HAZARD IDENTIFICATION AND RISK ASSESSMENT ON GAS PIPELINE INSTALLATION WORKS

DASHAN A/L SENGENY

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2022

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DASHAN A/L SENGENY

RESEARCH REPORT SUBMITTED IN FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SAFETY, HEALTH AND ENVIRONMENT ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITY OF MALAYA
KUALA LUMPUR

2022

UNIVERSITY OF MALAYA

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[HAZARD IDENTIFICATION AND RISK ASSESSMENT ON GAS PIPELINE INSTALLATION WORKS]

ABSTRACT

Gas supply contributes to major fuel requirements for petrochemical plants, power generation, large and small industries to upkeep the operation and production to meet the consumer's demand. To achieve that, gas pipeline construction plays an important role to provide the infrastructure for gas transportation through the pipelines to ensure uninterruptible supply. Constructing a gas pipeline involves high-risk activities such as excavation works, Horizontal Directional Drilling (HDD), lifting, confined space activities, and welding works which are required to be performed along the construction process. This activity requires serious attention for hazard identification associated with the task, performing risk assessment, and implementation of control measures to minimize the occurrence of occupational accidents. Hazard identification, Risk Assessment, and Risk Control (HIRARC) is a fundamental tool that helps to minimize and prevent accidents to take place in the workplace by cultivation a safe work system through matrix analysis which reveals the likelihood and severity of accidental occurrences. This study aims to perform hazard identification, conduct a risk assessment, and propose control measures based on the hazard and risk associated with the gas pipeline construction activities. Performing hazard identification based on the construction activities leads to several findings which can be evaluated and improved to prevent accidents. The evaluation and analysis are conducted based on the site practicability, experienced personnel opinions, and previous lesson learned. Upon risk assessment completion, a control measure is proposed according to worksite suitability. This is achieved through adaptation of several methods such as survey analysis conducted which consists of 127 respondent who is working in the gas pipeline-related construction field, site observation on actual construction practice, Fault Tree Analysis (FTA), and

HIRARC form is used to identify the hazard and analyses the risk associated with the gas pipeline construction activities. Findings show that the attitude of the workers and responsibilities of the employee and management plays an important role in cultivating a safe work system. Besides that, negligence in small flaws leads to critical accidents or contributes to the main event which leads to a more severe impact. Moreover, this study also demonstrated that the involvement of management focusing on safety aspects improves the site safety practices. Safety competence personnel also ensures the worksite safety through site inspection and induction briefing is carried out on daily basis. Implementation of more comprehensive HIRARC through this study improves the site safety practices through awareness to the construction personnel which emphasizes on safety is everyone's responsibility and working safely is the top priority.

[PENGENALPASTIAN HAZARD DAN PENILAIAN RISIKO PADA KERJA-KERJA PEMASANGAN TALIAN PAIP GAS]

ABSTRAK

Bekalan gas merupakan penyumbang utama kepada keperluan bahan api utama untuk loji petrokimia, penjanaan kuasa, industri besar dan kecil untuk mengekalkan operasi dan pengeluaran bagi memenuhi permintaan pengguna. Bagi mencapai tujuan tersebut, kerja-kerja pembinaan saluran paip gas memainkan peranan penting untuk menyediakan infrastruktur pengangkutan gas melalui saluran paip bagi memastikan bekalan tidak terganggu. Oleh kerana itu, pembinaan saluran paip gas dilakukan dimana ia melibatkan melibatkan aktiviti berisiko tinggi seperti kerja-kerja penggalian, kaedah korekan bawah tanah yang dikenali sebagai "Horizontal Directional Drilling" (HDD), aktiviti mengankat, bekerja di ruang terkurung, dan kerja-kerja kimpalan yang perlu dilakukan sepanjang proses pembinaan. Aktiviti ini memerlukan perhatian yang serius untuk mengenal pasti hazard yang berkaitan dengan tugas, serta pelaksanaaan penilaian risiko dan langkah kawalan untuk mengurangkan kejadian kemalangan di tempat kerja. Pengenalpastian Hazard, Penaksiran Risiko dan Kawalan Risiko dimana ia lebih dikenali sebagai HIRARC ialah panduan asas yang boleh membantu dalam mengurangkan dan mencegah kemalangan di tempat kerja melalui sistem kerja selamat yang ditafsir melalui analisa matriks yang mendedahkan kemungkinan dan keterukan kejadian kemalangan. Matlamat kajian ini adalah untuk melaksanakan pengenalpastian bahaya, menjalankan penilaian risiko dan mencadangkan langkah kawalan berdasarkan hazard dan risiko yang berkaitan dengan aktiviti pembinaan saluran paip gas. Pengenalpastian bahaya berdasarkan aktiviti pembinaan membawa kepada beberapa penemuan yang boleh dinilai dan diperbaiki untuk mengelakkan kemalangan di tempat kerja. Penilaian dan analisis hazard dijalankan berdasarkan kebolehpraktisan tapak, pendapat kakitangan pembinaan yang berpengalaman serta daripada ikhtibar yang telah dipelajari melalui pengalaman lepas.

Setelah penilaian risiko selesai, langkah kawalan dicadangkan mengikut kesesuaian tapak kerja. Penilaian and analisa ini dicapai melalui penyesuaian beberapa kaedah seperti pemerhatian dan analisa tinjauan yang dijalankan terdiri daripada 127 responden yang bekerja dalam bidang pembinaan berkaitan saluran paip gas, pemerhatian tapak terhadap amalan pembinaan sebenar, Fault Tree Analysis (FTA) dan borang HIRARC digunakan untuk mengenal pasti hazard dan menganalisis risiko yang berkaitan dengan aktiviti pembinaan saluran paip gas. Berdasarkan kajian ini, ia menunjukkan bahawa, sikap pekerja dan tanggungjawab pekerja serta pihak pengurusan memainkan peranan penting dalam memupuk sistem kerja yang selamat. Selain itu, kecuaian dalam leka dalam melaksanakan perubahan membawa kepada kemalangan kritikal atau menyumbang kepada penyebab utama yang membawa kepada kesan yang lebih teruk. Selain itu, kajian ini juga menunjukkan bahawa, penglibatan pihak pengurusan yang memfokuskan aspek keselamatan meningkatkan amalan bekerja dengan selamat dalam kalangan pekerja di tapak binaan. Kecekapan kakitangan keselamatan dalam memastikan keselamatan tapak kerja melalui pemeriksaan tapak dan taklimat induksi dijalankan setiap hari memberi kesedaran kepada pekerja. Pelaksanaan HIRARC yang lebih komprehensif melalui kajian ini menambah baik amalan keselamatan tapak melalui kesedaran kepada kakitangan pembinaan yang menekankan keselamatan adalah tanggungjawab bersama dan bekerja dengan selamat adalah keutamaan setiap individu.

ACKNOWLEDGEMENTS

Sincere thanks to my supervisor Assoc.Prof. Dr. Che Rosmani Binti Che Hassan for the continuous guidance, providing knowledge sharing and supervision since the beginning of this research project which helps until the completion.

Next, I would like to thank both of my parents Mr.Sengeny A/L Mari and Ms.Jayasre A/P Perimal, my siblings and other family members for the continuous moral support and encouragement given to me throughout the conduct of the research project make me overcome all the hardship and complete the research project successfully.

Finally, I would like to thank all my friends and work colleagues who helped me to distribute the survey form and provided me with the required information and opinions from other organizations which meant to be a lot for the completion of this research project.

TABLE OF CONTENTS

Abstract iii

Abstrak v

Acknowledgements vii

Table of Contents viii

List of Figures x

List of Tables xii

List of Symbols and Abbreviations xiii

List of Appendices xv

CHAPTER 1: INTRODUCTION 1

1.1 Introduction..1

1.2 Problem Statement..2

1.3 Objectives..3

1.4 Research Question 4

1.5 Scope of Research..4

CHAPTER 2: LITERATURE REVIEW 5

2.1 Proposed Approach of HIRARC with Control in Oil Industry................................5

2.2 Integration of Occupational Safety and Health during Pre-construction Stage in Malaysia 13

2.3 Ranking of human factor affecting contractor's risk attitude in the Malaysian construction industry 17

CHAPTER 3: METHODOLOGY 21

3.1 Introduction to Methodology 21

3.2 Conduct Survey Analysis 23

3.3 Site Observation 25

3.4 Fault Tree Analysis 27

3.5 Proposed HIRARC Form 30

CHAPTER 4: RESULT & DISCUSSION 33

4.1 Survey Analysis 33

4.2 Site Observation 44

4.2.1 Confined Space Practice 44

4.2.2 Pipeline Welding Works 46

4.2.3 Pipe Lifting Operation 50

4.3 Fault Tree Analysis 53

4.3.1 Excavation and Trenching 53

4.3.2 Horizontal Directional Drilling (HDD) 57

4.4 Proposed HIRARC 61

CHAPTER 5: CONCLUSION & RECOMMENDATION 81

5.1 Conclusion 81

5.2 Future Recommendation 83

REFERENCES *85*

APPENDIX A : Survey Form 89

LIST OF FIGURES

Figure 2.1 : Accidents in domain area in 2016 7

Figure 2.2 : Accidents in domain area in 2018 8

Figure 2.3 : Accidents in domain area in 2018 8

Figure 2.4 : hierarchy of risks control 9

Figure 2.5 : Stages involves in the Construction Project Management........................15

Figure 2.6 : Conceptual framework where Government Policy as a moderator 20

Figure 3.1 : Google Form used for Survey Conduct. 23

Figure 3.2 : Construction personnel answering survey questionnaire..........................24

Figure 3.3 : Management walkabout on construction site...25

Figure 3.4 : Fault tree diagram with the combination of event symbol and logic gates. .. ………………………………………………………………………………........ 27

Figure 3.5 : HIRARC form 30

Figure 3.6 : Risk matrix...32

Figure 3.7 : Risk range indication 32

Figure 4.1 : Question 1 and result obtained from respondents from the survey 33

Figure 4.2 : Question 2 and result obtained from respondents from the survey 34

Figure 4.3 : Question 3 and result obtained from respondents from the survey 35

Figure 4.4 : Question 4 and results obtained from respondents from the survey..........36

Figure 4.5 : Question 5 and results obtained from respondents from the survey..........37

Figure 4.6 : Question 6 and results obtained from respondents from the survey..........38

Figure 4.7 : Question 7 and result obtained from respondents from the survey 39

Figure 4.8 : Question 8 and result obtained from respondents from the survey 40

Figure 4.9 : Question 9 and result obtained from respondents from the survey 41

Figure 4.10 : Question 10 and result obtained from respondents from the survey 42

Figure 4.11 : Question 11 and result obtained from respondents from the survey 43

Figure 4.12 : Example of a valve chamber considered as a confined space 44

Figure 4.13 : Safe confined space work practice 45

Figure 4.14 : Pipeline welding activities. 46

Figure 4.15 : Fire extinguisher and first aid box usage briefing 48

Figure 4.16 : Site safety supervisor inspecting first aid box onsite 49

Figure 4.17 : Site safety supervisor inspecting fire extinguisher on site. 50

Figure 4.18: Pipe loading and unloading activities. 50

Figure 4.20: Lifting form to be approved before lifting activity 52

Figure 4.19 : Lifting belt inspection and new belt standby onsite. 52

Figure 4.21 : fault tree conducted for excavation and trenching accident occurrence ...53

