DEVELOPING A GENERIC SAFETY PERFORMANCE EVALUATION PROTOTYPE FOR CONSTRUCTION PROJECTS IN MALAYSIA

ALI ASGHAR BAVAFA

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Universiti Teknologi Malaysia

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This thesis lovingly dedicated to my Mom and Dad .
Their support, encouragement, and constant love
have sustained me throughout my life.

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ABSTRACT

Despite recent efforts that have been made to improve construction safety, this industry yet considered unsafe (hazardous) due to high number of recorded accident. Based on the statistics released by Department of Occupational Safety and Health (DOSH) in Malaysia, between 2009 to 2015 the highest rate of fatality is for construction sector. To avoid accidents in construction projects there is a need to implement proper safety and health program and ensure that safe working practice is in place. Moreover, safety performance must be monitored and evaluated. This research addresses the interactions among safety factors during evaluation process which have not been considered before. Moreover, majority of the measurement techniques disregards the (pivotal) role of parties such as owner, designer and subcontractors who have consequential affecting the construction safety and health. This research aims to develops a Generic Safety Performance Evaluation Prototype (GSPEP) for construction projects in Malaysia. The first objective is to identify and verify, the significant safety performance factors and sub-factors that affect the construction projects in Malaysia. The second objective is to obtain the interactions between safety performance factors through Decision Making Trial and Evaluation Laboratory (DEMATEL) method while the decision model is developed. The results indicate that "Safety Commitment" is the most influential safety factor while, "Management Implementations" has the highest total effect rate. In the third objective, the Analytic Network Process (ANP) is employed to derive weightage of factors and sub factors of new safety framework. The GSPEP is developed in objective 4, which comprises 11 factors, 53 sub factors and 125 indicators that carry weightage according to their effectiveness in preventing of the occurring of construction accidents. The score of a project safety would be calculated according to evaluation of indicators in complying to safety standards. As the last objective, the GSPEP is then implemented in real case studies and evaluated through the judgments of two groups of construction safety experts and academic researchers to determine its applicability and validity level in evaluating safety and health performance of construction projects in Malaysia. The experts in both groups recognized the performance and effectiveness of the GSPEP as a new method for safety evaluation. The GSPEP evaluate the safety level of a construction project and its weaknesses within the construction organization. The GSPEP also be able to facilitate the awareness in improving safety culture on construction projects, since it involves the cooperation of all personnel from top management to ordinary workers. This research on GSPEP is a comprehensive decision maker that can be employed as a new system to benchmark the safety and health performance level of construction companies in Malaysia.

