UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT AND VALIDATION OF CONSTRUCTION OCCUPATIONAL SAFETY AND HEALTH RISK ASSESSMENT MATRIX FOR CONSTRUCTION INDUSTRY IN MALAYSIA

MOKHTAR ZAMIMI BIN RANJAN

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By

MOKHTAR ZAMIMI BIN RANJAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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The construction industry has a high-risk working environment in the context of occupational safety and health (OSH). The OSH risk assessment is the first and critical step towards supporting the decision-making process in the OSH plan to reduce occupational accident. Most of the conventional risk assessment methods, particularly common RAM, cannot produce an accurate result, which may increase the risk. This research aims to establish and validate the construction occupational safety and health risk assessment matrix (COSHRAM). The COSHRAM is developed based on the likelihood of an occupational construction accident (L), the consequences of an occupational construction accident (C) and the modifying risk factor of an occupational construction accident (MRF). The magnitude of the risk difference between common RAM and COSHRAM was compared in this study. This study also determined the relationship between the L, C and MRF with the residual risk (RR) value in the COSHRAM analysis. The study then investigates how the L, C and MRF predict the RR value. The study was divided into three phases. In phase one, a field survey was conducted to obtain the MRF of an occupational construction accident. Concurrently, construction accident data for ten years was acquired from the Department of Occupational Safety and Health (DOSH). During this phase, all of the data is analyzed using a descriptive method. In the second phase, the development and validation process of COSHRAM was carried out. The Fuzzy Delphi Method (FDM) was used to analyze COSHRAM validation data. Meanwhile, data were analyzed using paired sample t-tests, correlation analysis, and multiple linear regression in the third phase. Data in phases one and three were analyzed using version 25 of SPSS and version 16.3 of Microsoft Excel. The COSHRAM experts' evaluation found that the average threshold value was 0.066, which was below 0.2. The overall percentage of each item evaluated by the panellists was 84%, which is greater than 75%, which indicates a good degree of validity. There were significant differences between the common RAM analysis and COSHRAM analysis results for each participating construction site. The COSHRAM analysis was also found to result in superior accuracy, almost twice the common RAM analysis. Additionally, the analytical results also found that risk value is overestimated when common RAM is used. At the same time, L (r-0.573, p<0.01), C (r-0.800, p<0.01) and MRF (r-0.346, p<0.01) were also positively correlated with RR in the COSHRAM analysis. Furthermore, the regression analysis also indicated a significant RR values prediction by the L, C and MRF (p = 0.001, p < 0.05). The COSHRAM has successfully resolved the unavailable and unreliable data that had been misleading its users by providing clarity in determining the L rating scale. Furthermore, the incorporation of MRF in determining risk magnitude enables organizations to assess the efficacy of risk controls that have been applied. Therefore, the COSHRAM resulted in a better risk magnitude estimation and appears to be a reliable OSH risk assessment tool, particularly in the Malaysian construction industry.

Keywords**:** construction industry, modifying risk factor, occupational safety and health, risk assessment matrix.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PEMBANGUNAN DAN PENGESAHAN MATRIK PENILAIAN RISIKO KESELAMATAN DAN KESIHATAN PEKERJAAN PEMBINAAN UNTUK INDUSTRI PEMBINAAN DI MALAYSIA

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Industri pembinaan mempunyai persekitaran kerja berisiko tinggi dalam konteks keselamatan dan kesihatan pekerjaan (OSH). Penilaian risiko OSH adalah langkah pertama dan kritikal untuk menyokong proses membuat keputusan dalam perancangan OSH untuk mengurangkan kemalangan pekerjaan. Sebilangan besar kaedah penilaian risiko konvensional, terutama RAM biasa, tidak dapat menghasilkan keputusan yang tepat, yang dapat meningkatkan risiko. Penyelidikan ini bertujuan untuk membangunkan dan mengesahkan matriks penilaian risiko keselamatan dan kesihatan pekerjaan pembinaan (COSHRAM). COSHRAM dibangunkan berdasarkan kemungkinan kemalangan pembinaan pekerjaan (L), akibat kemalangan pembinaan pekerjaan (C) dan faktor risiko pengubahsuaian kemalangan pembinaan pekerjaan (MRF). Perbezaan magnitud risiko antara RAM biasa dan COSHRAM dibandingkan dalam kajian ini. Kajian ini juga menentukan hubungan antara L, C dan MRF dengan nilai residual risk (RR) dalam analisis COSHRAM. Kajian kemudian menyiasat bagaimana L, C dan MRF meramalkan nilai RR. Kajian ini dibahagikan kepada tiga fasa. Pada fasa pertama, soal-selidik lapangan dilakukan untuk mendapatkan MRF dari kemalangan pembinaan pekerjaan. Pada masa yang sama, data kemalangan pembinaan selama sepuluh tahun diperoleh dari Jabatan Keselamatan dan Kesihatan Pekerjaan (JKKP). Dalam fasa ini, semua data dianalisis menggunakan kaedah deskriptif. Pada fasa kedua, proses pembangunan dan pengesahan COSHRAM telah dilakukan. Kaedah Fuzzy Delphi (FDM) digunakan untuk menganalisis data pengesahan COSHRAM. Sementara itu, data dianalisis menggunakan ujian-t berpasangan, analisis korelasi, dan regresi linear berganda pada fasa ketiga. Data dalam fasa satu dan tiga dianalisis menggunakan versi 25 SPSS dan versi 16.3 Microsoft Excel. Penilaian pakar COSHRAM mendapati bahawa nilai ambang rata-rata adalah 0.066, iaitu di bawah 0.2. Peratusan keseluruhan setiap item yang dinilai oleh panelis adalah 84%, yang lebih besar daripada 75%, yang menunjukkan tahap kesahan yang baik. Terdapat perbezaan yang signifikan antara analisis RAM biasa dan hasil analisis COSHRAM untuk setiap tapak pembinaan yang mengambil bahagian. Analisis COSHRAM juga didapati menghasilkan ketepatan yang unggul, hampir dua kali analisis RAM biasa. Selain itu, hasil analisis juga mendapati bahawa nilai risiko terlalu tinggi apabila RAM biasa digunakan. Pada saat yang sama, L (r-0,573, p <0,01), C (r-0,800, p <0,01) dan MRF (r-0,346, p <0,01) juga berkorelasi positif dengan RR dalam analisis COSHRAM. Selanjutnya, analisis regresi juga menunjukkan ramalan nilai RR yang signifikan oleh L, C dan MRF (p = 0,001, p <0,05). COSHRAM telah berjaya menyelesaikan data yang tidak tersedia dan tidak boleh dipercayai yang telah mengelirukan penggunanya dengan memberikan kejelasan dalam menentukan skala penilaian L. Tambahan pula, pengintegrasian MRF dalam menentukan magnitud risiko membolehkan organisasi menilai keberkesanan kawalan risiko yang telah diterapkan. Oleh itu, COSHRAM menghasilkan perkiraan magnitud risiko yang lebih baik dan merupakan alat penilaian risiko OSH yang boleh dipercayai, terutama dalam industri pembinaan Malaysia.

Kata kunci: industri pembinaan, faktor risiko diubahsuai, keselamatan dan kesihatan pekerjaan, matrik penilaian risiko

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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LIST OF ABBREVIATIONS

ACFE	Association of Certified Fraud Examiners
ANOVA	Analysis of Variance
AOT	Adequacy of Training
APC	Accident Prevention Cost
CVI	Content Validity Index
CVR	Content Validity Ratio
CIDB	Construction Industry Development Board
DOSH	Department of Occupational Safety and Health
DV	Dependent Variable
ECSS	European Cooperation for Space Standardization
ERC	Effectiveness of Risk Control
FAA	Federal Aviation Administration
FAO	Food and Agriculture Organization
FDM	Fuzzy Delphi Method
FOI	Frequency of OSH Inspection
HaSPA	Health and Safety Professionals Alliance
HSE	Health & Safety Executive
HIRARC	Hazard Identification, Risk Assessment and Risk Control
ICAO	International Civil Aviation Organization
ICV	Itemized-Content Validity
I-CVI	Itemized-Content Validity Index
IIA	The Institute of Internal Auditors – North America
IV	Independent Variable

ILO	International Labour Organization
INSHPO	International Network of Safety and Health Practitioners Organisations
ISO	International Organization for Standardization
MLR	Multiple Linear Regression
MRF	Modifying Risks Factor
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Act
RAM	Risk Assessment Matrix
SIA	Safety Institute of Australia
SPSS	Social Packages for Social Sciences
USDoD	United States Department of Defence
S-CVI	Scale-Content Validity Index
SRA	Society for Risk Analysis
USNRC	United States Nuclear Regulatory Commission
VIF	Variance Inflation Factor

CHAPTER 1

INTRODUCTION

The background of this study is briefly described in this chapter. It also includes information the research problem and the rationale behind it. Besides, the objectives, hypothesis, operational definitions, and conceptual framework are also described in this section.