Figure 4.22 : Underground utility detection before excavation works. 55

Figure 4.23 : Existing utilities indication slab. 56

Figure 4.24 : Sheet pile installed to prevent soil collision with warning tape 56

Figure 4.25 : Fault tree conducted for excavation and trenching accident occurrence...57

Figure 4.26 : Pipe placed on roller ready for pulling process. 59

Figure 4.27 : Illustrates the reamer, swivel, and pipe configurations. 60

Figure 4.28 : Testing swivel before attaching to rod for pipe pulling 60

LIST OF TABLES

Table 2.1 : Risk reduction weightage in percentage (%)...10

Table 2.2 : Risk register criteria and risk rating scale 12

Table 2.3 : Example of work activities causes of hazard in oil industry with risk level. 12

Table 2.4 : Number of recorded accidents in Malaysia Jan-July 2011..........................14

Table 3.2 : Description of the gate symbol..28

Table 3.1 : Description of the event symbol..28

Table 3.3 : Rating values for likelihood. 31

Table 3.4 : Severity values for severity 32

LIST OF SYMBOLS AND ABBREVIATIONS

AE	: Authorized Entrant
AGTES	: Authorized Gas Tester and Entry Supervisor
CIDB	: Construction Industry Development Board
DOSH	: Department of Occupational, Safety and Health
DOSM	: Department of Statistics Malaysia
EC	: Energy Commission
Eqn	: Equation
ES	: Entry Supervisor
FMEA	: Failure Modes and Effects Analysis
FMECA	: Failure Mode, Effects & Criticality Analysis
FTA	: Fault Tree Analysis
FW	: Fire Watcher
GPP	: Gas Processing Plant
HAZID	: Hazard Identification
HAZOP	: Hazard and Operability Analysis
HDD	: Horizontal Directional Drilling
HIRARC	: Hazard Identification, Risk Assessment and Risk Control
HSE	: Health and Safety Executive
ICOP 2010	: Industry Code Of Practice 2010
IOGP	: International Association of Oil & Gas Producers
JHA	: Job Hazard Analysis
LS	: Lifting Supervisor

NIOSH	: National Institute for Occupational Safety and Health
NOPSEMA	: National Offshore Petroleum Safety and Environmental Management Authority
OSH	: Occupational Safety and Health
OSHA 1994	: Occupational Safety and Health Act 1994
PE	: Project Engineer
PTW	: Permit To Work
QRA	: Quantitative Risk Assessment
SHO	: Safety Health and Officer
SOP	: Standard Operational Procedure
SP	: Standby Person
SSS	: Site Safety Supervisor
TMO	: Traffic Management Officer
TSCF	: Trillions of Standard Cubic Feet of Gas.

LIST OF APPENDICES

Appendix A: Survey Form………………………………………………………. 90

CHAPTER 1: INTRODUCTION

1.1 Introduction

Gas pipelines are mainly used as a medium of transportation to supply combustible gases such as natural gases from the gas processing plant to the industrial, power plants, and residential usage. Pipelines consist of two major stages which are known as upstream and downstream. Upstream is from the offshore platform where gas will be transferred from the origin through a subsea pipeline installed at the seabed to the gas processing plant (GPP) for the further process before supplying to the consumers. Downstream is where gas will be distributed to the consumers through onshore pipelines according to the required demand. One of the core factors of industrial bloom that leads to the economic development of a nation is the continuous affordable gas supply that can be used as fuel for goods production and power generation. According to the Energy Commission National Energy Balance 2016 report, natural gas contributes up to 41% of energy supply in the year 2016 which is ten times larger compared to the year 1983 and currently gas contributes the largest fuel contributor for power generation, small and large industries. Gas supply is the backbone of Malaysia's petrochemical industry that aids the significant expansion of downstream oil and gas industries.

Natural gas is expected to play a vital role in Malaysia's economy and assuring national energy supply security until 2050 with a total estimated resource in the year 2015 was 100 tscf which can withstand for another 40 years at the current production rate (Malaysia Natural Gas Industry Annual Review, 2016). To meet economical requirements, gas pipeline construction becomes highly necessary and has been carried out globally including in Malaysia to expand the pipeline networking to ensure the availability of natural gases meets the consumer's demand. The construction industry in Malaysia does not only contributes to the development of infrastructure but also an increased number of occupational accidents every year. Even though the government has taken several initiatives such as involvement of safety competence personnel, made compulsory training for workers, and continuous improvement on safety compliance procedures but still the accidental cases in the construction industry make a significant contribution to total occupational accident cases. Accident occurrence during pipeline construction might lead to severe consequences such as permanent disabilities and fatalities. This study focuses to identify the associated hazard, analyze and propose control measures for the risk involved in onshore pipeline construction. Proper risk assessment and implementation of control measures will help in reducing the number of accidents and cultivate safe work culture especially in high-risk construction industries such as pipeline installation works.

1.2 Problem Statement

In Malaysia construction industry contributes the largest number of fatalities among other occupational accident cases. As reported by the DOSH, in the year 2020 the number of fatalities was the second-largest which was 66 cases whereas in the year 2021 was 56 cases which contributes to the largest count. Even though there is a slight reduction in the number of cases, the total fatality in the construction industry is still high compared to other sectors. On the other hand, DOSM reports that the total number of occupational accidents in the year 2019 was 40,811 cases whereas in the year 2021 was recorded as 32, 674 cases and for the fatality was 312 cases and 266 cases in the year 2020 and 2021 respectively. The various factor could have contributed to the fatal incidents, but preventive action must be taken to overcome these issues. The government has imposed several policies such as the implementation of safety competence person to be on construction site to monitor, evaluate and advise on safety-related issues. Besides that, several government agencies such as DOSH and CIDB made it mandatory for the employer to train and qualify their employees for a particular task to be conducted to ensure a safe work system is established as a preventive measure to reduce worksite accidents. Nevertheless, all the implementation and action plan is in place, but still, several accidents are at a high pace. In the current practice of construction, many organization has established HIRARC as a comprehensive tool to minimize the number of accidents based on the past incidents and analyzed opinion adapted from experts in the related field, but still, accidents that lead to fatality occurs in workplaces especially in the construction field. This study focuses on developing a more comprehensive HIRARC that analyses the hazard associated with each task involved in gas pipeline construction. Then from the identified hazard, the risk assessment will be conducted and control measures will be proposed and implemented by stages to establish a safe workplace for gas pipeline construction.

1.3 Objectives

The objectives of the research are:

i. To perform hazard identification on the work step performed in the pipeline construction.

ii. To conduct a study on the possible risk assessment involved in pipeline construction.

iii. To propose control measures for the identified risk assessment and risk analysis.

1.4 Research Question

i. Why do pipeline construction accidents occur even though there is an established HIRARC is introduced?

ii. Does the contractor of work understand and comply with the developed HIRARC on the construction site?

iii. Who is responsible to ensure the strict compliance of the HIRARC to be carried out on the construction site, is it the contractor's personnel itself or the project owner/client?

iv. Does the developed HIRARC indicate all the work step together with the control measure or only list the critical task only?

v. Does the HIRARC indicate the severity of each task to be performed accurately and from what basis or benchmark does the severity is been identified?

1.5 Scope of Research

The scope of the study will be based on actual onsite gas pipeline installation works observation where each work step will be observed and possible hazard identification will be carried out and listed accordingly. Based on the hazard identification, risk analysis and assessment will be carried out. The implementation of control measures will be proposed with the opinion and suggestion from actual industrial experienced personnel and expertise. More comprehensive HIRARC will be developed as an improvement to the current existing HIRARC in pipeline construction works.

CHAPTER 2: LITERATURE REVIEW

2.1 Proposed Approach of HIRARC with Control in Oil Industry.

Identification and action mitigation of hazards for a specified work activity or task with controls is a structured process known as Hazard Identification and Risk Assessment with controls (HIRAC) where prioritizing and managing the risk is a common approach (M. Ismail Iqbal et al, 2020). Documented system which is a part of the Local Operating Management System (LOMS) is a procedure that clearly identifies the roles and responsibilities of every personnel. Assigned person must have the minimum capabilities and required training to carry out the responsibilities, where these should be documented accordingly (Y. Zhang et al, 2011). This system is also known as an effective HIRARC process to ensure every personnel involved is aware of the responsibilities and the possible risk that might occur upon executing the assigned task.

Risk assessment is divided into two parts which is qualitative and quantitative. Qualitative risk assessment is based on the opinion of the expertise involving many competencies. Quantitative is used in engineering and fabrication, which have been improved in some aspects such as development of the amount of data available, advancement of technologies, precision of analytical models and improvising data accessibility and storage over the years.

In this study, to ensure all possible hazard is identified, it is essential to conduct risk evaluation and assessment in order to identify the risk associated with the identified hazard. Several processes can be used to obtain identification of hazards such as previous experience of accidents, performs fault tree analysis to determine the possible potential hazards that might not be considered initially, record of safety statistics, work process evaluation, significant incident, near miss and accident reports and consultation with experienced employees. The information obtained can be divided into subcategories such as minor, major, likely and less likely hazards which can be examined separately and record the obtained findings. On the other hand, the main objective of risk assessment is to determine the hazards involved and put them into risk ranking with related control measures. Besides that, the risk assessment also can be used as tool to revise the implementation of risk control based on the previous assessment conduct, where it is a process of assessing the possibilities of the existing hazards that might lead to particular consequences or undesirable events of known severity (M. Ismail Iqbal et al, 2020).

Methodology adopted in this study is to assess the risk according to the ranking of the based on the occurrence probability on the exposed hazards. This can be specified in term of expose of people towards the hazards, individual hazards and potential consequences. Risk of such hazards is also dependent of the way of possibilities it can happens that is the probability, then the impact of the occurrence which is the consequences and also the exposure of the hazards that can be also be formulated as risk score where by:

Risk Score = Consequences x Exposure x Probability. (Unguras et.al, 2020)

The background of this study is based on a hydrocarbon industry which is been divided into three main components that is upstream, middle stream and downstream. According to the statistic obtained from IOGP bench mark report (2018), as shown in figure 2.1, the highest accidental domain area is at the upstream on the activity involving drilling operations. This is where the importance of the risk assessment takes place. Once the highest risk involving area is known, planning, safety mitigation such as risk assessment and management to be placed according to the assessed risk score to minimize any accidental to take place during drilling operations.