ABSTRAK

Disamping usaha terkini yang telah dibuat bagi meningkatkan keselamatan pembinaan, industri ini masih lagi lagi dianggap tidak selamat (berbahaya) kerana ketinggian bilangan kemalangan yang telah direkodkan. Berdasarkan statistik yang dikeluarkan oleh Jabatan Keselamatan dan Kesihatan Pekerjaan (DOSH) di Malaysia, di antara 2009-2015, kadar tertinggi kematian adalah untuk sektor pembinaan. Untuk mengelakkan kemalangan dalam projek-projek pembinaan, perlaksanaan program keselamatan dan kesihatan yang baik dan pemastikan amalan kerja yang selamat adalah sangat perlu. Selain itu, prestasi keselamatan juga perlu dipantau dan dinilai secara berterusan. Kajian ini mengambil kira interaksi di antara faktor-faktor keselamatan semasa proses penilaian keselamatan yang tidak pernah dipertimbangkan sebelum ini. Selain itu, sebahagian besar teknik pengukuran keselamatan sedia ada tidak mengambil kira peranan pihak pemilik, pereka dan sub-kajian ini bertujuan untuk membangunkan Prototaip Penilaian Keselamatan Am Prestasi (GSPEP) untuk menilai keselamatan projek pembinaan di Malaysia. Objektif pertama kajian adalah untuk mengenal pasti dan mengesahkan faktor-faktor utama dan sub-faktor prestasi keselamatan yang memberi kesan kepada keselamatan projek pembinaan di Malaysia. Objektif kedua adalah untuk mendapatkan interaksi antara faktor prestasi keselamatan melalui Kaedah Penilaian Makmal Pembinaan Percubaan dan Keputusan (DEMATEL). Keputusannya menunjukkan bahawa komitmen keselamatan adalah faktor semasa yang paling berpengaruh, sementara perlaksanaan pengurusan adalah faktur yang mempunyai kadar kesan tertinggi terhadap keselamatan. Pada objektif ketiga, Proses Analitik Rangkaian (ANP) diambil kerja untuk memperolehi wajaran faktor dan sub faktor rangka kerja keselamatan yang baru. Prototaip GSPEP dibangunkan dalam objektif 4, yang terdiri daripada 11 faktor, 53 faktor sub dan 125 petunjuk yang membawa wajaran mengikut keberkesanannya dalam mencegah daripada berlaku kemalangan pembinaan. Status keselamatan projek dikira mengikut penilaian petunjuk dalam mematuhi piawaian keselamatan. Pada objektif terakhir, GSPEP ini dilaksanakan di kajian kes sebenar dan dinilai melalui timbangtara dua kumpulan pakar keselamatan pembinaan dan penyelidik akademik untuk menentukan tahap kebolehgunaan dan kesahihannya dalam menilai prestasi keselamatan dan kesihatan projek pembinaan di Malaysia. Kedua-dua kumpulan penilai ini mengiktiraf prestasi dan keberkesanan GSPEP sebagai kaedah baru untuk penilaian keselamatan. GSPEP berupaya menilai tahap keselamatan projek pembinaan dan kelemahan dalam perlaksanaan keselamatan organisasi pembinaan. GSPEP juga memberi kesedaran dalam meningkatkan budaya keselamatan dalam projek pembinaan, kerana ia melibatkan kerjasama semua pihak pengurusan atasan sehingga ke peringkat pekerja biasa. Dalam kajian ini, GSPEP telah berupaya membuat keputusan keselamatan yang komprehensif dan ia adalah satu sistem baru kepada penanda aras tahap prestasi keselamatan dan kesihatan syarikat pembinaan di Malaysia.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

AHP	-	Analytic Hierarchy Process
ANP	-	Analytic Network Process
BBS	-	Behavioural Based Safety
BS	-	British Standard
CIDB	-	Construction Industry Development Board
DEMATEL	-	Decision Making Trial and Evaluation Laboratory
DOSH	-	Department of Safety and Health
DSS	-	Decision Support System
HIRARC	-	Hazard Identification, Risk assessment and Risk Control
MCDM	-	Multiple Criteria Decision Methods
OHSAS	-	Occupational Health and Safety Assessment Series
OSHA	-	Occupational Safety and Health Act
OSHA	-	Occupational Safety and Health Administration
PASS	-	Performance Assessment Scoring System
PDSS	-	Pay for Safety Schemes
PHA	-	Preliminary Hazard Analysis
PPE	-	Personal Protective Equipment
ST	-	Safety Training
UK	-	United Kingdom
CEO	-	Chief Executive Officer
CIMP	-	Construction Industry Master Plan
SHASSIC	-	Safety and Health Assessment System in Construction
GSPEP	-	Generic Safety Performance Evaluation Prototype
SHO	-	Safety and Health Officer
SSS	-	Site Safety Supervisor
FMA	-	Factories and Machinery Act
BOWEC	-	Building Operation of Work Engineering and Construction
CIS	-	Construction Industry Standard

OHSMS	-	Occupational Health and Safety Management System
ILO	-	International Labour Organisation
SC	-	Score Card
IR	-	Incidence Rate
US	-	United States
SMS	-	Safety Management System
SCSH	-	Sustainable Construction Safety and Health
EMR	-	Experience Modification Rate
WSM	-	Weighted Sum Model
WPM	-	Weighted Product Model
IRM	-	Impact Relation Map
CSF	-	Critical Success Factors
FBR	-	Faulty Behaviour Risk
CII	-	Construction Industry Institute
HSE-MS	-	Health, Safety, and Environment Management System

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Research Background

The construction industry in Malaysia is currently being recognized as a major economic deriving force to generates the country development. Various studies have pointed out to the important role of construction industry in the economy of developing countries (Anaman and Osei- Amponsah, 2007). However, despite the rapid advancement of technology in the construction industry, it is accepted that construction industry is one of the most hazardous in comparison to other industries. Researchers in different studies have revealed that fatality rate in construction industry is extremely high (Im *et al*., 2009). A construction site is more dangerous than other places of work according to the UK Health and Safety Executive (HSE), those who spend their working lives on construction sites have a 1 in 300 chance of being killed at work (Wamuziri, 2006).