1.1 Background of study

The terms 'risk' and 'hazard' are commonly used to identify possible perils faced by workers when discussing occupational safety and health (OSH) concerns. Gan (2019) classified OSH hazards into five types: physical, ergonomic, chemical, psychosocial and biological hazards. The hazardous circumstances may affect the individual or the organisation as a whole or separately. Some are identified before any accidents or incidents occur, while others may be hard to identify at an early point of time.

The Occupational Safety and Health Act (OSHA) (1994) stipulates that employers should ascertain the safety and health of employees in all aspects of their work at each workplace. These include barriers to occupational hazards, the provision of information and training to workers, and the provision of resources to implement appropriate risk control measures.

In compliance with the requirements set out in the OSHA (1994), each workplace shall perform a risk assessment to recognise each hazard in each job sequence, the extent of the risk exposure, and the appropriate risk control needed. The risk assessment findings enable the workplace managements or operators to take the necessary measures to protect workers' safety and health. The risk assessment process needs to be well established, objective-oriented, consistent, and articulated accurately to be successful. When an accident occurs, and a risk assessment assumes that an occurrence is impossible, everyone would want to see what has gone wrong. If risks cannot be adequately measured, the risk assessment process itself is the most severe risk (Health & Safety Executive [HSE], 2017; Hubbard & Seiersen, 2016). As a result, the process requires guarantees that it will work under normal circumstances.

On the other hand, the risk assessment process would have more queries to be addressed by the authorities, the perpetrators, the vulnerable parties, or the media (Association of Certified Fraud Examiners [ACFE], 2008). The types of questions asked would almost be the same most of the times. Who was attending? When were those decisions taken? Why didn't it feel like it was working? Did anyone test the predicted results before the process was implemented? What trust had been inspected at the time to ensure that the assumptions were considered correct? This sounds like the same kind of concern about a questionable science model that one might have raised. It is, therefore, vital that the risk assessment is carried out more precisely and vigorously, so that appropriate risk controls can be put in place effectively (Harms-Ringdahl, 2001).

Although the goal of a risk assessment encompasses the prevention of occupational risks, which is the primary aim, it hasn't always been feasible in practice. In a case that risk eradication is not possible, the risks should then be minimised, and the residual risk appropriately managed. At a subsequent point, these residual risks will be re-evaluated as a component of the review programme, and the option of eliminating the risk may be reconsidered in the context of new knowledge (Lele, 2012).

1.1.1 The current practice of an occupational risk assessment tool

There are numerous types of risk assessment tools used in the workplace to assess occupational safety and health (OSH) risks. However, the common risk assessment matrix (RAM) has become the priority of preference for most firms due to its simplicity of use and capacity to produce immediate results (Ahmad, Zin, Othman & Muhamad, 2016; Buchari, Matondang & Sembiring, 2018; Ismail & Rasdi, 2019; Saedi, Thambirajah & Pariatamby, 2014; Supriyadi & Ramdan, 2017). It is also widely used in construction projects throughout the world, including Malaysia (Bakri, Zin, Omar & Kuang, 2008; Purohit, Siddiqui, Nandan & Yadav, 2018; Salim, Romli, Besar & Aminian, 2017).

However, the use of common RAM did not produce the desired outcome, as indicated by the stagnation of occupational accidents, particularly those involving fatalities (Dias, 2009; Rosa, Haddad, & de Carvalho, 2015), which is due to certain limitations that require improvement to overcome each of its shortcomings (Landell, 2016).

1.1.2 Justification on the selection of the construction sector as the study's focus

Statistics on occupational accidents in the United Kingdom, United States, Singapore, and Malaysia for the 2015 to 2017 period are reported in Figure 1.1 to 1.4. The services sector is responsible for most occupational accidents in the United Kingdom, the United States, and Singapore. In Malaysia, however, the manufacturing sector comes out on top in terms of occupational accidents. Nevertheless, a detailed examination of Figures 1.1 to 1.4 reveals that the construction sector remains among significant contributor to the number of occupational accidents in each country involved.

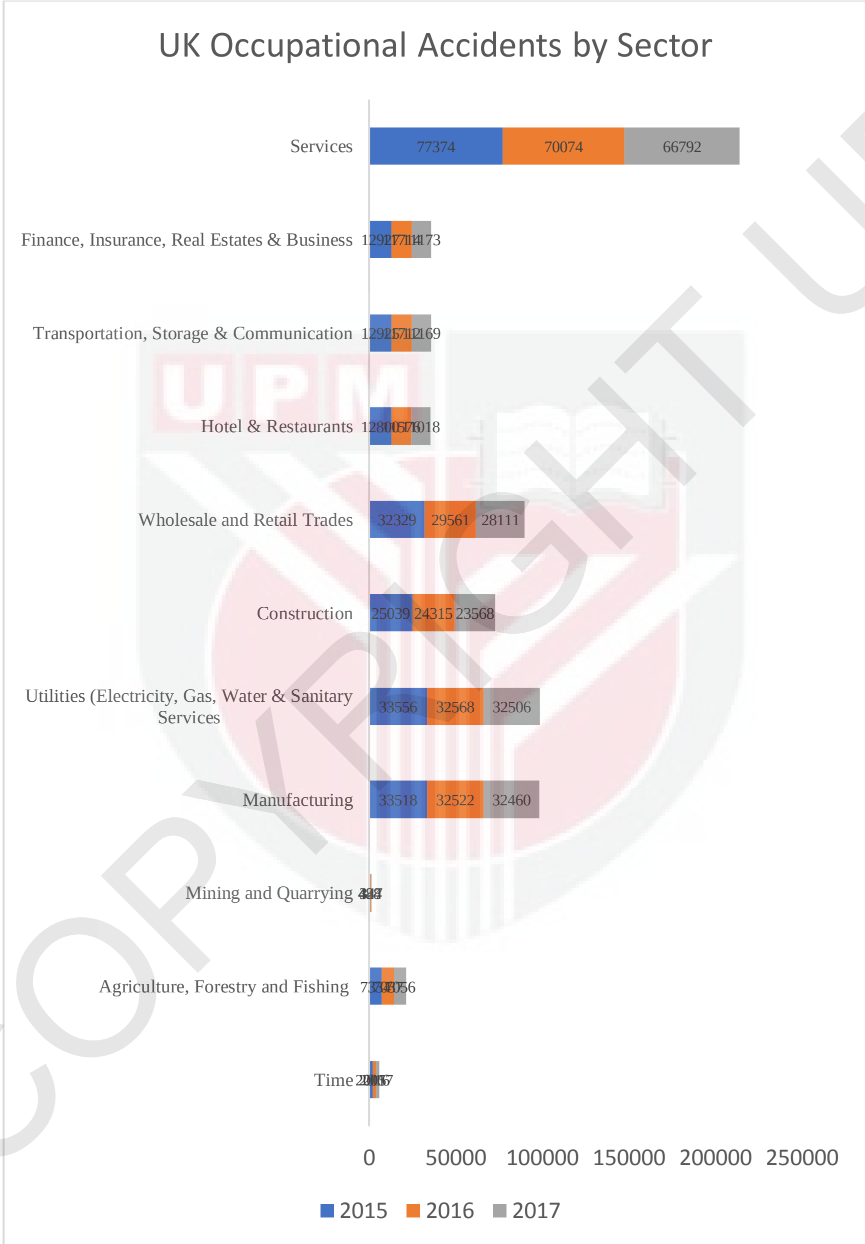

Figure 1.1 : The number of UK occupational accidents by sector (2015-2017)
(Source : ILO, 2018)