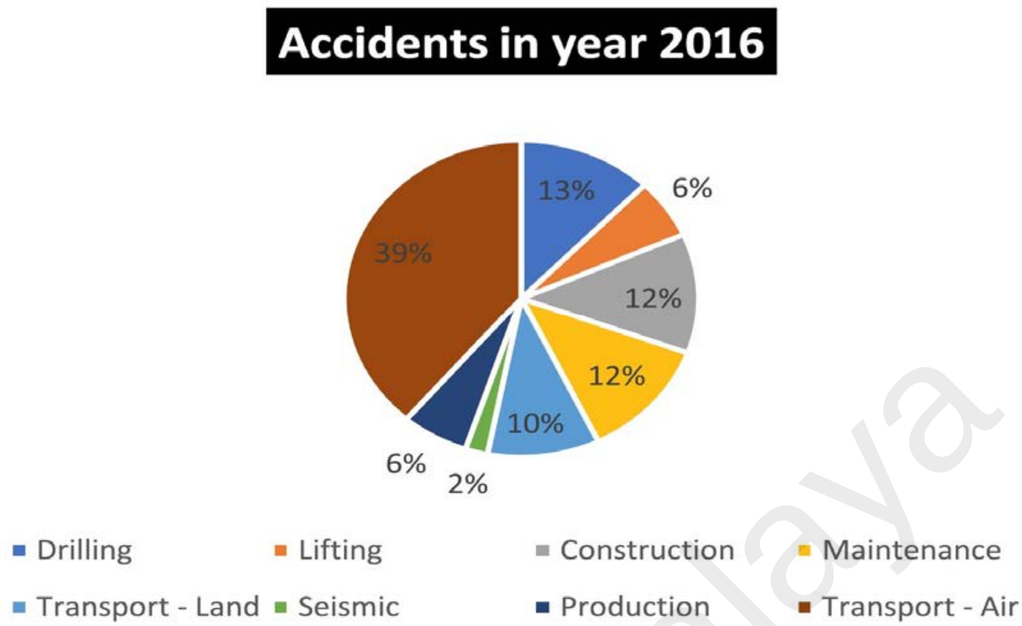


Figure 2.1: Accidents in domain area in 2016
(Source: IOGP bench mark report).

Poor risk management leads to increase in the accidental statistics as reported by IOGP. As shown in figure 2.2 and 2.3, the accidents at the domain area of drilling operation have increased from 13% in the year 2016 to 31% and 38.7% in the consecutive year of 2017 and 2018 respectively. Besides the drilling, other operations such as transportation and construction accidental case also shows an increment in number of cases.

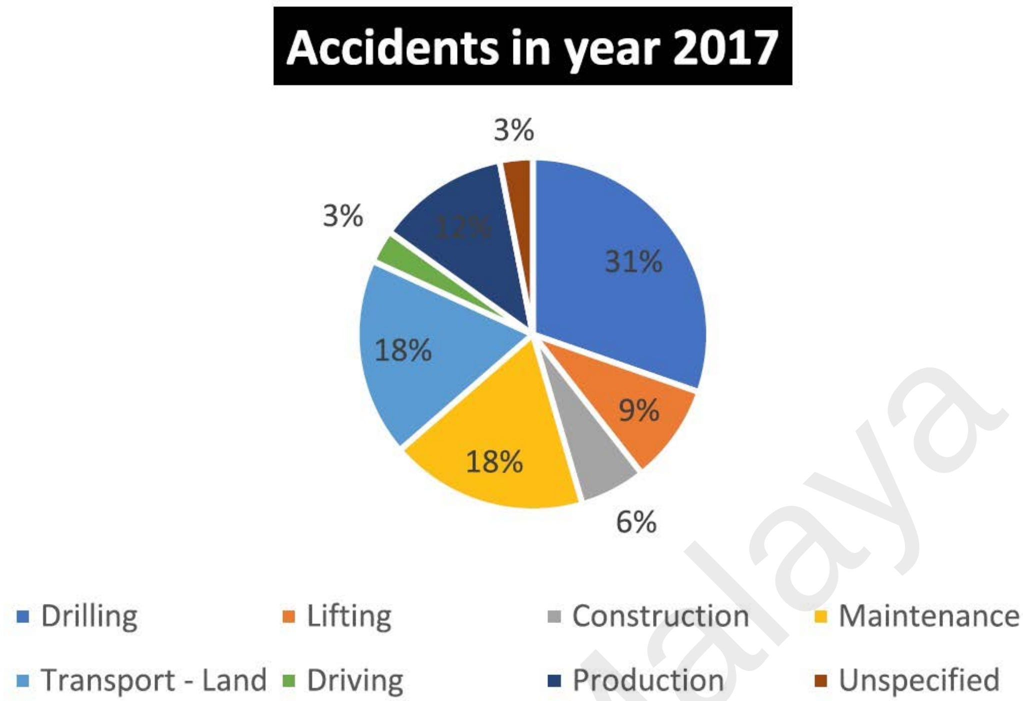


Figure 2.2: Accidents in domain area in 2018 (Source: IOGP bench mark report).

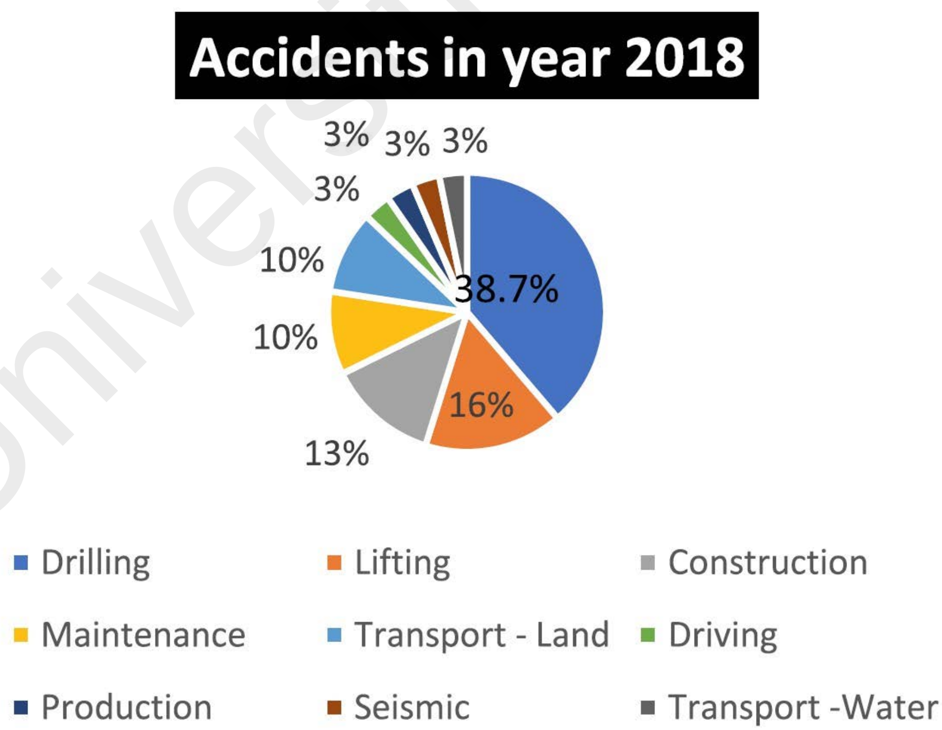


Figure 2.3: Accidents in domain area in 2018 (Source: IOGP bench mark report).

Risk identification, risk ranking and risk assessment play an important when it comes to the implementation of methods that controls the hazards. By executing risk ranking, both qualitative and quantitative can be identified, but in order to provide risk control, hierarchy of control is required. As shown in figure 2.4, in hierarchy of control, it consist of risk elimination, substitution, engineering control, administrative control and personal protective equipment (PPE). Implementation of hierarchy of control leads to a safe work system where it aids decrease the risk of injuries provided that the top most of the hierarchy provides the most efficient control method compared the one present at the bottom of the triangle. Proposed action plan for reducing the risk at workplace must emphasize higher priority to the top most element of the hierarchy of control compared to the bottom control methods as shown in table 2.1, where the percentage of risk reduction effectiveness that is developed based on risk control hierarchy based on the previous experience.

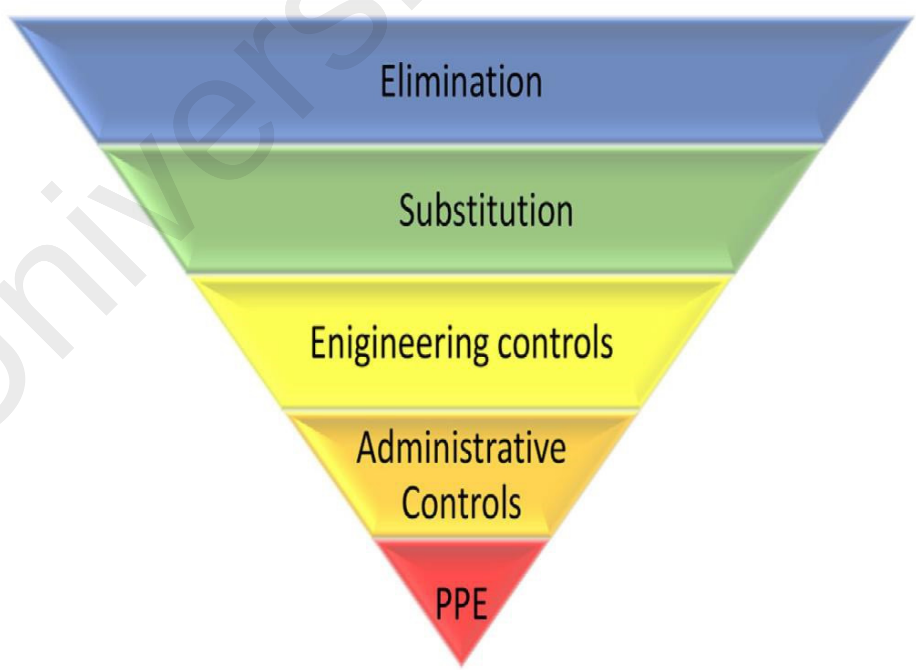


Figure 2.4: hierarchy of risks control (Source: M. Ismail Iqbal et al, 2020).

Table 2.1: Risk reduction weightage in percentage (%).
(Source: M. Ismail Iqbal et al, 2020)

Method	Risk Reduction or Effectiveness
Elimination	100%
Substitution	75%
Separation	50%
Administration	30%
Training	20%
PPE	5%

Besides that, potential to reduce, minimize or eliminate the risk using hierarchy of control can be considered based on the effectiveness that is given in term of percentage as shown in table 2.1. Before the consideration of replacing or even substituting the hazards, the first priority must be given to the hazard that can be removed physically from our workplace. Then, simplified solution can be applied by removing or eliminating the risk through re-engineered or improved process which improves the safety of the workflow that is involved in the process.

Global benchmarking companies and case studies revealed that, hydrocarbon companies undergoes several challenges such as productivity loses, lack in management of time, quality, cost, equipment, material and leadership due to cost overruns in term of major operations especially drillings. This results in poor project and operational deliveries. According to Hazard Identification and Risk Assessment report by NOPSEMA in 2020 and (Y. Zhang & LXing, 2011), as a result, risk assessment for poor project leads to lack of competent owner or contractor to supply quality and management capabilities, does not have a clarity in authority lines, discipline, and poor project scope and management duties, does not have capabilities to expand the current operating plants, less exposure to government authority requirements, safety requirements, construction practices and does not have sufficient knowledge in risk analysis.