A research conducted by Murie (2007) revealed that in developing countries proportion of accidents on construction sites are relatively high. Malaysian construction industry also has been identified as one of the most dangerous industries. Apart from global prospective of construction safety, records show only in 2015, the construction sector in Malaysia experienced 88 deaths, which was the highest rate of death in comparison to other industries, 11 permanent disability cases and 138 non-permanent disability cases (DOSH, 2016). The Department of Occupational Safety and Health (DOSH) is a department under the Ministry of Human Resources. This department is responsible for ensuring the safety, health and welfare of people at work as well as protecting other people from the safety and

health hazards arising from the activities sectors which include: Manufacturing Mining, Construction, Agriculture, Transport, Public Services and Utilities. As a government agency, DOSH is responsible for the administration and enforcement of legislations related to occupational safety and health of the country, with a vision of becoming an organization which leads the nation in creating a safe and healthy work culture that contributes towards enhancing the quality of working life.

Safety and health which is one of the essential aspect of the construction industry, has lacked the attention it deserves (Alpmen, 2013). Due to absolute concentration on the time and budget, safety has rarely considered as a first priority in construction projects. While, construction accidents and injuries bring on human tragedies, direct and indirect expenses which is also not appropriate. Direct Expenses include medical costs and workers' compensation insurance, while indirect expenses contain delay progress disruption construction processes, workers motivation diminishing, adverse effects on reputation of the construction companies (Mahmoudi *et al.*, 2014; Wang *et al.*, 2006). A study by Darshi De Saram and Tang (2005) revealed the non-material expenses of accidents, i.e. pain, suffering expenses and loss of life quality, and mentioned that these expenses were almost 30% of direct accident expenses. With the increasing costs of accidents, professionals have realized that even one incident might bankrupt the company due to the lawsuits and claims against the owner (Alpmen, 2013). Most importantly, it has been also made clear that no project is worth losing a human life.

The other aspect that has been recognized by the professionals is that the projects that are driven by safety are expected to stay on budget and be completed on time (Cooper, 2000). Nonetheless, the importance of construction safety has been realized in the last few decades and it has improved. Researchers strongly emphasize the idea that safety is not a luxury anymore and must be considered as a necessity. Every individual in life whether one is employed or not, both at the workplace and outside the workplace has the intrinsic need to be safe. Correspondingly, for evaluation of a construction projects success, the safety has become a new index beside the triangulation of cost, time and quality (Ngacho and Das, 2014; Alzahrani

and Emsley, 2013). Figure 1.1 demonstrates the construction safety researches published between 1996 and 2015 (Web of Science, 2015).