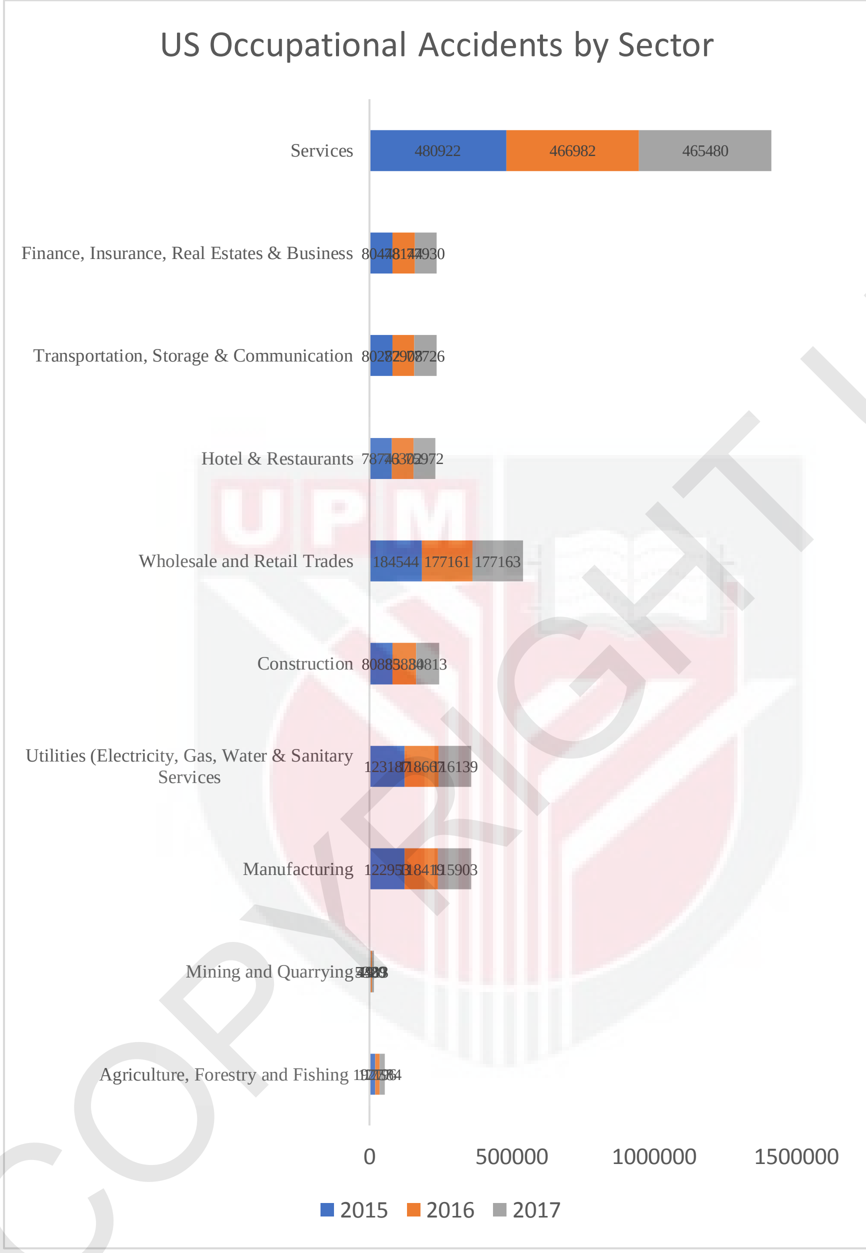

Figure 1.2 : The number of U.S. occupational accidents by sector (2015-2017)
(Source : ILO, 2018)

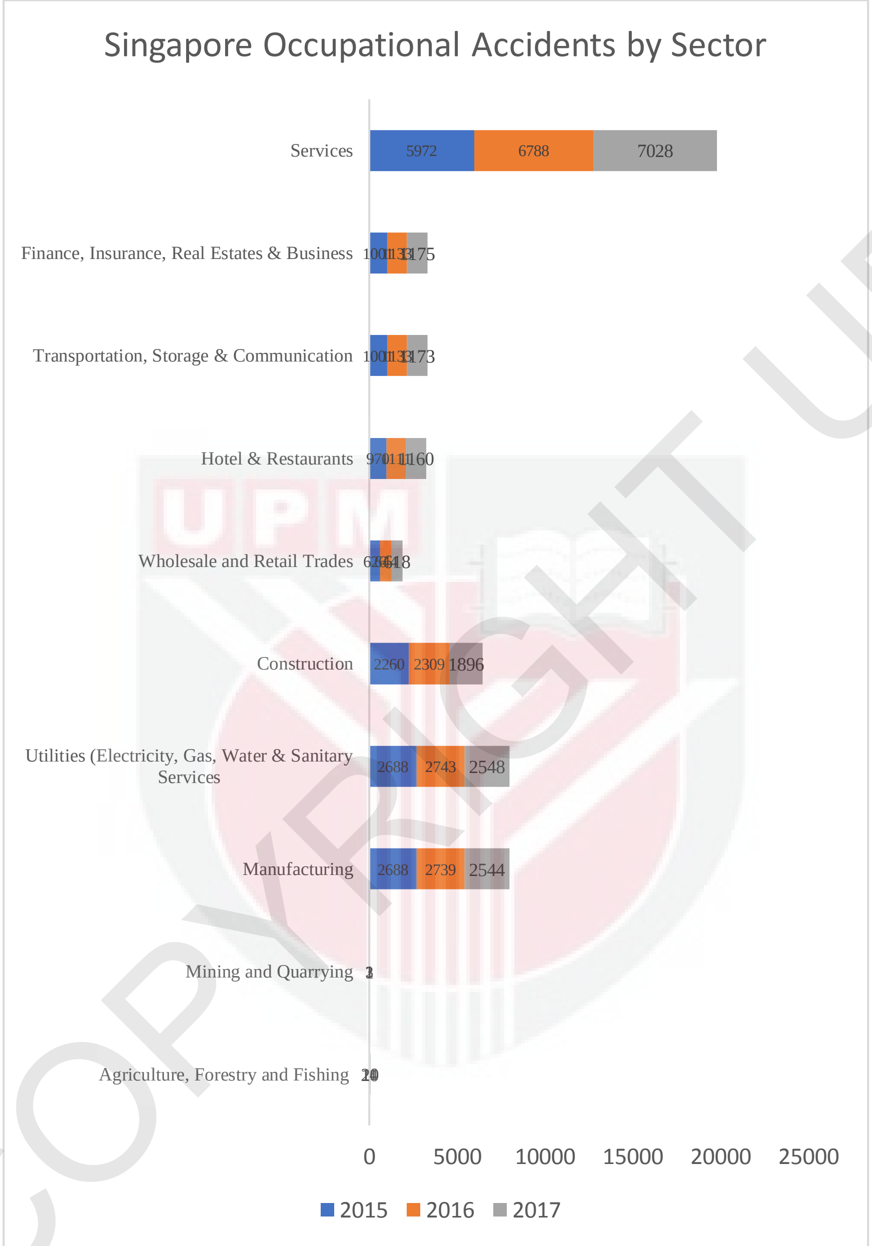

Figure 1.3 : The number of Singapore occupational accidents by sector (2015-2017)
(Source : ILO, 2018)