On the other hand, technical risk assessment also must be taken into consideration which includes the well design that consist of surface and subsurface conditions. The assessment should be undertaken by team consist of petroleum engineers, drilling engineering, production engineers, geologists, geophysicists, reservoir engineer and completion engineer. Risk assessment conducted on the technical aspect should include the purpose, whether does it includes or excludes hydrocarbon, geological information, chemical hazards, petro-physical properties of well such as depth, temperature, pressure and various type of possible hazards that might be present which can be explosion, occupational health and chemical hazards (B. Vamanu et al, 2016).

Risk assessment technique can be divided into two, which are qualitative and quantitative assessments. In oil and gas industries, the widely used qualitative assessment is risk analysis procedure which can have several approaches such as HAZID, HAZOP, bow-tie analysis, FMEA and JHA. Quantitative assessment includes data and numeric values that can reflects the consequences and probabilities of the highest risk based on the activities through layers of protection analysis, FMECA, event tree analysis, fault tree analysis and QRA. Qualitative risk does not quantifies, hence it is challenging to account the risk rating, whereas the quantitative assessment provide risk ranking which can be scaled and tabulated as risk register criteria in an acceptable scale according to the work activities, potential and cause of hazards and risk level as shown in table 2.2 and 2.3. This approach helps to identify and evaluate the risk associated with the hazards to ensure the organization pre-plan the work flow of any activities before potential hazards takes place and provides a mitigation plan to minimize the hazards present in the work activities.

Table 2.2: Risk register criteria and risk rating scale. (M. Ismail Iqbal et al, 2020)

Risk Register					
Consequence Criteria	Scale	Expose Criteria	Scale	Probability Criteria	Scale
Many Dead	5	Continuous	10	Expected	10
Only One Dead	1	Daily (Regularly)	5	likely	7
Chance of Fatality	0.3	Weekly (often)	3	Rare but chance of possibility	3
One Permanent Disability	0.1	Monthly (unusual)	2.5	Possible only when in remotely	2
Small Chance of Fatality	0.1	Yearly (occasionally)	2	Conceived but unlikely	1
Many Lost Time Injuries	0.01	Once in 5 years	1.5	Not possible practically	0.5
One lost time injury	0.001	Once in 10 years	0.5	Not possible virtually	0.1
Small injury	0.0001	Once in 100 years	0.02		
Scale of Risk Rating					
Intolerable Risk					>90
Very High Risk					75-89
High Risk					45-74
Substantial Risk					20-44
Moderate Risk					10-19
Risk Perhaps acceptable					0-9

Table 2.3: Example of work activities causes of hazard in oil industry with risk level. (M. Ismail Iqbal et al, 2020).

	Work Activities	Cause of Hazard	Associated Effects	Consequence	Exposure	Probability	Risk Level
1	Maintenance Operation	Using tongs and slips during drilling, trip-in and out	Injury to personnel	5	10	7	350
2	Maintenance Operation	Slip/Trip due to mud/oil	Physical Injury	1	10	7	70
3	Vehicle Movement	Fire due to spark	Fire Hazard	5	5	3	75
4	-	Cyclone	Damage to plant, Equipment, Physical Injury.	5	2	3	50

2.2 Integration of Occupational Safety and Health during Pre-construction Stage in Malaysia.

Implementation of Occupational Safety and Health (OSH) during the pre-construction stage for both construction and industrial provides an advantage step for the OSH management in term of early consideration of safety and health requirement that assist in effective way in to elimination or reducing hazards from the source (DOSH 2008). The aim of the study is to determine the OSH elements of construction industries involved in the pre-construction stage. Reasons for this study to focus on the OSH practices during the pre-construction stage involves construction industry is to reflect the gap that is to be filled to up keep the standards and improvements that is currently been practiced in other countries (Saifullah N..M et al, 2012).

As shown in table 2.4, in the year 2011, eight (8) out of twenty-five (25) fatality cases reported to Department of Occupational Safety and Health Malaysia is from the construction industry which contributes about 32% of the incidents occurs due to no safe work procedure established and other comes under the scope of management controls (CIDB, 2009; DOSH, 2011; HSE, 2003). Increasing in the number of accidents and health issues from OSH raised concern within the construction industries (Solicitors, 2010). Due to this increasing number of OSH incidents, construction industries have been labeled as the most hazardous industry that contributes to the highest number of incidents and fatalities. According to (Haywood, 2004), OSH problem is not only comprises from the management at construction stage, but also throughout the entire project duration which also include the pre-construction and post construction.

Table 2.4: Number of recorded accidents in Malaysia Jan-July 2011. (Source: DOSH, 2011)

No	Classification of Accident	Date	Industry	Reason
1	Pinched	31-07-2011	Workshop	No Safe Work Procedure & Not competent.
2	Crushed by falling object	28-07-2011	Construction	No Safe Work Procedure
3	Fall from height	04-07-2011	Office	No monitoring
4	Fall	02-06-2011	Construction	Crane not well maintain & no inspection
5	Rolled over by object	31-05-2011	Factory	No Safe Work Procedure
6	Crushed by object	23-05-2011	Construction	No Safe Work Procedure
7	Buried alive	17-04-2011	Estate	No Safe Work Procedure
8	Suffocation	17-04-2011	Services	No Safe Work Procedure
9	Crushed by object	14-04-2011	Logging	No Safe Work Procedure
10	Fall from height	09-04-2011	Construction	No Safe Work Procedure
11	Fall from height	05-04-2011	Construction	No Safe Work Procedure
12	Crushed by object	29-03-2011	Estate	No Safe Work Procedure
13	Rolled over by object	26-03-2011	Estate	No Safe Work Procedure
14	Wedged	25-03-2011	Factory	No Safe Work Procedure
15	Struck by object	16-03-2011	Factory	No Safe Work Procedure
16	Fall	09-03-2011	Service	No Safe Work Procedure
17	Hit by object	01-03-2011	Estate	No Safe Work Procedure
18	Fall from height	24-02-2011	Construction	No Safe Work Procedure
19	Hit by object	14-02-2011	Logging	No Safe Work Procedure
20	Drowning	13-02-2011	Mining	No Safe Work Procedure
21	Fall from height	12-02-2011	Construction	No Safe Work Procedure
22	Hit by object	27-01-2011	Estate	No Safe Work Procedure
23	Fall from height	12-01-2011	Factory	No Safe Work Procedure
24	Fell and buried alive	03-01-2011	Construction	No Safe Work Procedure
25	Fell into machine	02-01-2011	Factory	No Safe Work Procedure

Construction project management is mainly divided into three (3) parts which are Pre- construction, Construction and Post-construction as shown in figure 2.5, (K.S., 2002; Tregenza, 2004). Inception and Feasibility, Design, and Tendering is covered in the pre- construction stage (K.S., 2002). This stage focuses on the client requirement such as aim of the projects, land issues, feasibility study and establishing the organization chart. Whereas for design, it covers the conceptual, schematic and detailing design development, cost estimation, obtaining planning approval and engineering aspects (Hendrickson & Au, 2000). The final stage of pre-construction will be tendering where the complete details of the project will be issued for evaluation and selection of appropriate contractor for work execution (College, 2011). Even though, several key personnel such as engineers, town planner and quantity surveyors, but the responsibilities of the entire project for the pre-construction stage fall under the project owner (Hung, 2006).

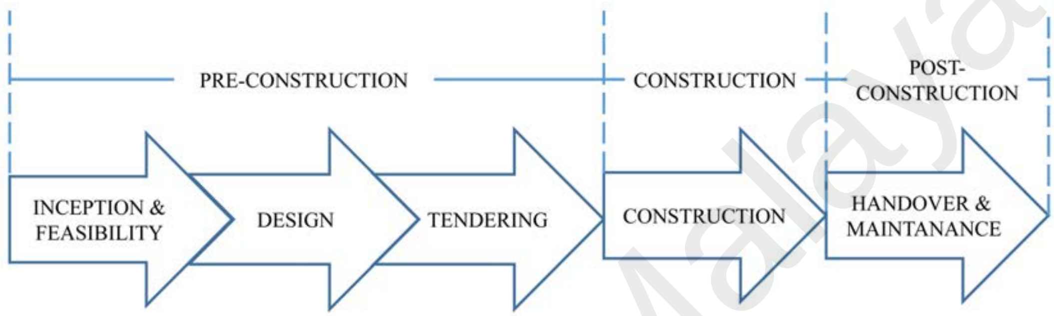


Figure 2.5: Stages involves in the Construction Project Management. (Source: K.S., 2002; Tregenza, 2004)

Success of the project is depending on the effective planning that is designed during pre-construction stage. According to Waly & Thabet (2003), macro planning play an essential role in pre-construction planning where the major decision influences the delivery and execution of the project. Design and planning which is under pre-construction stage is a upstream activities which requires more attention from the government on the OSH element compared to the construction that is categorized as downstream activities (Sulaiman & Mahyuddin, 2005).

In the inception and feasibility stage, numerous common health and safety problems that faced during construction and operation period can be prevented if problem consideration is taken into account while project brief and design stage during pre-construction (Haywood, 2004). According to Section 15 in OSHA (1994) mention, employer is accountable to his employees' safety & health. At the same time, Employer also has a responsibility for the visitor or public as state in Section 17 (OSHA, 1994). In this context, the project owner have the full responsibility to raise a concern and include

OSH during objective identification and project brief. Since the project owner is the major contributor for the project funding, they can positively control the project safety and health performances (Huang & Hinze, 2006; Sulaiman & Mahyuddin, 2005). Moreover, since the safety and health of the employee is under the employer's management responsibilities, change of the behavioral towards safety is also meant to be employer's responsibility to ensure the employees obey the imposed Safety and Health implementation in the workplace (Thye, 2006).

Design plays an important role in getting the construction to be completed according to the required specification and standards. In most of the construction execution, designs will be more focusing on the engineering phase of the project completion and deviated for the safety part to follow the minimum requirement required by the local authorities. Despite, inadequate design emphasis lead to half of the occupational safety and health issue to be increased (Flemming, 2005). According to Gambatese (1996), this occurrence is due to the design professional who deviated themselves from emphasizing the safety design just because they have a limited safety education and training, safety design tools and to reduce the exposure towards the liability itself. On the other hand, the architect and engineers should work towards to build it safely, rather than just build it to create a safer workplace besides focusing on changing the attitudes of the bottom pier. Safer construction industries will only be created if the health and safety factors becomes part of the design to ensure the construction player to put a higher considerations (Hung, 2006).

Final stage of pre-construction is the tendering, where the entire project covers the standards, requirement, completion and handover which need to be documented and legalized in written form. Safety and health is one of the elements that consist the legal and moral responsibilities that needs to be undertaken by the contractor and clients to meet the safety performance (Huang & Hinze, 2003). Working in efficient manner is key point here rather than following the traditional procurement method that only focuses on the tender cost that indirectly restricts the contractor's efficiency (Flemming, 2005). Besides that, tendering need to be more focusing on the element of best value which does not only considering to reduce the tender cost, but also the capabilities to look into many criteria such as prediction of possibilities for safe project performance and equality of application bid by other contractors for the overall evaluation (Levitt, 1981). This practice does not only reduce the helps to reduce the safety and health hazards, but also improve the productivity which helps the project deliverable for the contractors.