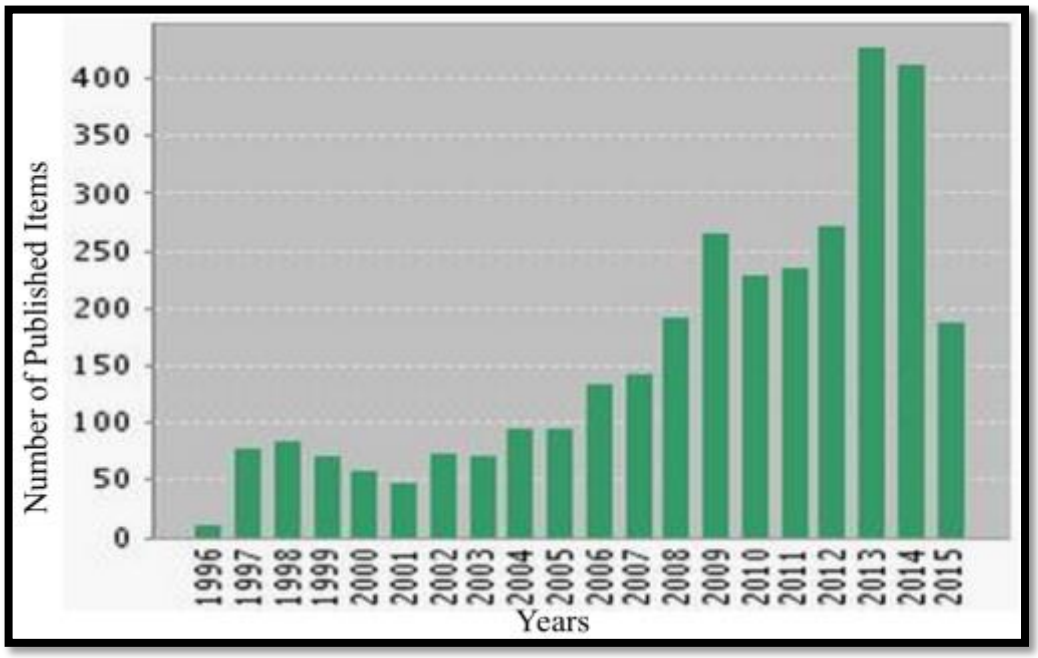

Figure 1.1: Researchers Publications in Construction Safety Through Years (Web of Science, 2015)

The major causes of construction accidents are related to the unique nature of the industry. Unique characteristics, distinguish the construction industry from other industries and contribute to a high accident rate construction sites (Fredericks et al., 2005). Characteristics such as dynamic work environments, extensive use of sophisticated plants, heavy equipment and multiplicity of operations turned construction sites to a hazardous place. A study by Jannadi and Bu-Khamsin (2002) mentioned that the major causes of construction accidents are unique nature of industry, various workplace conditions, inappropriate safety management and human behavior, which bring up unsafe work procedures and equipment.

With the continuous pressures for speed, productivity and competitiveness, the challenge for construction researchers and practitioners is to develop work systems that are simultaneously highly productive and reliable. Systems that function safely and effectively in construction projects that are dynamic, complex and competitive conditions (Mitropoulos *et al.*, 2009). Therefore, preventing occupational injuries and illness should be a primary concern and responsibilities of

all parties including owner, designer contractor/subcontractors in construction projects. As various studies have pointed out to the important role of construction industry in economy of developing countries (Anaman and Osei-Amponsah, 2007), subsequently the necessity of safety becomes more noticeable and preparations must be made to enhance the safety in construction projects.

In Malaysian construction industry, the safety and health regulated by three main acts: Occupational Safety and Health Act 1994 (Act 514) (OSHA), Factories & Machineries Act 1967 (Act 139) (FAMA) and Construction Industry Development Act of 1994 (Act520) (CIDB) (Marhani *et al.*, 2013). OSHA is an Act to make provisions for securing the safety, health and welfare of person at work. The long-term goal of the Act is to create a healthy and safe working culture among all Malaysian employees and employers (Bakri *et al.*, 2006). With the purpose of gearing up the Malaysian construction industry towards globalization and competitiveness, the government had launched the Construction Industry Master Plan 2006 to 2015 (CIMP) initiated by the Construction Industry Development Board (CIDB) Malaysia. The CIMP contains seven strategic thrusts and the third, is emphasizes on striving for the highest standard of quality, occupational safety and health, and environmental practices. Following that, in November 2008, CIDB with the assistance of a technical committee on safety and health in construction has developed a Safety and Health Assessment System in Construction (SHASSIC). It is an independent system that tries to assess and evaluates the safety and health performance of construction contractors in Malaysia. SHASSIC was also published as Construction Industry Standard (CIS 10, 2008).

Evaluation of safety performance is a fundamental segment of any safety program. It assists to avoid or reduce to a minimum of the possibility and loss through an accident by providing information about the system's quality in terms of development, implementation and results (Sgourou *et al.*, 2010). The literature revealed that construction safety in Malaysia lacks an extensive evaluation system. Hence, a comprehensive method is essential to cover all proactive and reactive factors, which affect worker's safety and health throughout the project lifecycle. Moreover, not only the role of contractor but also influence of parties such as owner,

designer and subcontractors who have consequential control on construction safety and health should be pondered (Rajendran and Gambatese, 2009). While, one the main limitations of SHASSIC method is the disregarding the roles of owner, designer and subcontractors in safety performance measurement.

1.2 Problem Statement

The creation of the sustainable development is one of the main priorities of Malaysian construction industry (Ramli *et al.*, 2014). In the following, this the question up that: "Is a project sustainable, while a death or injury happens during the construction?". To reach a sustainable development in construction industry, the safety and health of workers must be significantly involved during the construction (Rajendran and Gambatese, 2009).