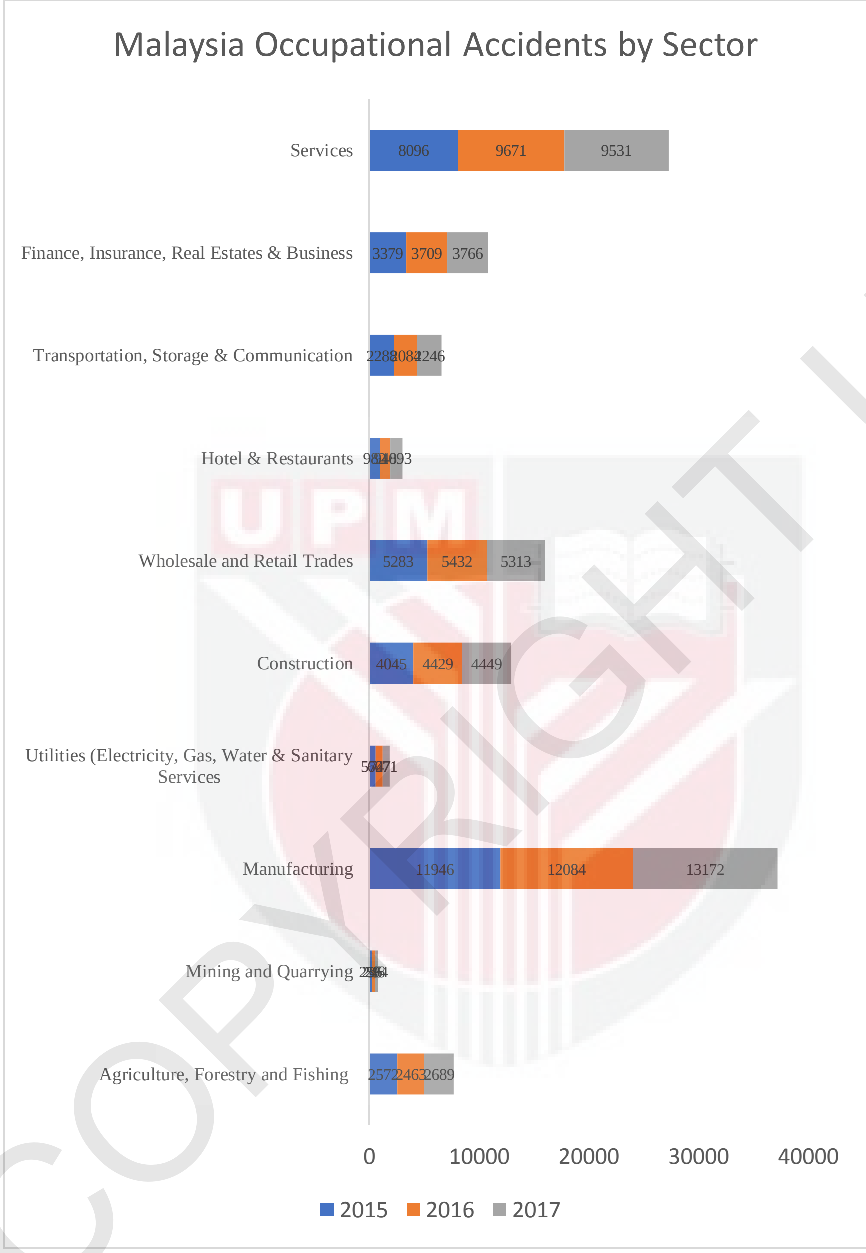

Figure 1.4 : The number of Malaysia occupational accidents by sector (2015-2017)
(Source : DOSH, 2018)

Figures 1.5 to 1.8 show the United Kingdom, the United States, Singapore, and Malaysia fatal occupational accident statistics from 2015 until 2017. It emphasized that the construction sector is the primary source of these statistics in Singapore and Malaysia. The transportation, storage, and communication sectors are the main contributors in the UK, whereas the services sector is the primary contributor in the US, closely followed by the construction sector.

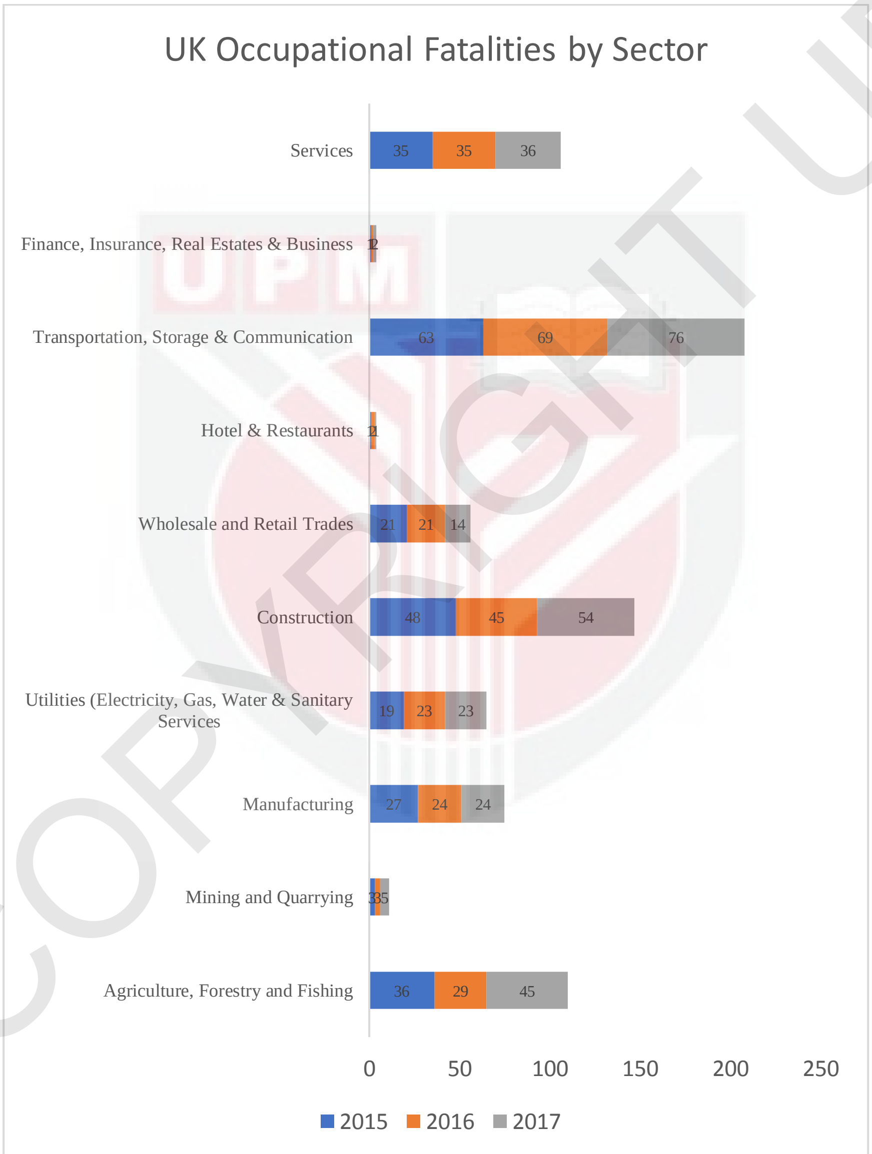

Figure 1.5 : The number of UK occupational fatalities by sector (2015-2017)
(Source : ILO, 2018)

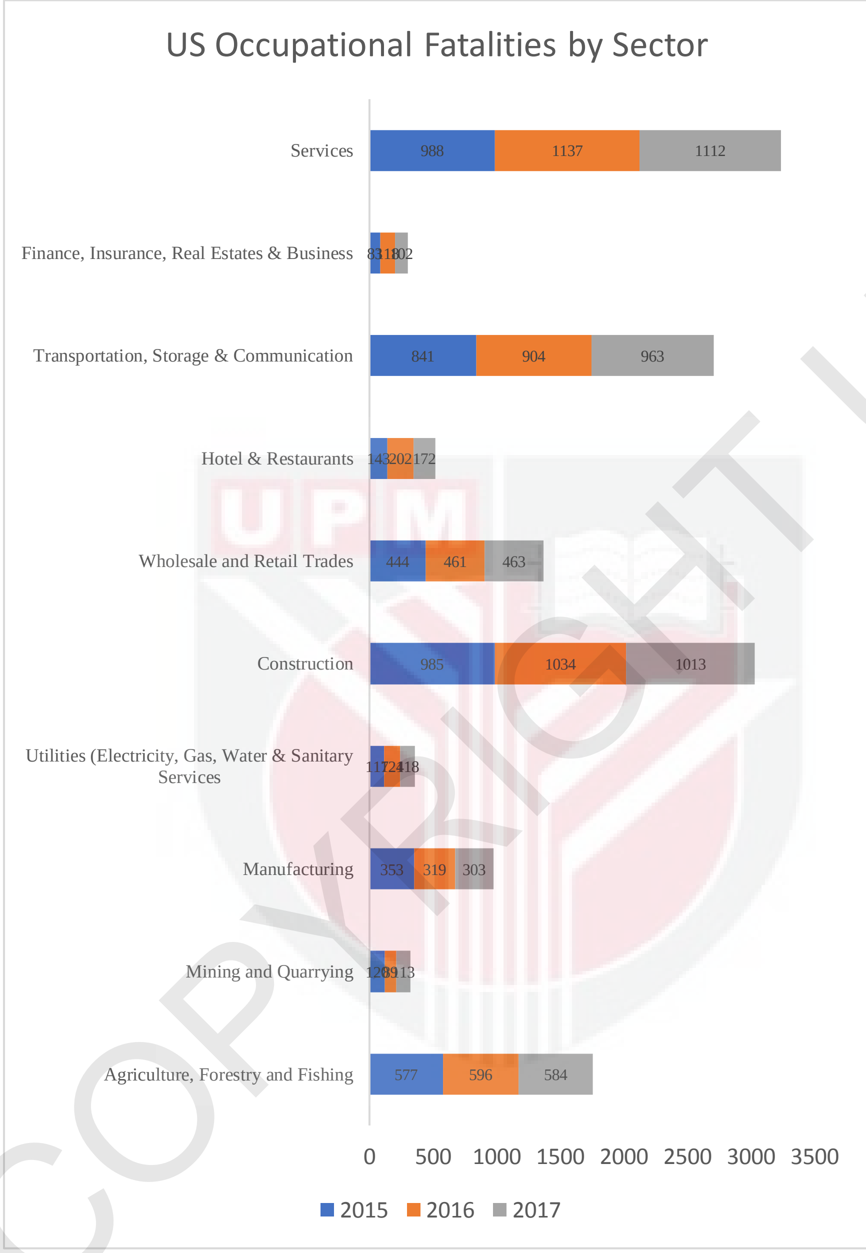

Figure 1.6 : The number of U.S. occupational fatalities by sector (2015-2017)
(Source : ILO, 2018)