2.3 Ranking of human factor affecting contractor's risk attitude in the Malaysian construction industry.

Risk management consist of several elements, where one of the process is defining, analyzing risk and deciding the appropriate action that can be taken or implemented to reduce the risk while achieving the goals of the company. Proper project implementation should consider and include all the risk management process steps that required to handle the risk. In the process of the building erection, construction risk management is essential due to the nature of the construction industry (Liu et al., 2010). Construction industries are the largest and important economic contributor for Malaysia which certainly involves many processes such as initiating, planning, controlling, executing, and closing involves high level of risks. Among construction companies, usually the risk can be identified within the processes involved in the project management (Taofeeq & Adeleke, 2019). According to (Tserng et al., 2009), risk management must be carried out from the initial stage of the construction until the commission of the project because the construction industry is overloaded with risk compared to other sectors due the complex process involves in erecting the entire construction projects. Managing risk in construction project is very important that leads to the achievement of the project in term of time, cost, quality, safety, and environmental sustainability.

The objective of the study conducted is to identify the standing on construction risk management among contractors and to rank the particular factor that affecting the risk attitudes among the contractors of Malaysian construction companies. Likert sale from one (1) to five (5) is used to collect the data in risk management and ranking human factors that influences the contractors behaviors for Malaysian construction company. Focus of the study was on the five leading factors such as work experience, physical health, educational background, professional competence, and emotional intelligence that is not highly implemented by G7 contraction in Malaysian construction industry.

According to a previous study conducted by (Kartam & Bouz, 1998) in Kuwaiti which analyzed construction companies reveals that root cause of the accidental occurrence that happened to works was due to false acts, poor safety performance, insufficient cleaning, and unusable materials, destiny, poor maintenance of the tools, faulty supervision, and misplacement of items. More detailed publication study from the United States relates that the root cause of the accidents is by the humans and physical influences (Abdelhamid and Everett, 2000) that includes the discarded personal protective equipment (PPE), operating equipment without authorization, working at unsafe speed, personal factor, insufficient of safety devices, fixing of moving and energized machinery, hazardous place or posture, usage of faulty equipment or facilities, and other dangerous behaviors. Besides that, another study conducted by (Lubega et al., 2000) in Uganda reveals another perspective. In Uganda, the cause of accidents happens was mainly due to insufficient knowledge and implementation of safety regulations, lack of understanding of health by people participating in construction projects, the participation of inexperienced personnel non-vibrant professionalism, technical failure of construction machinery and equipment, physical and emotional stress. According to Adeleke et al.,(2016b) and (Bamgbade et al., 2017), 90% of accidental occurrences is due to the human error whereas another 10% is due to technical error due to uncontrollable conditions, where most of the time, the contractor only enforces the minimum training requirement for the workers and managers.

Attitude of the people who have confident in the task they perform influence the behaviors, where they believe on the confident of capabilities to perform that is influenced by the intended behavior according to the resource availability, competency, other people's encouragement, and prior experience with the conduct in question. Workers with sufficient knowledge, preparation, skills and experience will be more motivated and dedicated for their duties and position and reflect a good behavior in term of complying to the with organizational safety requirements (Mohd Zakir, 2012). It is known that, a professional employee always have the readiness that is needed for high performance at work, competitiveness, and, most importantly is the safety values.

Even though an individual reflects a positive behavior by safety compliances, government as a policy maker have a significant role as a moderator in providing a policy that act as a guidance for the establishment of organizational regulations. Government policy could be a starting point to implement the necessary action to be taken to be benefited in real-life changes which targeting on maintaining a safe working environment in the construction business (Rahim et al., 2003). As shown in figure 2.6, the conceptual framework suggest that, the contractor's risk attitudes among construction companies in Malaysia might be influenced by the work experience, physical health, educational background, professional competence, and emotional intelligence as human factors with government policy which is rules and regulations as the moderator. Rules and regulation are the base governance for establishment of statement and standard or procedure as a general guidelines to be adopted and practice an organization board that facing some issues related to types of construction risk management to be applied, process and steps involve before project execution and safety of employees (Adeleke et al., 2019).

According to study conducted by (Gibb, 2011) and (Niu, 2010), discovered that organization that complies effectively to the rules and regulation implemented by the government, where the policy itself act as a moderator on the relationship between human factors and contractors' risk attitudes are less likely to be affected with construction risk.

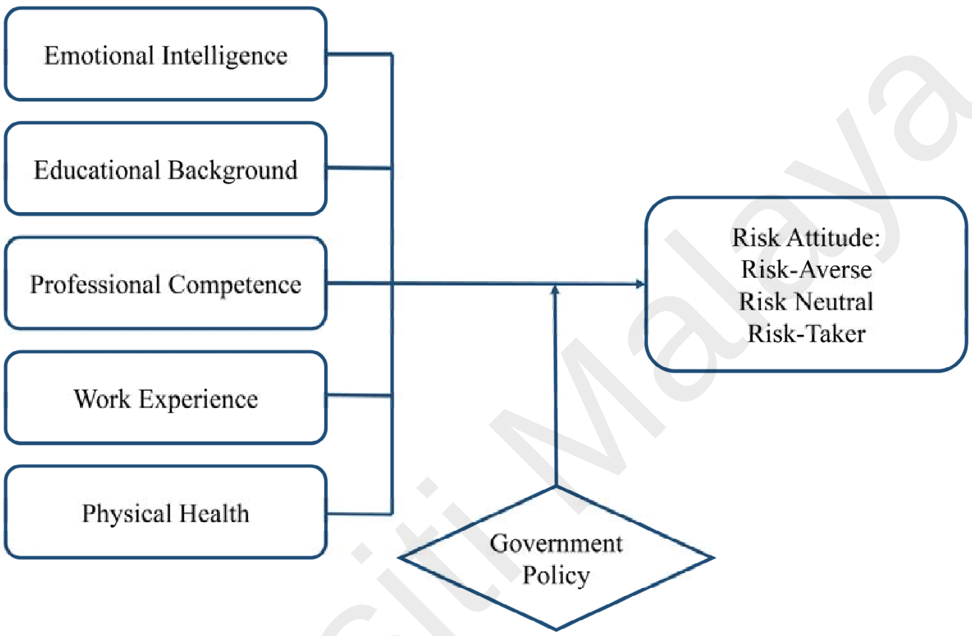


Figure 2.6: Conceptual framework where Government Policy as a moderator (Moshood et al., 2020).

CHAPTER 3: METHODOLOGY

3.1 Introduction to Methodology

The methods used in this study are to reveal the root of cause and practice that is been carried out in pipeline construction. Several methods are adapted to study hazard identification, risk assessment, and risk control. Control measure is also recommended and implemented to observe the improvement of the safe working system. To achieve that, this study is conducted on an actual gas pipeline installation construction site with the flow of methodology which is executed as preliminary works to acquire some input for the analysis.

Classification of major work steps in gas pipeline construction works will be identified and classified step by step from the commencement of work up to pipeline commissioning to form the HIRARC table. It is important to ensure the workflow is listed accordingly so that even the person who is not involved in gas pipelines construction understands the entire process such as visiting authorities and area owners. The commencement of pipeline construction will be excavation which has a lower risk compared to the commissioning part, which requires purging of high-pressure gas during the gas in phase.

Consultation is done to obtain the opinion and suggestions from experienced and competent personnel for information gathering based on past experiences and accidents together with the improvement that has been implemented. Experienced construction personnel and expertise will be referred to adopt a safe work system for the particular work step. Learning from past incidents will provide a better step in implementing new systems which will be more comprehensive to prevent the previous mistake through lessons learned.

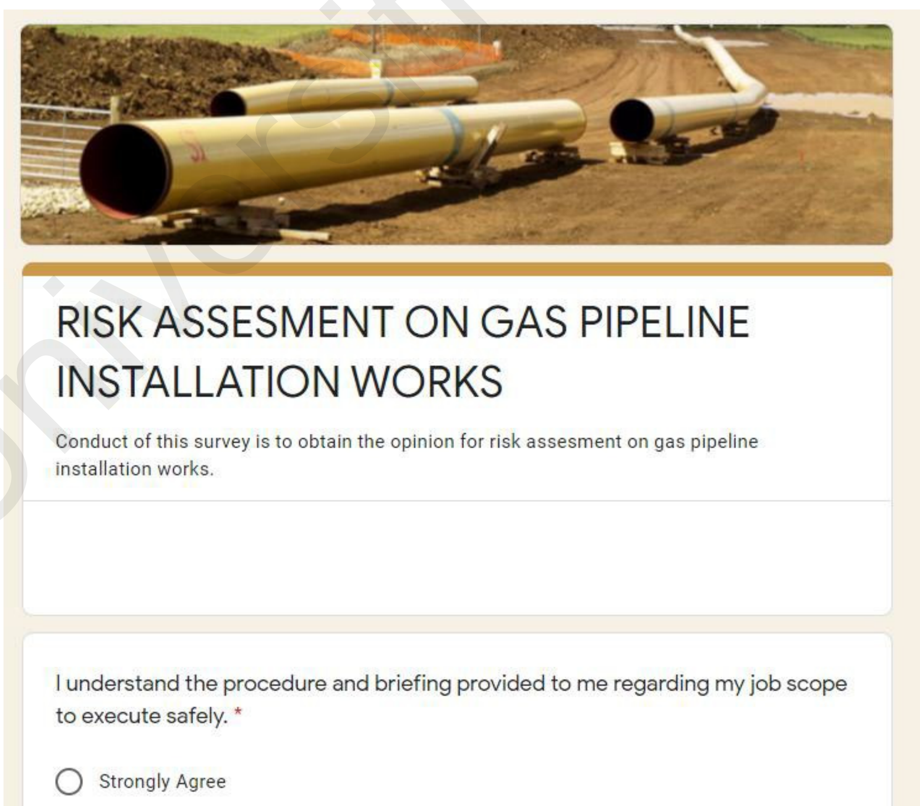
Then, identification of hazards will be conducted according to the involved work step based on on-site observation and all the identified hazards will be listed accordingly. Hazard identification is a part of the process used to find and record possible hazards that may be present in any workplace. Based on the identified hazard, risk assessment and control measures can be conducted according to the severity of the hazard. Hazard identification can be implemented before the task commencement, during the conduct of the task, during the site inspection, and upon accidental occurrence. In this study, one of the methods used in identifying the hazard is through site observation to conduct risk assessment and control measures for better implementation of safety on gas pipeline construction sites.

The risk assessment will be assessed based on the identified hazard, the severity of the task, and the frequent times of accidents that occur in the industries that involve the particular work step. In this study, some high-risk activities have been identified to conduct a risk assessment and propose control measures for the implementation. High-risk activities in gas pipeline construction such as excavation, Horizontal Directional Drilling (HDD), welding works which involve hot work and lifting activities. Through the conduct of risk assessment, analysis on the possibilities of a person getting harmed or injured based on the associated hazard can be identified and potentially reduce the risk of accidental occurrence to take place on construction sites.