Even though injury rates have declined dramatically since the introduction of OSHA 1994 in Malaysia, but safety performance in the Malaysian construction industry has lagged behind most other industries, as is evidenced by its disproportional high rate of accidents. Based on the DOSH, as shown in Figure 1.2, from 2009 through 2015 the highest rate of fatality was belonged to construction industry sector. The statistics also showed that although construction sector accounted for only 5% of occupational accidents, most of them have ended as fatality.

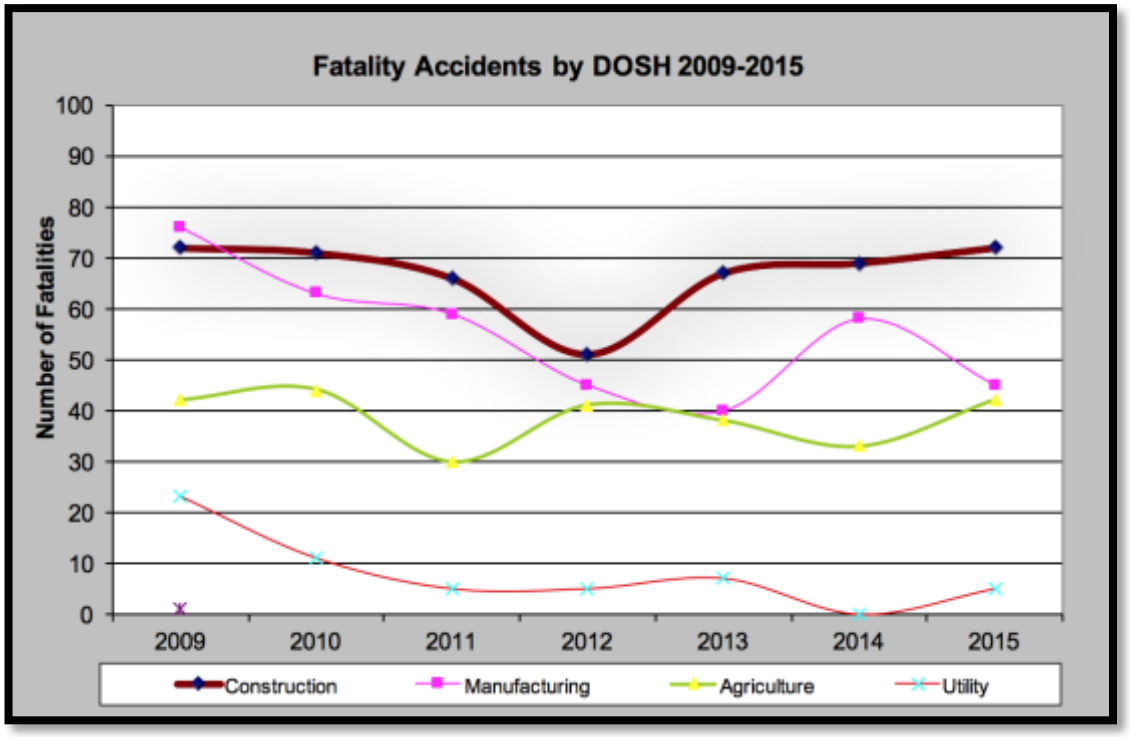

Figure 1.2: Construction Fatality Accidents Rate in Malaysia From 2009 to 2015 (DOSH, 2015)

In last decade, many efforts have been done to enhance safety culture in Malaysian construction industry as Kamar *et al.* (2014) in his study revealed that most of the class A contractors are aware of occupational safety and health management. It is a necessity to achieve zero rate of accident at construction sites. Implementation of OHSAS 18001 which defined as Occupation Health and Safety Assessment Series for health and safety management systems is one of the efforts, while it is not a legal requirement (Marhani *et al.*, 2013). Considering attempts have been made to improve safety, still results are far from satisfactory as construction accidents continue to dominate. Hence, adequate monitoring and control of construction hazards is essential to decrease the level of risks and enhance employees' safety.

As measuring performance assist management to provide feedback and implement continuous improvement strategies, the roles of safety performance factors become vital (Webster and Hung, 1994). While the basic issue attributed is to study those factors and find out which affects performance level and by how much. The traditional approach to evaluate safety performance is through measurement and

statistical analysis of incident-related data (such as number of injuries and ill-health, accident frequency and severity rates and accident costs), which are often referred to as retrospective or lagging indicators (Sgourou *et al.*, 2010). To achieve a world-class performance, leading or proactive indicators of safety management must be realized for safety evaluation phase (Hallowell *et al.*, 2013) while lagging indicators shall be adopted as a complementary measures (Jafri *et al.*, 2005). Proactive indicators such as management involvement, safety training and hazard identifications are metrics to identify and control the potential hazards before they result in injuries at construction sites.