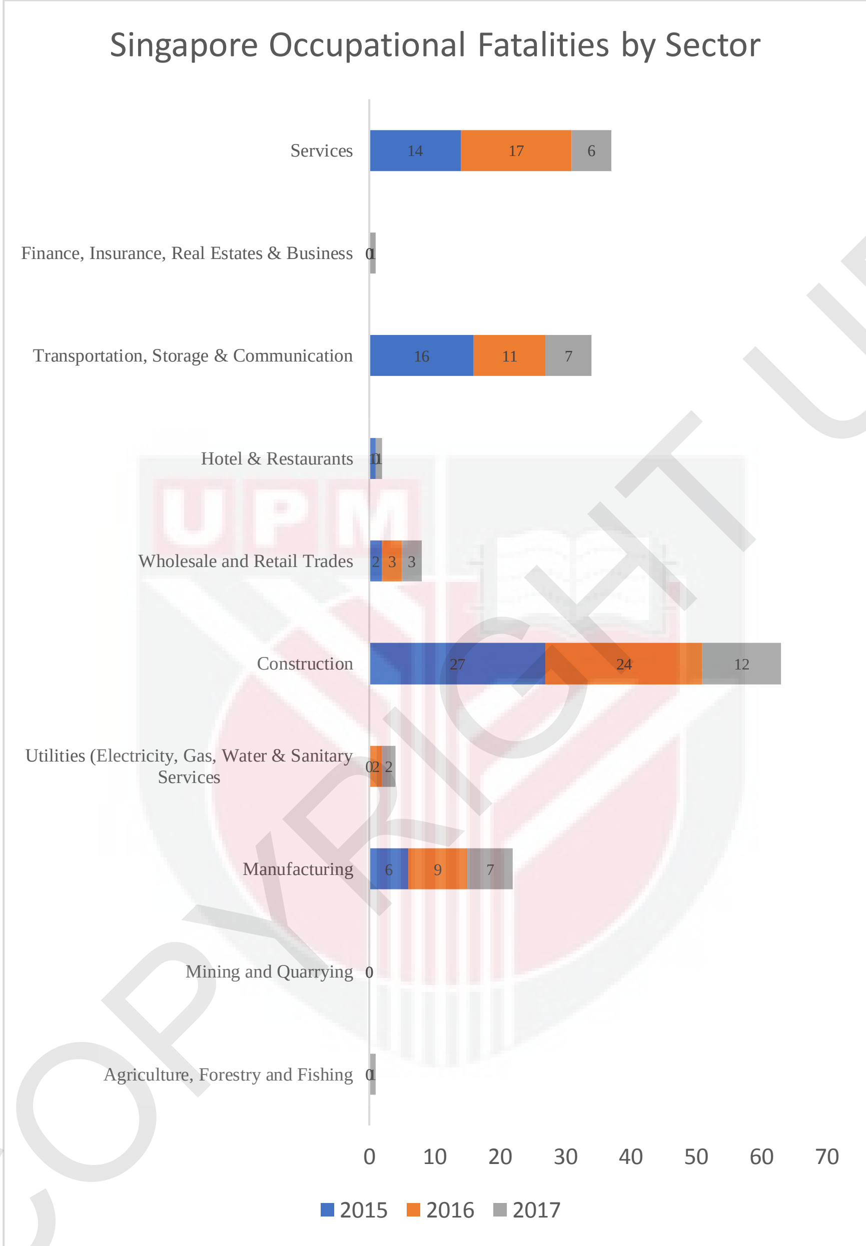

Figure 1.7 : The number of Singapore occupational fatalities by sector (2015-2017)
(Source : ILO, 2018)

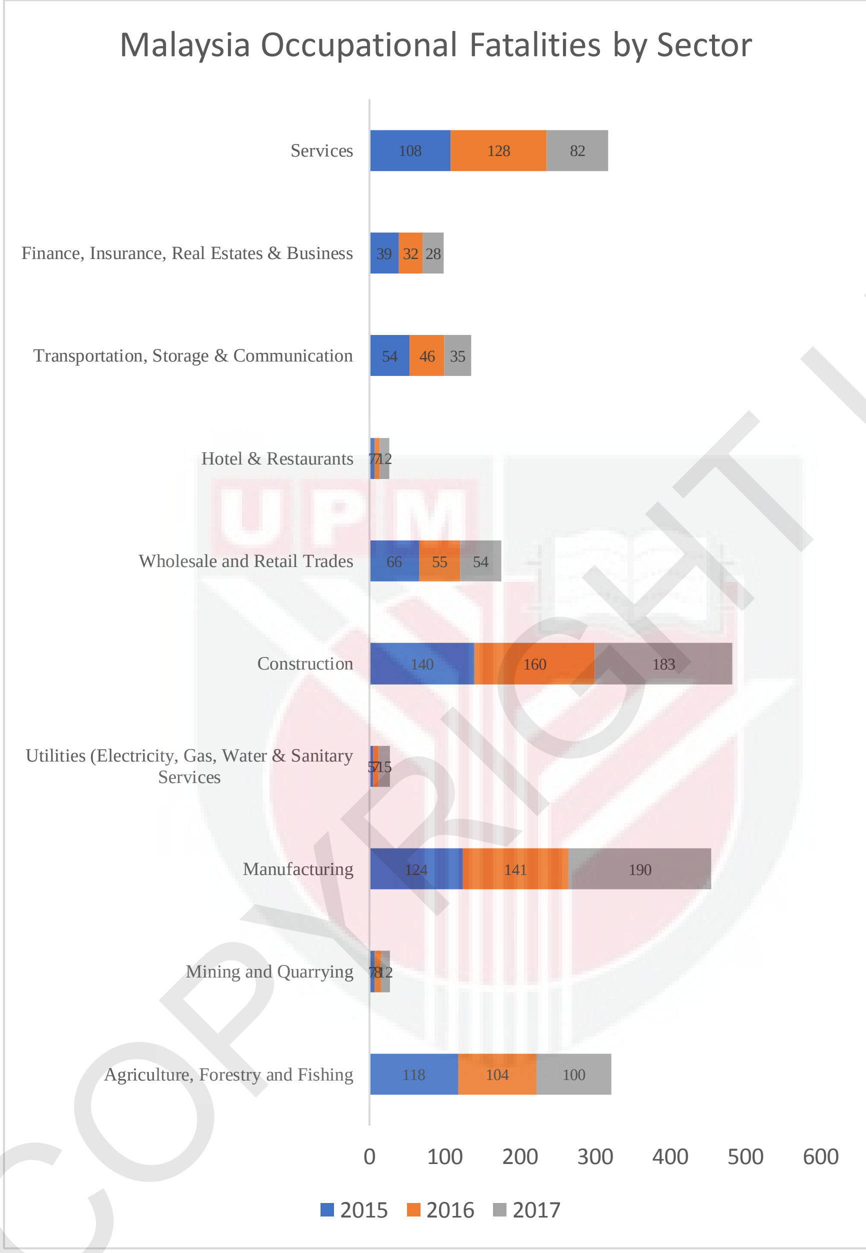

Figure 1.8 : The number of Malaysia occupational fatalities by sector (2015-2017)
(Source : DOSH, 2018)

Figure 1.9, on the other hand, depicts the average number of occupational fatalities per country and sector from 2015 to 2017. From these statistics, the construction sector dominates the chart with 1242 cases, closely followed by the services sector with 1232 incidents. Meanwhile, Figure 1.10 depicts the average occupational fatal accidents by sector for the four countries studied over the same period. It was revealed that the construction sector leads with 311 cases, while the services industry comes in second with 308 cases.