Preparation of risk control action plan is based on the proposed control measures that will be a part of the HIRARC according to the identified hazards and conducted risk assessment. The main objective of the control measure is to eliminate a hazard or at least reduce the risk of exposure to an acceptable level. As priorities on the hierarchy of control, from most effective to the least effective, hazard associated with the task conduct can be controlled or minimized to reduce the damage caused by the risk to enhance a safe working environment.

3.2 Conduct Survey Analysis

As shown in Figures 3.1 and 3.2, the distribution of the survey is given to the pipeline construction personnel to obtain their opinion on pipeline construction work for the risk assessment based on the response provided in the survey form. The survey is conducted using Google form and the data obtain to be analyzed for the HIRARC improvement and development process. A simple questionnaire is developed with a discussion with safety competent personnel and experienced individuals in the pipeline construction. Discussion conduct with experienced personnel provides insight into the safety aspect and the actual practice that is been carried out on site which varies among other organizations. Data collected through this survey will be analyzed and discussed on the improvement that can be done for the workplace based on the collected opinion from the people working in the same field of construction.


RISK ASSESMENT ON GAS PIPELINE INSTALLATION WORKS

Conduct of this survey is to obtain the opinion for risk assesment on gas pipeline installation works.

I understand the procedure and briefing provided to me regarding my job scope to execute safely. *

Strongly Agree

Figure 3.1: Google Form used for Survey Conduct.

Question asked in the survey conduct comprises the safety, procedure compliance, training, appropriated personal protective equipment (PPE) and understanding the risk of the work with own evaluation. It is an essential practice to understand the procedure and the ability to recognize the risk of the workplace before we conduct any task. It is expected based on the survey to obtain the variable trend that can explain the entire picture of the construction personnel on their opinion of the current working construction site for gas pipeline installation works.

Advantages of the survey conduct method are, a large amount of data from respondents can be collected remotely via the online method by just using a mobile phone in a shorter period compared to another analysis method. In this study, data collecting is done remotely from respondents from different sites located in different states which makes the administration cost-effective, easy to manage by just sending links for the survey, and summary of responses is presented graphically by the Google form concurrently while the survey is answered by the respondents. Despite that, the disadvantage of the survey conduct is the data integrity that is based on the respondents' honesty in answering the questionnaire. The answer also depends on the interpretation of the question asked in the survey by the respondent which might lead to misunderstanding and affects the output of the survey.

Figure 3.2: Construction personnel answering survey questionnaire.

3.3 Site Observation

Conducting a site visit for the activity observed is important to identify the associated hazard within the task being carried out on site. Physical observation leads to appropriate findings of the unsafe act and unsafe condition which can be rectified immediately without any delay at the same time of the occurrence. Eventually, this method will reduce the risk of accidental occurrence. Sometimes, workers might not aware of the unsafe conditions that are present on-site, but as a management team, the responsibilities are there to observe the site and advice accordingly. Besides that, higher possibilities of accidents usually occurring on site are due to the unsafe act, where the supervisor and workers take the shortcut way to complete the task. For example, going into the confined space without informing or confirmation of AGTES personnel might lead to breathing suffocation if there is any poisonous gas or oxygen deficiency present in the location.

Figure 3.3: Management walkabout on construction site.

In this study, the method of site observation is conducted more to the inspection way to identify the risk associated with activities that involved in gas pipeline construction works and the output of the observation for three selected activities which is confined space activities, welding works, and lifting operation is discussed according to the practice and compliance that is adapted by the construction organization. Besides that, as shown in figure 3.3, site observation is also conducted during the monthly management walkabout onsite joined by client representative, project management, and safety team. Observed unsafe act, unsafe condition, and hazard are discussed and minutes of monthly safety meeting is recorded to be rectified in the given timeframe. Finding will be included in the risk assessment and control measures will be implemented on-site to enhance safe work culture.

The advantage of the site observation method is, the risk associated with the particular task can be observed and rectified onsite immediately compared to other methods that required detailed analysis. It is easy to propose a control measure that is practical to be implemented according to the site conditions. Do not depend on others to provide the current site condition that might be varied and inaccurate depending on their way of understanding and experience in identifying the hazard and risk. The disadvantage of the site observation method is the limitation to looking through the risk of the entire process within the same time and activity conduct. This is because, each time during the observation, the way the task is performed might be slightly different to suit the site conditions. So the hazard and risk associated might defer, for example, excavation during dry and raining seasons might be slightly different, as rainy seasons provide a swampy and muddy ground that requires special care for excavation to avoid third-party utility damages that share the same corridor with our proposed alignment of gas pipeline. Besides that, site observation is also considered less cost-effective, as we have to travel to the site to conduct the study and obtain the required information.

3.4 Fault Tree Analysis

Fault tree analysis is another method adopted in this study to conduct the risk assessment associated with a particular activity involved in gas pipeline construction works as shown in figure 3.4. Generally, fault tree analysis (FTA) is used in failure analysis to understand the possibilities of the system failure using Boolean logic that consist of a combination from top to bottom event and is widely used in safety and reliability engineering to understand the occurrence of the system failure. FTA analytic method is where an undesired event will be selected, and as a subsystem, the combination of the basic event will be identified which lead to the failure of the predefined system (Vesely WE et al., 1981). As shown in figure 3.4, the entire identified events will be presented in a graphical view for the analysis.

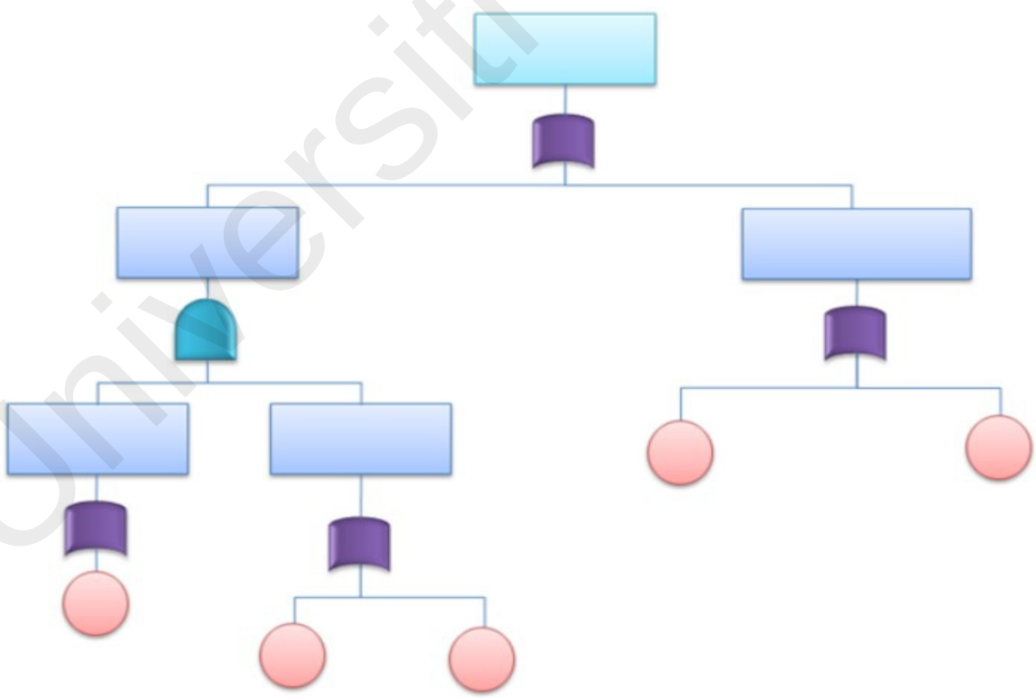


Figure 3.4: Fault tree diagram with the combination of event symbol and logic gates.

Table 3.2: Description of the event symbol.

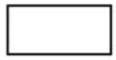
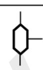
Symbol No	Event Symbol	Description
1		Symbol used for representing random event and sufficient data is made available in primary and basic failure event.
2		Represents the state of system, subsystem or component event.
3		Represents secondary failure or developed event, can be explored further.
4		Conditional event and is associated with the occurrence of some other event.
5		Represents either occurrence or non-occurrence of an event.
6	 In  Out	Transfer in and transfer out symbols uses to replicate a branch or sub-tree of the Fault Tree Analysis (FTA)

Table 3.1: Description of the gate symbol.

Symbol No	Event Symbol	Description
1	 AND Gate	The output event occurs when all the input events occur.
2	 OR Gate	The output event occurs when at least one of the input events occur.
3	 Priority AND Gate	The output event occurs when all the input events occur in the order from left to right.
4	 Exclusive OR Gate	The output event occurs if either of the two input event occurs but not both.
5	 Inhibit Gate	The output event occurs when the input event occurs and the attached condition is satisfied.

As shown in Tables 3.1 and 3.2, fault tree analysis uses event and gates symbols to form the FTA diagram. The first step in the development of the FTA is to identify the top event. In this study, two main events of the gas pipeline construction are selected separately which are physical excavation and trenching and another method of gas pipeline installation is the trenchless technology known as Horizontal Directional Drilling (HDD). Analysis of both events will be conducted using FTA to know the severity of the events in case accidental takes place and the associated subsystem that leads to the occurrence of the main event. Secondly, once the top event is identified, then the first level is to be identified, which is also known as the subsystem which will be based on the preliminary works conducted, such as the gathering of details and site observations. Then, link the obtained information way through to the top event to identify the suitable logic gates to be applied to the FTA diagram. Using the same step, another level of contributors will be linked until the basic causes. As a final step, once the FTA is completed, the analysis will be conducted and probability from bottom to top event occurrence will be calculated will be converted to percentage to analyze the tendency of the accidental occurrence for the selected top event.

Using FTA for risk analysis provides some advantages such as the fault tree diagram itself uses visuals for interpretation that helps the risk assessment process to be conducted more efficiently through the linked event symbols and logic gates instead of long words. FTA highlights the critical components which are linked to system failure and the occurrence of the top event that can be easily seen through the developed diagram. Besides that, FTA provides both quantitative and qualitative analysis for the assessment consideration. Compared to another analysis method, FTA includes human error consideration in the conduct of the analysis. On the other hand, FTA has several disadvantages which are complicated top events might have a complex diagram with numerous usage of event and logic gated to be evaluated. The analysis and probability will only focus on one top event at a time. It also requires experienced personnel to come up with possible contributors and logic gates to be applied according to the selected top event occurrence.

3.5 Proposed HIRARC Form

Generally, the HIRARC form is developed to identify the hazard, conduct risk assessment, and provide control measures for the task involved in gas pipeline construction work. The HIRARC form is adapted from the Guidelines for Hazard Identification, risk assessment, and Risk Control published by the Department of Occupational Safety and Health (DOSH) Malaysia in 2008.

As shown in figure 3.5, the HIRARC form begins by listing the work activity up to the recommended control measure and the person in charge to ensure the implementation within the provided time frame. In this study, the method used to develop the HIRARC form is by listing down step by step all the activities involved in the gas pipeline construction. Then based on the site observation, survey conduct, consultation with experienced personnel, previous incidents, and safety discussion conduct, analysis for likelihood, severity, and risk is identified.