SHASSIC is the main method to assess and evaluates the safety and health performance of construction contractors in Malaysia. Disregarding some critical safety performance factors is one of the tangible weaknesses of SHASSIC method. Factors such as Employee Involvement, Pre-task Planning, Substance Abuse Programs and Choosing Competent Sub-contractors are not available in SHASSIC. Moreover, the weightage of all of safety performance factors in SHASSIC method are equal to one, which it means the level of importance and effectiveness of each factor is undetermined.

It is the responsibility of the contractors to ensure proper implementation and to follow the safety standards, legislations requirement and guidelines in construction projects (Toole, 2002). However, it is also necessary to consider the impact of owner, designer and subcontractors on construction workers safety and health to have a sustainable safety performance measurement system (Rajendran and Gambatese, 2009). Various studies revealed that involvement of client could positively influence the safety performance through choosing safe contractors, allocating safety budget and managing safety in different phases of construction (Huang and Hinze, 2006; Ilias *et al.*) . Moreover, it was concluded that 42% of the construction fatalities and 22% of the injuries are related to decisions made during the design (Hallowell *et al.*, 2013). For instance, safety can be considered during the design of the permanent facility and it can be integrated into the constructability reviews (Yi and Langford, 2006; Gambatese *et al.*, 2005). While, the literature also suggests that the impact of main parties involved on safety and health performance evaluation of construction

project has almost ignored in Malaysia. This study can also narrow that gap with considering influences of all parties involved on worker's safety and health in construction progress.

Additionally, it is widely recognized that the empirical validation of how the key enablers are inter-related within a safety performance-based model is limited in previous literature (Feng *et al.*, 2014). As Hallowell and Gambatese (2009) and Li and Li (2009) mentioned that, interaction between safety program factors have not been investigated specifically and suggested this issue as future research.

Moreover, Tuan Omar Mat director of Johor Department of Occupational Safety and Health (DOSH) believed that Fatal accidents at construction sites is a major concern. He mentioned that conducting regular safety evaluation at sites by related department is necessary to ensure contractors and construction companies are following occupational safety rules and regulations. Subsequently, sites that are identified to be unsafe could be presented with a stop-work order until the issue is resolved whilst the company involved could be given a fine or be charged in court

This study seeks to bridge the gap in the existing body of knowledge regarding study the current safety measurement models and propose a generic safety performance evaluation prototype (GSPEP) for construction projects in Malaysia. The interactive effects between main safety performance factors were applied during the development of the GSPEP. With the aid of GSPEP, not only safety performance of contractors but also the safety commitment level of main parties including owner, subcontractors and designer can be assessed. This would allow a strategic move towards a high and continuously safety performance improvement as emphasized in Construction Industry Master Plan (CIMP).

1.3 Research Aim and Objectives

This research has categorized the construction safety performance factors and sub factors in Malaysia. The interactions and relationships between safety

performance factors were explored to determine accurate weight of each factor for better estimation of project safety performance. Therefore, the aim of the research is to propose a generic prototype to evaluate safety performance of construction projects in Malaysia. This will be realized through the following objectives:

- To identify the significant safety performance factors and sub-factors which affect construction projects in Malaysia
- To investigate and determine the interactions between safety performance factors
- To analyze weightage and priorities of safety performance factors and sub-factors by considering interactions between factors
- To develop a generic safety performance evaluation prototype (GSPEP) for construction projects in Malaysia
- To validate proposed generic safety performance evaluation prototype (GSPEP)

1.4 Significance of Study

Despite the availability of safety legislation and regulative institutions, improving occupational health and safety in the Malaysian construction industry is not an easy task (Ismail *et al.*, 2012). Although interest in safety awareness among construction companies has greatly increased in the past decade but still the accident records are high. It was the construction accidents that were costly in both financial and human terms. The ever increasing cost of medical treatment and the potential for lawsuits can lead to higher insurance premiums, and thus have a negative impact on a company's profit (Wilson and Koehn, 2000).