The main reason for this predicament can be linked to the organization's inability to conduct a comprehensive and accurate assessment of occupational risk, which leads to risk control ineffectiveness (Fasoranti, 2015). Furthermore, it is associated with relying entirely on common RAM as a risk assessment tool during the risk assessment process on each construction activity, which leads inaccuracies in the selection of appropriate risk control (Al-Anbari, Khalina, Alnuaimi, Normariah, & Yahya, 2015; Construction Industry Development Board [CIDB], 2018a).

The fundamental justification for choosing this sector as the focus of this study is examining the alarming numbers of fatal occupational accidents in the construction sector.

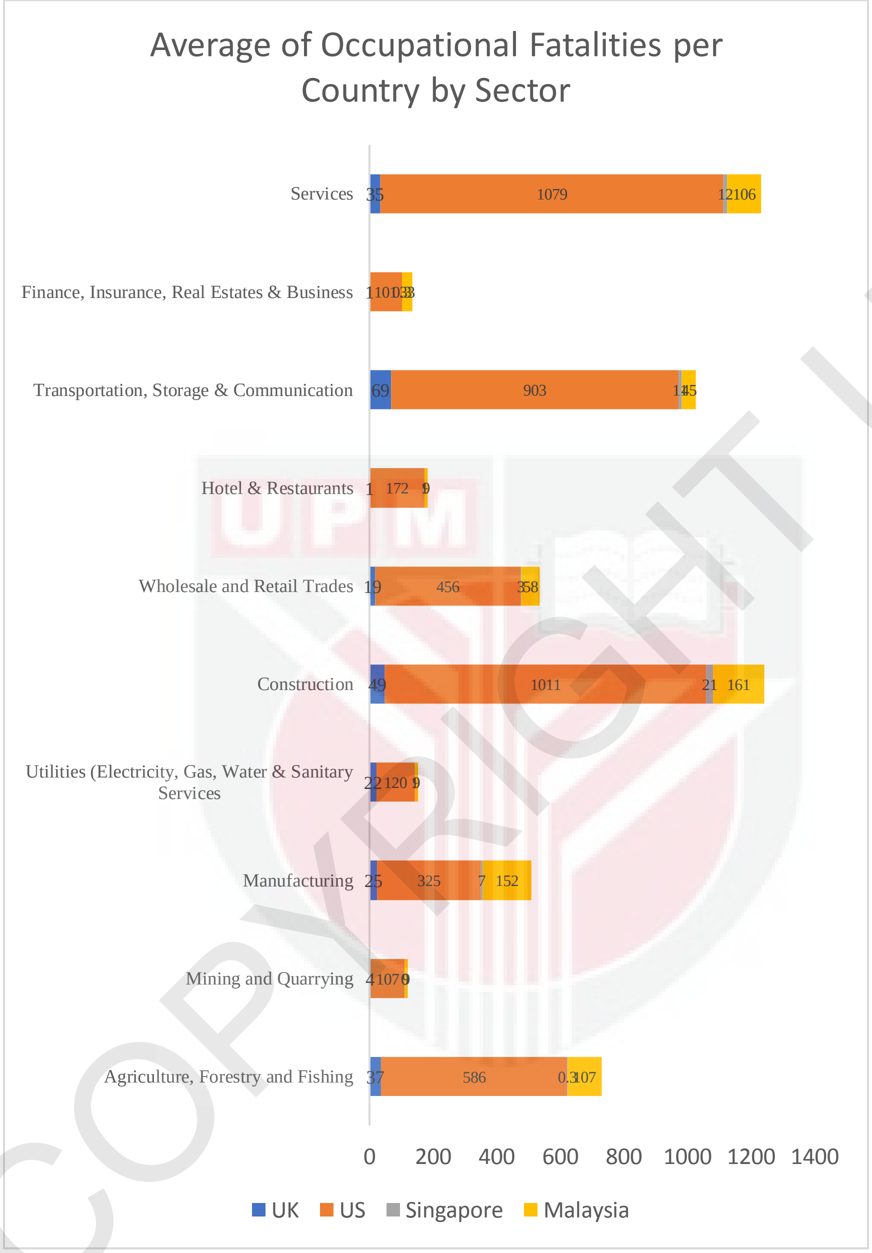

Figure 1.9 : The average of occupational fatalities per country by sector (2015-2017)
(Source : DOSH, 2018; ILO, 2018)

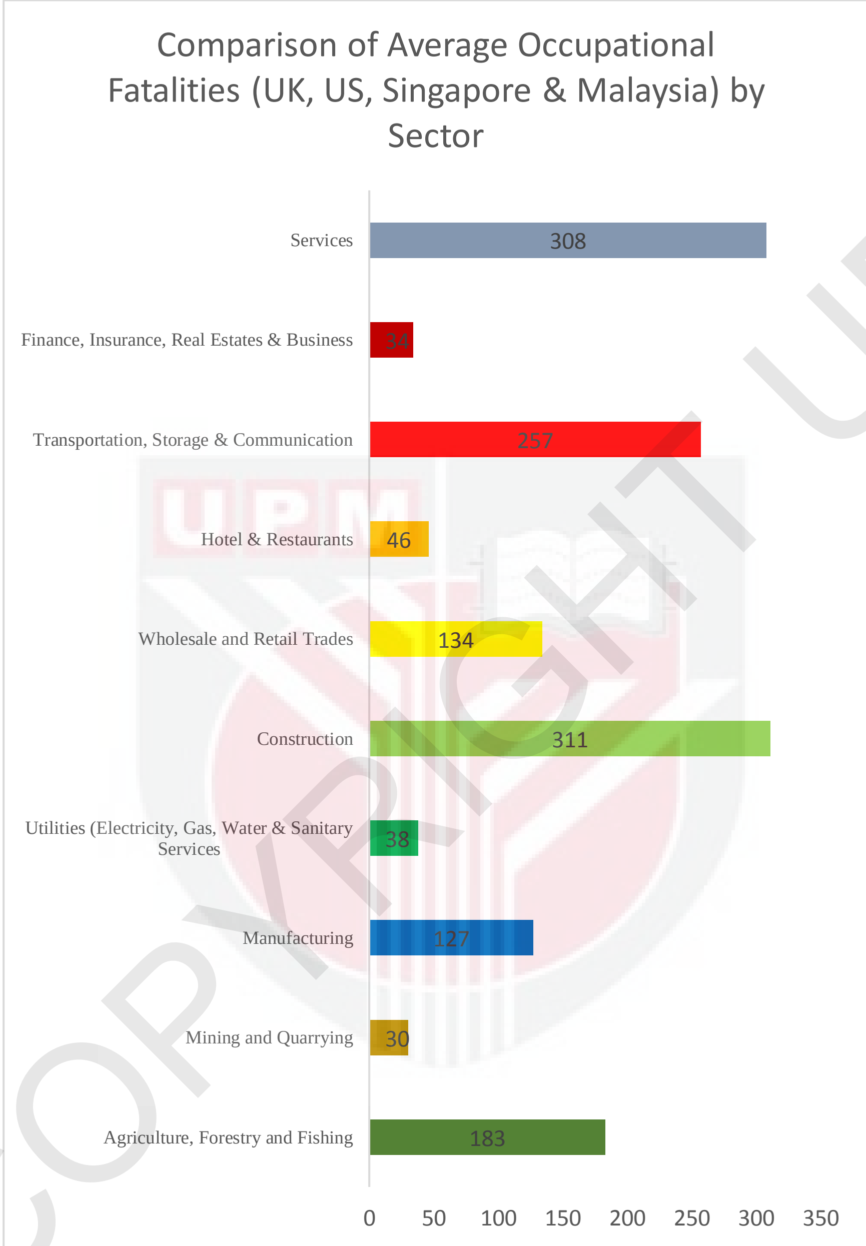

Figure 1.10 : The comparison of average occupational fatalities (UK, U.S., Singapore & Malaysia) by sector (2015-2017)
(Source : DOSH, 2018; ILO, 2018)

1.2 Problem statement

The construction industry is synonymous with a high-risk work environment that straightforwardly exposes construction personnel, vendors, visitors, the public and their surroundings to the possible consequence of accidents. Aside from minor, severe, and fatal injuries and property damage, construction site accidents cause a delay in work progress and cost implications such as recruiting a new worker, training a new employee, compensating injured workers or settling death claims (Ahmed, 2019; Zaini, Salleh, Hasmori & Abas, 2020). Therefore, risk assessments are essential for all construction activities to avoid any exposure to accident risk to prevent such consequences. Due to the dynamics of construction projects, including open operations, high mobility, inadequate worker OSH knowledge, and the quick and easy usage of common RAM, most of the site management prioritizes common RAM as an OSH risk assessment tool to estimate the magnitude of risk pose by site activities to implement adequate risk control (Youli, Yingjian, Xiaoxia & Airan, 2018; Purohit, Siddiqui, Nandan & Yadav, 2018; Salim, Romli, Besar & Aminian, 2017).