HIRARC FORM			
Company		Conducted by: (Name, Designation) Date : (from….to…)	
Process/Location:			
Approved by: (Name, Designation)			
Date:		Review Date:	Next Review Date:

1.Hazard Identification				2.Risk Analysis				3.Risk Control	
No	Work Activity	Hazard	Which can cause/effect	Existing Risk Control (if any)	Likelihood	Severity	Risk	Recommended Control Measure	PIC (Due date/status)
1									
2									
3									
4									
5									

Figure 3.5: HIRARC form (Source: Guideline HIRARC DOSH,2008).

According to the guidelines of HIRARC published by DOSH in 2008, the risk is the combination of the likelihood and severity of a specified hazardous event occurrence which can be equated in a mathematical term as;

Risk = Likelihood x Severity (Equation 1) -Source: Guideline HIRARC DOSH)

The likelihood is the possibility of the event happening within a particular time or condition, whereas severity is the output from the event which indicates the condition of severe injury for people, property damage, impairment to the environment, or a combination of those events. As shown in table 3.3, the likelihood is given a rating from most likely to inconceivable based on how frequent is the event can occur and according to that, the rating is determined. Whereas for severity, as shown in table 3.4, it is divided into five categories which are based on the highest severity of catastrophic that might cause multiple fatalities to the lowest level of negligible, that indicate only minor cuts injuries that can be given first aid treatment. Then risk analysis will be based on the assigned rating of likelihood and severity values as mentioned in equation 1 and will be determined based on the risk matrix as shown in figure 3.4. Based on figure 3.5 risk ranges in three different categories, which are high, medium, and low based on the obtained risk matrix.

Table 3.3: Rating values for likelihood. (Source: Guideline HIRARC DOSH,2008).

LIKELIHOOD (L)	EXAMPLE	RATING
Most likely	The most likely result of the hazard / event being realized	5
Possible	Has a good chance of occurring and is not unusual	4
Conceivable	Might be occur at sometime in future	3
Remote	Has not been known to occur after many years	2
Inconceivable	Is practically impossible and has never occurred	1

Table 3.4: Severity values for severity. (Source: Guideline HIRARC DOSH,2008)

SEVERITY (S)	EXAMPLE	RATING
Catastrophic	Numerous fatalities, irrecoverable property damage and productivity	5
Fatal	Approximately one single fatality major property damage if hazard is realized	4
Serious	Non-fatal injury, permanent disability	3
Minor	Disabling but not permanent injury	2
Negligible	Minor abrasions, bruises, cuts, first aid type injury	1

	Severity (S)				
Likelihood (L)	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5

Figure 3.6: Risk matrix. (Source: Guideline HIRARC DOSH,2008).

RISK	DESCRIPTION	ACTION
15 - 25	HIGH	A HIGH risk requires **immediate** action to control the hazard as detailed in the hierarchy of control. Actions taken must be documented on the risk assessment form including date for completion.
5 - 12	MEDIUM	A MEDIUM risk requires a planned approach to controlling the hazard and applies temporary measure if required. Actions taken must be documented on the risk assessment form including date for completion.
1 - 4	LOW	A risk identified as LOW may be considered as acceptable and further reduction may not be necessary. However, if the risk can be resolved quickly and efficiently, control measures should be implemented and recorded.

Figure 3.7: Risk range indication. (Source: Guideline HIRARC DOSH,2008)

CHAPTER 4: RESULT & DISCUSSION

4.1 Survey Analysis

The survey conducted consist of eleven questions that covers, knowledge, understanding, compliance, training, and safety practice at the gas pipeline construction site. A total of 127 participants have provided their responses based on their points of view. Participants come from different organizations but in the same field of gas pipeline construction. Based on the result obtained through the survey, analysis for the risk assessment can be conducted and possible control measures is can be implemented on-site.

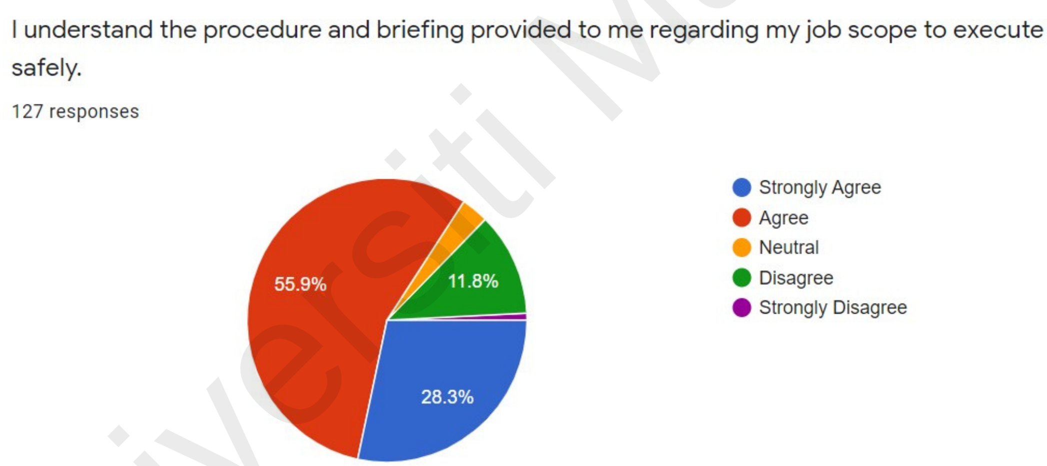


Figure 4.1: Question 1 and result obtained from respondents from the survey.

As shown in figure 4.1, the first question aims to obtain the data for the understanding and validity of the safety briefing conduct based on the personnel job scope conduct. The idea is, different job scopes should be briefed separately on the procedures and hazards involved in the task execution. The obtained result shows that 28.3% have strongly agreed, whereas 55.9% have agreed which shows the majority of the person knows and understand the procedure and work briefing conducted. Whereas 3.1% is at neutral, 11.8% disagree and only 0.8% have strongly disagreed. This shows that most of the construction personnel are aware of the procedure and scope of the task to be carried out.

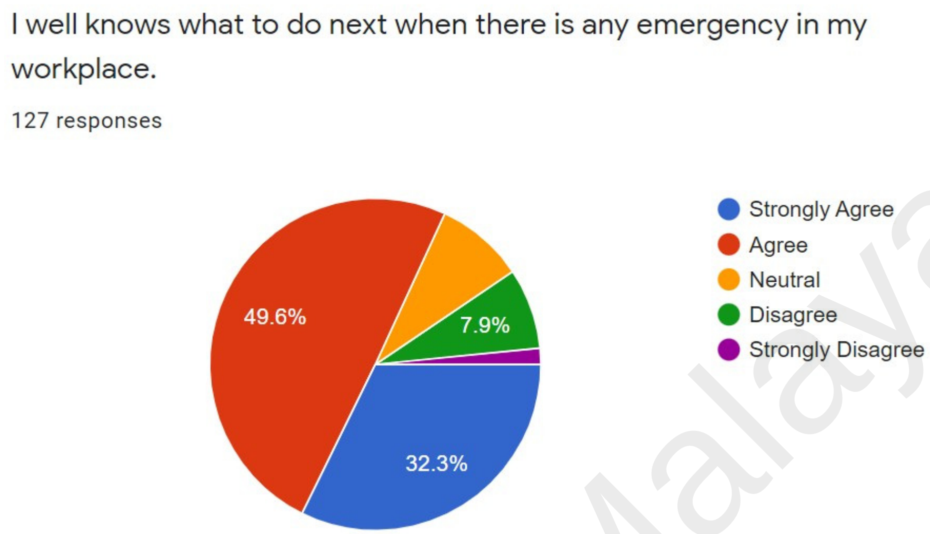


Figure 4.2: Question 2 and result obtained from respondents from the survey.

In some organizations, site emergency procedure is well established, but there is no demonstration is carried out on-site from time to time for the workers to well verse on what they supposed to do during an emergency including familiarizing with the emergency assembly area. Question 2 on the survey aims to obtain knowledge of the construction personnel in case of an emergency on-site. As shown in figure 4.2, 32.3% have responded strongly agree, 49.6% have agreed with the statement, which shows that the majority of them understand and know what to do during an emergency onsite. Then, 8.7% in neutral, which neither agree nor disagree, who probably might not have sufficient knowledge and awareness on the emergency evacuation. Whereas 7.9% of the respondent disagree and 1.6% strongly disagree, where this category of personnel might not have any knowledge or even be aware of the existing emergency procedure. Management of the organization should take a vital step by conducting demonstrations and least twice a year.

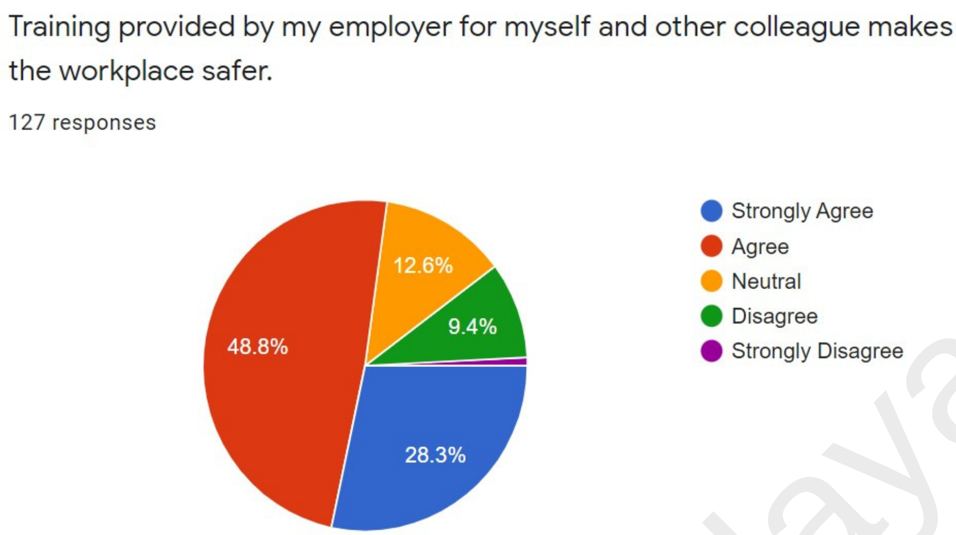


Figure 4.3: Question 3 and result obtained from respondents from the survey.

Training the construction personnel is an important element in cultivating a safe working environment within an organization, by updating themselves with new skills and knowledge. Question 3 on the survey aims to obtain the data for the training provided helps them to create a safer working environment. Based on figure 4.3, 28.3% of respondents have strongly agreed and 48.8% have agreed with the statement that training plays an important role in creating a safe working environment. Then 12.6% stands in a neutral point of view, that probably in their opinion, the trainer is not the only point to make the workplace safe or the training that provided by the employer is not a relevant training to the work execution. Besides that, 9.4% disagree and 0.8% strongly disagree with the statement. In this group of respondents' opinion, training will not make the workplace safer and even though the percentage is smaller, the management has a responsibility to ensure all their personnel gets trained according to the job scope and task execution on site. According to OSHA 1994 section 15, employer is responsible in making arrangements for training for the employees and obtain the evidence of training such as license and competency.