To avoid accidents in construction projects there is a need to implement proper safety and health program. The research is answering the question of "Is the safety and health program implementing successfully or not?". To ensure that safe working practice is being observed, after identification of safety and health hazards, assessment with certain actions must be taken to eliminate or decrease the probability of happening accident (Ahmad, 2000).

Commitment of all parties in a construction project is another vital aspect to run a successful safety and health program. Previous studies revealed that it is feasible by involving owner, designer and subcontractor in measuring safety performance (Rajendran, 2006). For instance, role of owner in choosing competent contractor who consider safety as a priority is absolutely critical (Huang and Hinze, 2006). Also, safety needs to be looked at and treated with the same kind of thoughtful project planning that goes into other project aspects. At the commencement stage of project, design and construction, professionals should be aware of related safety and health hazards while try to eliminate them in advance (Rajendran and Gambatese, 2009).

The core intention of this research is to propose a prototype to evaluate safety performance of construction projects in Malaysia. It will help to achieve one of CIMP objectives, which is strengthening occupational safety and health activities within the industry to reach a sustainable construction. It also will facilitate to increase awareness and identifying areas of deficiencies in construction safety.

1.5 Scope of Study

This research focused on only the safety and health performance of construction projects in Malaysia and performed after a careful study of relevance safety performance evaluation systems applied in construction industry.

This research focuses only on G7 construction companies and civil/building construction projects. The selected construction companies in Malaysia were Class A

contractors, with current project of RM20 million or above. Study carried out from 2013 to 2016 and data collection conducted when the actual physical work progress on construction projects had achieved or falls within 25% to 75%.

This research was carried out among academic professionals in construction management area, industrial safety officers/ supervisors and safety managers hired in construction sites, Construction Industry Development Board (CIDB) and Department of Occupational Safety and Health (DOSH) in Malaysia. This research focuses only on building/civil construction projects.

1.6 Research Questions

This research is the answer to the following questions:

1. How does the evaluation of safety performance being implemented for construction projects in Malaysian?

2. What are the safety performance factors and sub-factors for construction projects in Malaysia?

3. What are the interactions and relationships between major safety performance factors?

4. How much is the weightage and effectiveness of each safety performance sub-factor?

5. How to develop a prototype for evaluating the safety and health performance for construction projects in Malaysia?

6. How well the developed prototype is applicable in evaluation safety performance of Malaysian construction projects?

1.7 Structure of Thesis

This thesis included of eight chapters and the following is a brief explanation for each chapter. A framework regarding objectives and research methodologies is shown in Figure 1.3.