However, reliance on the common RAM as a sole tool in assessing the risk level is exaggerated. It is due to the tendency of the common RAM to produce inconsistent risk assessment results that can trigger inaccuracies during risk management actions (Bao, Wu, Wan, Li & Chen, 2017). The common RAM assesses risks using a predefined rating scale, which is extremely difficult for users to comprehend, particularly those who lack training and experience in the usage (Leveson, 2019; Peace, 2017). It also overwhelms risk assessors with an incorrect definition and interpretation of the likelihood and consequences (Jamaludin, Dahlan, Elias, & Baharudin, 2017; Leveson, 2019; Satishkumar & Shrihari, 2016). As a result, risk assessors tend to conduct assessments based on their respective perspectives, expertise and understanding (Al-Anbari et al., 2015). Consequently, they may misjudge situations as well as possess certain biases and realise their own agendas (Hubbard & Seiersen, 2016).

On the other hand, the feasible but realistic existence of the common RAM could conceal design issues and mislead risk assessors or produce worse than random tic analysis that contributes limited benefits in risk management (Duijm, 2015; Goerlandt & Reniers, 2016; Vatanpour, Hrudey, & Dinu, 2015). A poorly designed common RAM can convolute the risk rating process and generate incorrect risk levels for decision-making (Baybutt, 2017; Duijm, 2015; Goerlandt & Reniers, 2016; Leveson, 2019; Peace, 2017; Vatanpour et al., 2015). The inferior common RAM is likely to yield deceptive, even inaccurate results that may lead to false actualities or inappropriate allocation of resources, if it is used alone.

Therefore, a RAM needs to be developed or modified to suit the context. To achieve this, some data required must be available; for example, the historical accident statistics of an organisation's or related industry, to establish realistic likelihood scales (International Organization for Standardizatio [ISO], 2019), to guarantee that the risk assessment process yields credible and accurate results while undertaking a risk analysis.

Another aspect worth noting is the use of the common RAM as an analytical tool in the risk assessment process, which does not explicitly take into account the OSH internal risk factors that directly affect the day-to-day operations of the organisation (Kashwani & Nielsen, 2017). However, these internal risk factors can be avoided and controlled before they become unmanageable and affect the entire organisation. In this regard, Mard, Estiri, Hadadi & Mard (2017) recommend that these internal risk factors be transformed into MRF as a measure for the risk control (ISO, 2018b) taken by the organisation in its efforts to prevent or mitigate the occupational risks.

1.3 Significance of study

This study assists the management in taking decisions on administering of occupational risks at the construction site. A construction occupational safety and health risk assessment matrix (COSHRAM) has been used to benefit from characterising high-risk construction activities and thus promoting the OSH climate at the workplace.

Workers in the construction sector are subject to risks that are difficult to quantify owing to the particular or peculiar nature of activities of this field, where local changes in the working atmosphere will not only affect a limited specific group of employees, but they may impact all personnel on the site. This scenario can significantly alter the array of hazards encountered weekly, sometimes daily (Fung, Tam, Lo & Lu, 2010; Mehta & Agnew, 2010). The Malaysian construction industry must, therefore, evaluate the risks of accidents at work, develop strategies to prevent workplace accidents and alleviate or minimise their seriousness (CIDB, 2019; Department of Occupational Safety & Health [DOSH], 2015). It is due to the importance of the construction industry as one of the most significant economic sectors in any nation, strongly linked to other financial sectors and heavily dependent on labour-intensive jobs.

Throughout the years, the number of construction workers in Malaysia has shown a growing pattern, although, the accident statistics have shown that the construction industry is an extremely hazardous sector due to its elevated fatality rates given the recognition of distinctive OSH cultures (Abang Abdullah & Wern, 2010). All these facts and figures demonstrate the relevance of this industry and the need for more studies to improve the OSH level and reduce the accident frequency. The issue is anticipated to become more serious in the coming years, with more construction initiatives set up, as Malaysia moves towards the status of becoming a developed country.

Accordingly, this study offers insights into the establishment of a new OSH RAM, using the available accurate and reliable data integrated with the MRF of occupational construction accidents. This COSHRAM deals with hazards arising from faults of work activities or equipment. The COSHRAM is also part of a defined process intended to provide the best available data to OSH RAM users and decision-makers, thus assisting in resolving some intrinsic inaccuracies in outcomes of and decisions taken using a common RAM approach.

Researchers, OSH practitioners and OSH consultants can leverage the findings of this analysis for various purposes. At about the same time, construction project managements can use the study findings to take proactive steps and to introduce effective control measures to reduce the frequency of accidents among on-site employees. The COSHRAM also can be used as an alternative tool for risk assessors to conduct a more credible risk assessment in the construction industry.

Apart from assisting employers in reducing the likelihood of a work-related accident, results of the COSHRAM assessment could also help employers reduce and prevent fines, litigations, and penalties from noncompliance with the OSH legislation.

Occupational accidents can also lead to massive public relations concerns, such as unfavourable publicity and a distorted business image. When a construction company employs risk assessment techniques like COSHRAM, it sends a powerful message to the community and stakeholders. Clients and customers know they are doing business with a competent and proactive organization, and employees know they are working for a safe and responsible firm. Overall, a rigorous risk assessment indicates that an organization is trustworthy and operates at a decent range.

Simultaneously, the implementation of COSHRAM as an OSH risk assessment tool is projected to assist the government in lowering the accident and fatal accident rates, particularly on construction sites. In the event of a non-fatal, fatal, or dangerous occurrence accident, not only the contractor but the government will also suffer the loss in terms of time, cost, project progress delays, and skilled local workforce. The government had to deploy officials from the investigation process until legal action. Typically, this process takes three to six months. Furthermore, this will slow down the project's progress, causing it not to be completed within the time frame stipulated. The most notable loss is that of a skilled local workforce. As we all know, the cost of training for local skilled workers is very high.

1.4 Research questions

Considering the study goals, several pertinent questions are designed and listed as follows:

1) Is there a difference in risk value between common RAM analysis and COSHRAM analysis?

2) Is there a direct and significant relationship between the likelihood of an occupational construction accident and the residual risk value in the COSHRAM analysis?

3) Is there a direct and significant relationship between the consequences of an occupational construction accident and the residual risk value in the COSHRAM analysis?

4) Is there a direct and significant relationship between the MRF of an occupational construction accident and the residual risk value in the COSHRAM analysis?

5) How do the likelihood of an occupational construction accident, the consequences of an occupational construction accident, and the MRF of an occupational construction accident predict the residual risk value?

1.5 General objectives of the study

This study's general objective is to develop and validate a COSHRAM as an alternative tool for OSH risk assessment. The intent of the COSHRAM is for the construction industry, and in this context, the usage extends to a broad range of industry organisations, regardless of the scale, scope, type of construction and construction processes. The COSHRAM seeks to recognise, quantify and evaluate the risks associated with the likelihood of an occupational construction accident, the consequences of an occupational construction accident, and the MRF of an occupational construction accident.

1.5.1 Specific objectives

The study, based on the general objective, recognises ten specific objectives, which are described below:

1) To determine the MRF element of an occupational construction accident.

2) To determine the likelihood of an occupational construction accident

3) To determine the consequences of an occupational construction accident.

4) To develop a COSHRAM using the combination of the likelihood of an occupational construction accident, the consequences of an occupational construction accident, and the MRF of an occupational construction accident.

5) To validate the COSHRAM by examining its accuracy, functionality and efficacy in assessing the desired risk level.

6) To compare the difference in risk value between the common RAM analysis and COSHRAM analysis.

7) To determine whether there is a direct and significant relationship between the likelihood of an occupational construction accident, the consequences of an occupational construction accident, and the MRF of the occupational construction with the residual risk value in the COSHRAM analysis.

8) To determine whether the likelihood of an occupational construction accident, the consequences of an occupational construction accident, and the MRF of an occupational construction accident can predict the residual risk value in the COSHRAM analysis.

1.6 Research hypotheses

The hypotheses for this study are listed as below:

H1: There is a difference in risk value between the common RAM and COSHRAM analysis.

H2: The likelihood of an occupational construction accident is positively related to the residual risk value in the COSHRAM analysis.

H3: The consequences of an occupational construction accident are positively related to the residual risk value in the COSHRAM analysis.

