                 | 1           |
| Unforeseen circumstances                          | 1           |

The factors identified and sorted in Table 1 are then grouped according to their themes, which according to [17], there are four (4) identified themes which are human factors, management factors, technical factors and also environmental factors.

**Human Factors**
Defined as when human actions or behaviours related to the physical, experience, attitude and also the behaviour of the human themselves that contribute to the accidents [17].

**Management Factors**
Under this theme, the factors that include management policy, resource management, the management culture and also the safety aspects of the management handled on the site contributing to the accidents are grouped together [17].

**Technical Factors**
Described as the technical factor or also known as worksite factor involving the jobsite, poor site management, equipment and materials condition and also the tasks during the construction causing the accidents [17].

**Environmental Factors**
Known as the distant causes that relate to the politics and legislations issues on the construction sites that regards the economic perspective of when the services, materials and also the labour supplies are what causing the accidents [17].

In Figure 1 below, the factors identified from the journals are properly grouped into their themes according to the definition and description by [17]. The figure is known as the Subsystem Model that
will be used as variables to develop a System Dynamic (SD) model where the interactions between the factors will be related in a loop.

![Figure 2. The Subsystem Model with the Themes for the Factors of Accidents](image)

### Factors of Accidents under the Themes

**Human**
- Lack of training
- Unsafe method of handling materials/equipment/operations
- Fatigue by workers due to overwork
- Lack of compliance to safety regulation
- Unsafe behaviour

**Technical**
- Lack of personal protective equipment
- Defective/poor/unsafe equipment
- Unsafe condition of workplace
- Insufficient/lack/housekeeping program
- Poor site management
- Poor quality control system
- Poor illumination
- Excessive noise

**Management**
- Poor safety awareness among workers/managers
- Lack of experienced project managers/skilled workers
- Lack of concern for safety by management

**Environmental**
- Pressure between contractors
- Procurement & contract problem
- Nature of the industry
- Unforeseen circumstances

5. Conclusion
Safety management is very important to effectively reduce the number of accidents that happen at a workplace, especially in a complex industry such as the construction industry. By identifying the factors and themes of the accidents that happen, the interaction can be developed in the future as variables in the System Dynamic model.

Based on this study, by using the systematic review method, the findings discovered 18 factors of accidents from the analysis of seven (7) academic journals which are grouped under four (4) themes, known as human factors, management factors, technical factors and lastly environmental factors. The method used in this paper by analysing academic journals on the factors that contribute to the accidents happening at construction sites has enabled the identification of the common factors and grouped accordingly to their themes. The findings from this paper should be able to assist further investigation by providing the ground knowledge on the factors and themes of accidents happening at construction sites.

However, empirical investigation need to be conducted in order to verify the interactions between the factors and themes using the System Dynamic model. The future empirical investigation will assist to understand the interactions between the factors and the themes in order to properly plan the corrective actions to prevent accidents from happening, especially at a dangerous workplace such as a construction site.
Reference

[1] Accidents Statistics by Sector until June 2018 (Investigated) [Internet]. 2018. Available from: http://www.dosh.gov.my/index.php/en/occupational-accident-statistics/by-sector/489-statistics/occupational-accidents-statistics.

[2] Williams O S, Hamid R A and Misnan M S 2017 Analysis of Fatal Building Construction Accidents: Cases and Causes. Analysis. 4(8):8030-40.

[3] Williams O S, Hamid R A and Misnan M S 2018 Accident Causal Factors on the Building Construction Sites: A Review. International Journal of Built Environment and Sustainability. 5(1).

[4] Rampal K G and Nizam J M 2006 Developing regulations for occupational exposures to health hazards in Malaysia. Regulatory Toxicology and Pharmacology. 46(2):131-5.

[5] Construction Industry Development Board (CIDB). Functions Malaysia2018. Available from: http://www.cidb.gov.my/index.php/en/corporate-info/functions.

[6] Asilian-Mahabadi H, Khosravi Y, Hassanzadeh-Rangi N, Hajizadeh E and Behzadan A H 2018 Factors affecting unsafe behavior in construction projects: development and validation of a new questionnaire. International Journal of Occupational Safety and Ergonomics. 1-8.

[7] Choudhry R M 2014 Behavior-based safety on construction sites: A case study. Accident Analysis & Prevention. 70:14-23.

[8] Mohamed S and Chinda T 2011 System dynamics modelling of construction safety culture. Engineering, Construction and Architectural Management. 18(3):266-81.

[9] Shin M, Lee H-S, Park M, Moon M and Han S 2014 A system dynamics approach for modeling construction workers’ safety attitudes and behaviors. Accident Analysis & Prevention. 68:95-105.

[10] Hosseinion S S and Torghabeh Z J 2012 Major theories of construction accident causation models: A literature review. International Journal of Advances in Engineering & Technology. 4(2):53.

[11] Reason J, Hollnagel E and Paries J 2006 Revisiting the Swiss cheese model of accidents. Journal of Clinical Engineering. 27(4):110-5.

[12] Hollnagel E. FRAM: the functional resonance analysis method: modelling complex socio technical systems: CRC Press; 2017.

[13] Fang D, Xie F, Huang X and Li H 2004 Factor analysis-based studies on construction workplace safety management in China. International Journal of Project Management. 22(1):43-9.

[14] Hamid A R A, Majid M Z A and Singh B 2008 Causes of accidents at construction sites. Malaysian journal of civil engineering. 20(2).

[15] Khan K S, Kunz R, Kleijnen J and Antes G 2003 Five steps to conducting a systematic review. Journal of the royal society of medicine. 96(3):118-21.

[16] Pullin A S and Stewart G B 2006 Guidelines for systematic review in conservation and environmental management. Conservation biology. 20(6):1647-56.

[17] Jaafar M H, Ariffin K, Aiyub K, Razman M R, Ishak M I S and Samsurijan M S 2018 Occupational safety and health management in the construction industry: a review. International Journal of Occupational Safety and Ergonomics. 24(4):493-506.