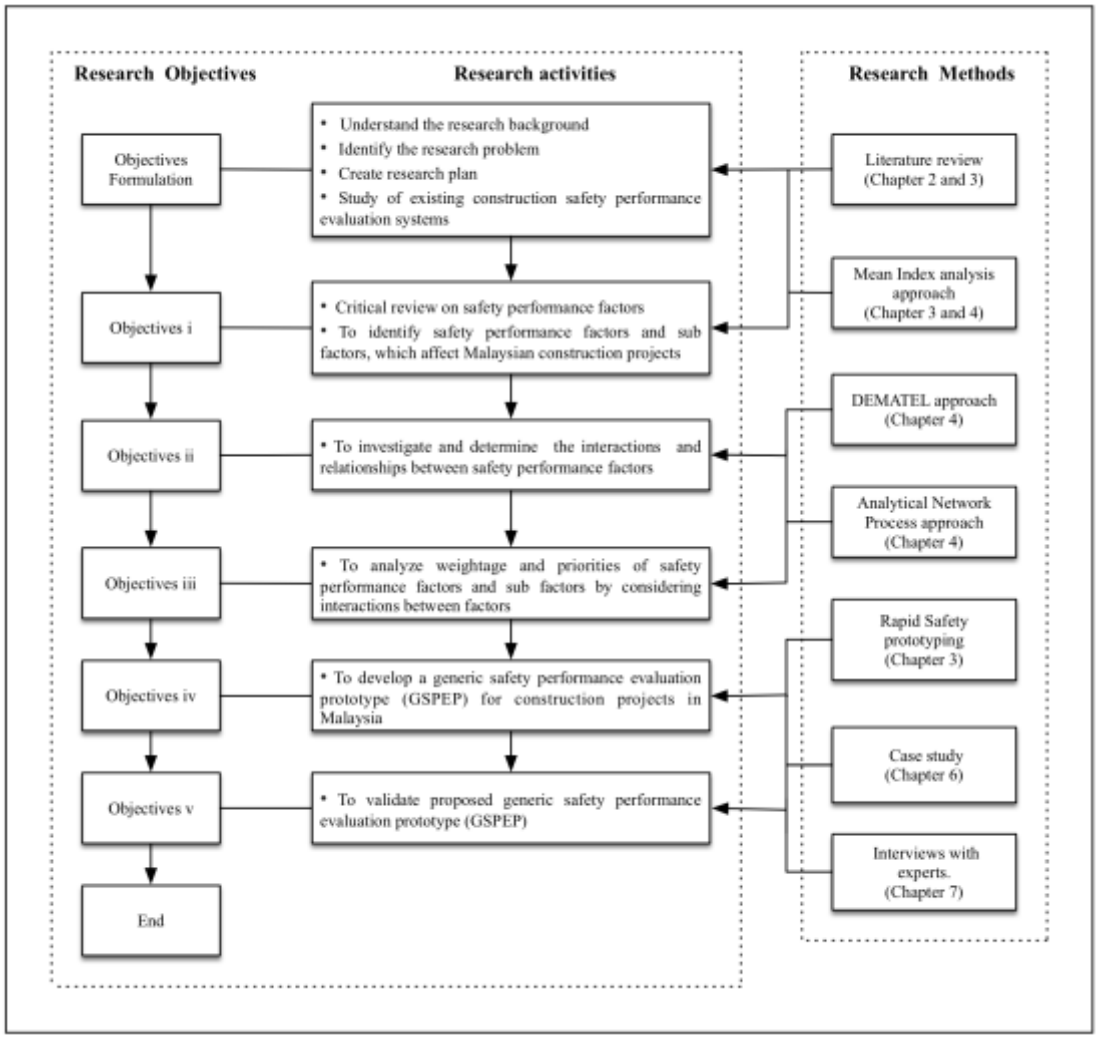

Figure 1.3: Research Objectives and Methodologies

Chapter 1 Introduction: This chapter presents a research background and states the problem of research. It also includes the aim and objectives of the research, significance of study, scope of study, research methodology, research questions and a brief summary of thesis structure.

Chapter 2 Literature Review: This chapter starts with presenting different accident causation models. It also discusses the importance of workplace safety and the causes of construction accident. In the following, this chapter looks into safety and health in Malaysian construction industry and provides a critical review of current construction safety performance evaluation methods. Lastly, this chapter discusses the theoretical development of research.

Chapter 3 Safety Performance Factors: This chapter provides an extensive literature review to extract the construction safety factors and sub factors for development of generic safety performance evaluation prototype.

Chapter 4 Research Methodology: This chapter present the methodologies applied in the study according to the objectives. It also looks into research instruments, sampling method, reliability and validity tests. In the following, this chapter discusses the process of data collection and data analysis techniques (i.e. Mean Index Analysis, Decision-Making Trial and Evaluation Laboratory and Analytical Network Process). In addition, the rapid prototyping method for GSPEP development and process of GSPEP evaluation was explained. Lastly, a research framework was demonstrated to highlight the steps to be taken in order to achieve the research aim and objectives.

Chapter 5 Data analysis and discussions: This chapter discusses the different sections of the data collection and analysis process. It includes three sections i.e. section A: Determination of safety performance factors and sub-factors, Section B: Development of decision model and investigate interactions between safety performance factors and Section C: Analysis of weightage and priorities of the safety performance factor and sub factors.

Chapter 6 Development and implementation of GSPEP: This chapter describes in detail the steps of GSPEP development through rapid prototyping method. It also discusses the implementation of GSPEP in real cases and demonstrates the results analyzed by the prototype for the case study.

Chapter 7 Evaluation of GSPEP: This chapter presents the process of GSPEP evaluation. It also discusses the analysis of evaluation results according to the questionnaires answered by the experts. Lastly, the limitation and benefits of GSPEP are discussed.

Chapter 8 Conclusion and Recommendations: This chapter provides the summary and conclusion of this thesis. It also indicates the extent to which objectives of study have been achieved. Lastly, it discusses research findings and provides recommendations for future research.

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