H4: The MRF of an occupational construction accident is positively related to the residual risk value in the COSHRAM analysis.

H5: The residual risk value can be significantly predicted by the likelihood of an occupational construction accident, the consequences of an occupational construction accident, and the MRF of an occupational construction accident.

1.7 Definition of terms

Table 1.1 : Conceptual and Operational Definitions

Terms	Conceptual Definition	Operational Definition
Consequence	Outcome of an event affecting objectives (ISO, 2018a).	The outcome of an event based on severity such as fatal injury; fatal occupational poisoning and disease; serious bodily injury or life-threatening occupational poisoning and disease; injury or occupational poisoning and disease requiring medical treatment leading to disability; or injury or occupational poisoning and disease requiring medical treatment leading to temporary disability or first aid.
Inherent risk (IhR)	Magnitude of risk that exists in the absence of controls (Ho, 2013).	Magnitude of risk that exists in the absence of existing control.
Initial risk (IR)	Magnitude of risk that exists in the presence of controls (United States Department of Defence [USDoD], 2012).	Magnitude of risk that exists in the presence of the existing control.
Likelihood	Chance of something happening, either specified, measured, or dictated objectively or subjectively, qualitatively or quantitatively and described using general terms or mathematically (such as probability or frequency over a given period) (ISO, 2018a).	Potential for something to happen quantified quantitatively using historical accident data in the construction industry over ten years (2008–2017). It is based on the types of accidents, such as fall of person, or struck by a falling object, or stepping on, striking against or struck by an object (excluding falling object), or caught in between objects, or overexertion or strenuous movements, or exposed to/contact with extreme temperatures, or exposed to/contact with electric current, or exposed to/contact with harmful substances or radiations, or other types of accidents.

Table 1.1 : Continued

Modifying risk factor (MRF)	An attribute that increases the likelihood of occurrence of accidents that can be modified, thereby reducing the likelihood of occurrence of accidents (Burt, 2001).	An element that enables a further reduction in the likelihood of an occupational construction accident.
Risk	A combination of the likelihood of an occurrence of a work-related hazardous event or exposure and the severity of the injury and ill health which may be triggered by an event or exposure (ISO, 2018a). R=L x S	A combination of the likelihood of an occupational construction accident and the consequences of an occupational construction accident that may be triggered by an event or exposure. R=L x C
Residual Risk (RR)	Remainder risk after risk prevention by opting not to start or continue with an activity that eventually leads to risk; taking or increasing the risk to pursue an opportunity; removing the risk source or retaining the risk by informed decision (ISO, 2018a).	Remaining risk magnitude after the presence of risk control and consideration of OSH modifying the risk factor. RR = IhR – (IhR * MRF); or RR = IR – (IR * MRF)
Risk level	Magnitude of risk or combination of risks, expressed in terms of the combination of consequence and their likelihood (ISO, 2018a).	The categorisation of risks into different types of levels, usually extreme, high , medium and low risks (HSE, 2018; Safety Institute of Australia [SIA], 2015).

1.8 Conceptual framework

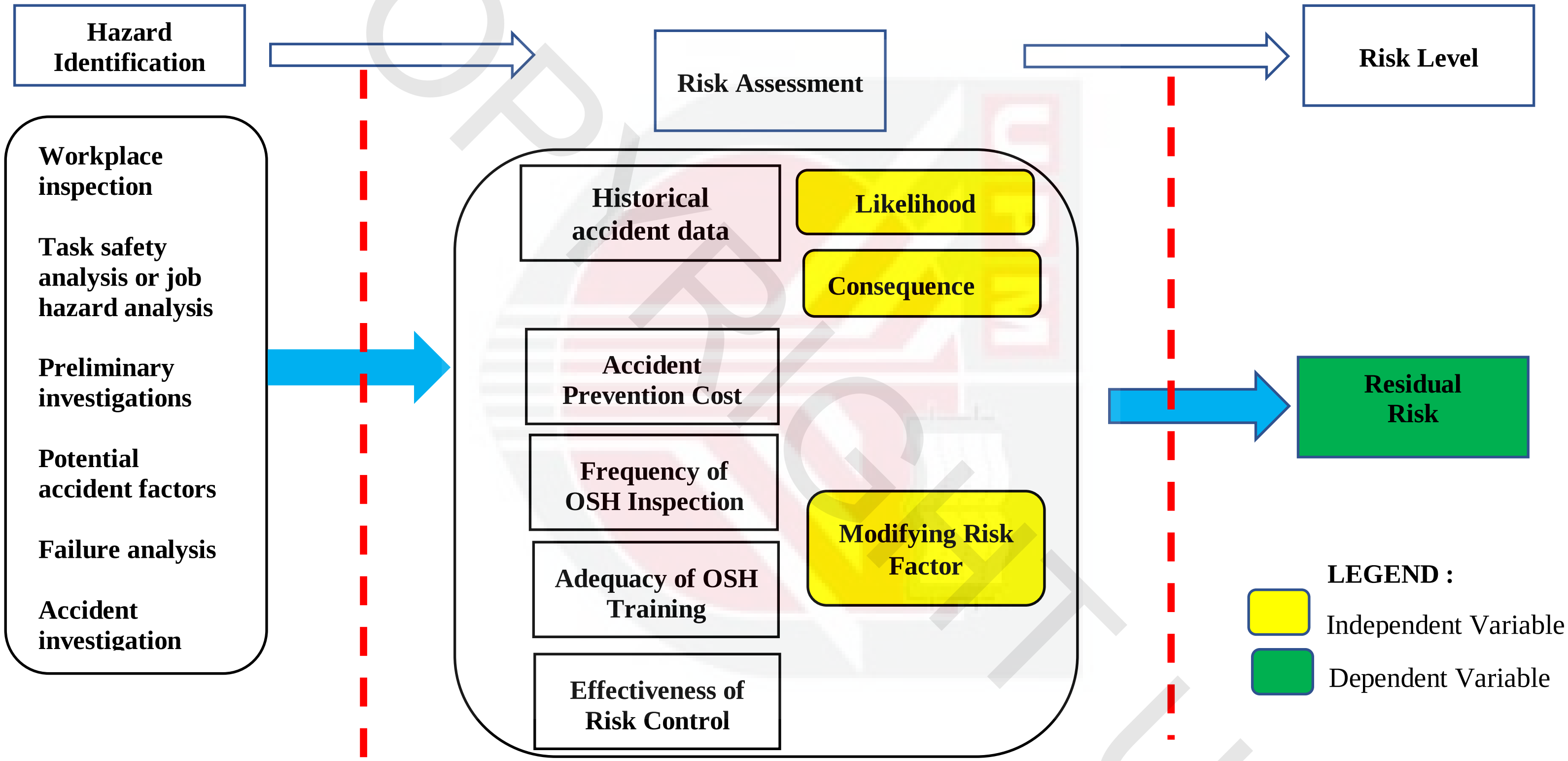

Figure 1.11 : The conceptual framework of the study

The conceptual framework of this study explains the elements related to the development of the COSHRAM. This conceptual framework is based on the HIRARC model (DOSH, 2008). It presents the key elements that influence the level of risk resulting from the OSH risk assessment. The ideas and theories engaged are shown in Figure 1.3. This study is conducted in the context of the Malaysian construction industry. The study assesses the level of risk generated when the COSHRAM is used as a risk analysis tool in the risk assessment of OSH.

The main elements of this study are the likelihood of an occupational construction accident, the consequence of an occupational construction accident, the MRF of an occupational construction accident, and the residual risk. The likelihood of an occupational construction accident is obtained from the historical accident data, consisting of the average number of accidents for each type of accident. Meanwhile, the consequence of an occupational construction accident is based on the actual effects of accidents experienced by each construction site, such as fatal injury or fatal occupational poisoning and disease or multiple serious bodily injuries, serious bodily injury or life-threatening occupational poisoning and disease, non-fatal injury or occupational poisoning and disease requiring medical treatment leading to disability, non-fatal injury or occupational poisoning and disease requiring medical treatment leading to temporary disability or first aid, and no injury or occupational poisoning and disease. The MRF of an occupational construction is obtained from the accident prevention cost (APC), frequency of OSH inspection (FOI), adequacy of OSH training (AOT), and effectiveness of risk control (ERC) practices of each construction site that has participated in the field survey.

The residual risk (RR) is a dependent variable in this study. On the other hand, the likelihood of an occupational construction accident, the consequence of an occupational construction accident, and the MRF of an occupational construction accident are independent variables in this study.

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