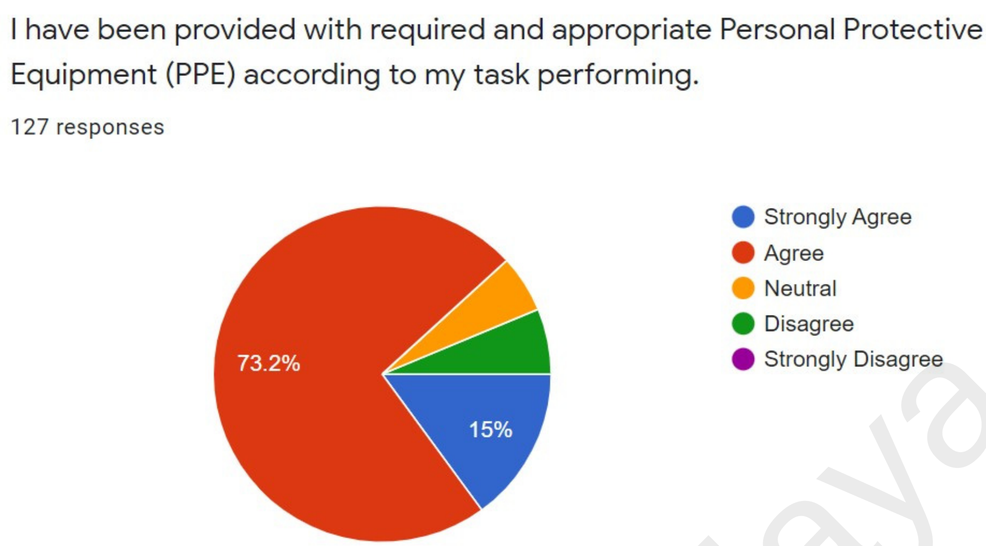


Figure 4.4: Question 4 and results obtained from respondents from the survey.

PPE is a mandatory practice in the construction industry. In some organizations, PPE is only provided just for the sake of basic requirements which does not suit or protect the personnel in the hazard generated through the work scope. According to OSHA 1994 section 26, employee must wear appropriate PPE and if it is not suitable, then should inform to the employer to change. For example, a cloth glove that is provided to the workers, is not applicable for the welder, as the high intensity of spark might burn down the gloves and cause a terminal burn to the welder's palm. So this question aims to obtain the data on the suitability of the PPE provided by the employer to the construction personnel. Figure4.4 shows that, 15.0% have strongly agreed and 73.2% have agreed that, the employer is providing the appropriate PPE for the task performed accordingly. Then 5.5% is neutral, where their neither agree nor disagree. This range of people probably is not sure about their effectiveness of the PPE as they might not aware of the hazard that is present in the job scope. Whereas, 6.3% disagree with the statement, and probably this group of people is not getting the appropriate PPE from the employer for the task performed. An employer must provide the appropriate PPE under the Occupational Safety Health Act (OSHA,1994), who can be fined not more than RM50,000 or a maximum jail term of two years or both if failed to comply.

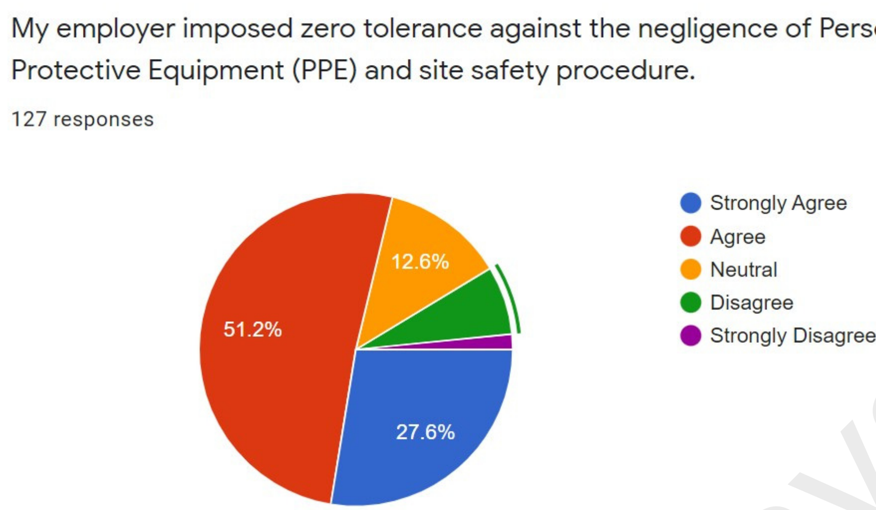


Figure 4.5: Question 5 and results obtained from respondents from the survey.

Negligence of safety procedures and PPE is a serious offense in the construction industry because it does not only harmful to the person who commits it but also endangers the life of other personnel working nearby. This is one of the reasons that some organization takes this into a serious matter and will not hesitate to terminate the employee. According to OSHA 1994 section 26, employer is responsible to provide PPE to employee without any charge. This question in the survey aims to obtain information on how strict is the non-compliance tolerance for safety procedures and PPE. Figure 4.5 shows that it can be seen that, 27.6% of respondents have strongly agreed and 51.2% have agreed that their employer has no tolerance against the negligence of safety procedures and PPE. This shows that the majority of the employer in Malaysia, are strictly following the established safety procedure and PPE accordingly. Whereas 12.6% is on neutral, which indicates two possibilities, such a way that, they are not aware of the safety procedure and PPE zero-tolerance compliance or the organization's implementation is not up to as what is established previously. Then there is 7.1% of respondents have disagreed and 1.6% have strongly disagreed. Probably, in this group of organizations, zero tolerance does not exist and requires serious attention even though it is a small percentage. The management and the safely competent person recognized by DOSH needs to undertake the responsibilities to prevent any accidents.

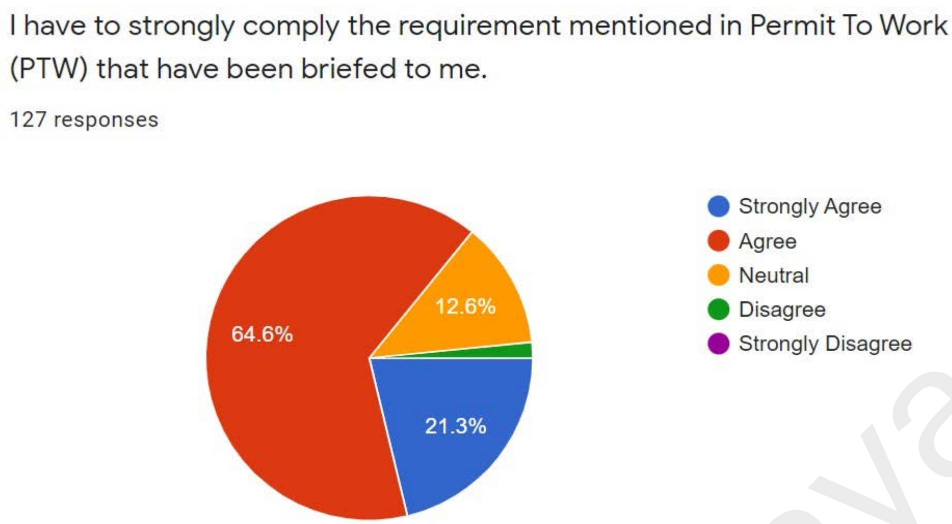


Figure 4.6: Question 6 and results obtained from respondents from the survey.

Permit to Work (PTW) is a safety management work system to ensure coordination between multiple tasks is carried out safely. In the construction industry, the area owner will be the permit issuer that controls activities to be carried out safely. For an example of confined space activity, the chamber cannot be painted and welded at the same time, which be harmful to both parties that carrying out the task, that might lead to poisonous or gaseous inhalation and cause accidents. So the permit issue will evaluate and allow the prioritized activity first follows by another. Figure 4.6 shows that 21.3% of the respondent strongly agrees and 64.6% agrees that they will comply with the PTW requirement. This data shows that the majority of the organization complies with the PTW and is aware of the risk involved in the non-compliance. Whereas 12.6% of the respondent is neutral, which probably indicates that, they are not aware of the PTW requirement and the practice that has been carried out on site. This group of people can cause harm to other people by doing any prohibited action within the permitted area which can lead to risk contribution. Only 1.6% of the respondent disagree with the statement which shows a small figure of non-compliance possibilities that required to be taken into serious consideration as it might be harmful to other personnel who complies with the PTW.

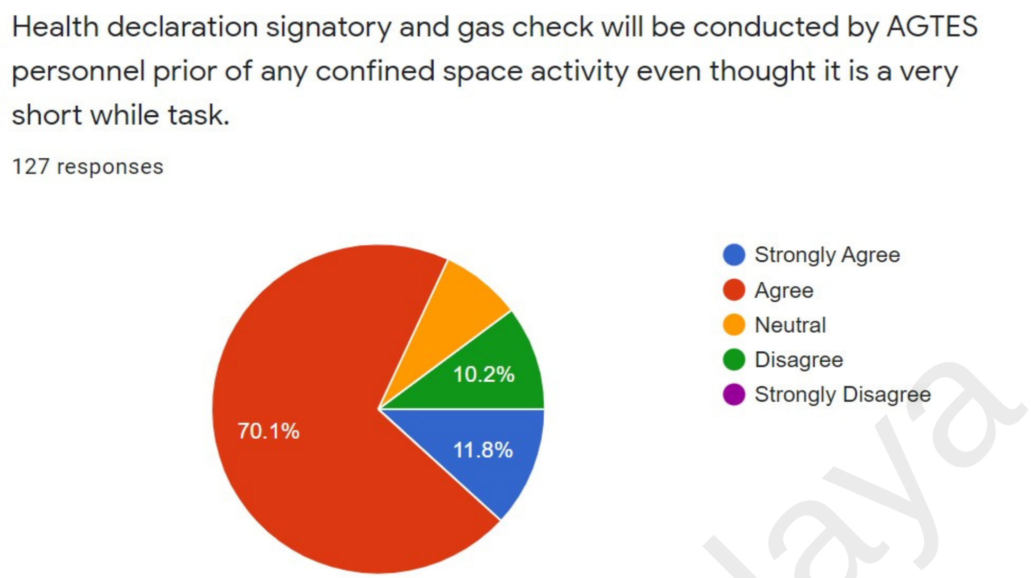


Figure 4.7: Question 7 and result obtained from respondents from the survey.

A health declaration checklist is a document where the person who enters the confined space declares himself healthy and fit to work in the confined space. This is a requirement by (ICOP,2010) and AGTES is required to ensure the regulation is complied by only allowing physically fit personnel to work in the confined space. Besides that, the AGTES is mandatory to conduct gas checks and record the gas reading to ensure the confined space is free from toxic and flammable gas. This question is aims to obtain the data, whether in the respective organization, is the practice is carried out even for the short period of work in the confined space. Figure 4.7 shows that 11.8% of respondents strongly agree and 70.1% agree that the health declaration and gas check is conducted in their organization even though it is a very short period of the task. This shows a good practice where the majority of the organization is complying with the ICOP 2010. Then 12.6% have responded as neutral, where probably, there might no any awareness and competent personnel to advise on the confined space practices. Whereas 10.2% have disagreed with the statement, which might probably lack knowledge, training, no established procedure, and competent personnel to advise the requirement and regulation that is mandatory for confined space practices.

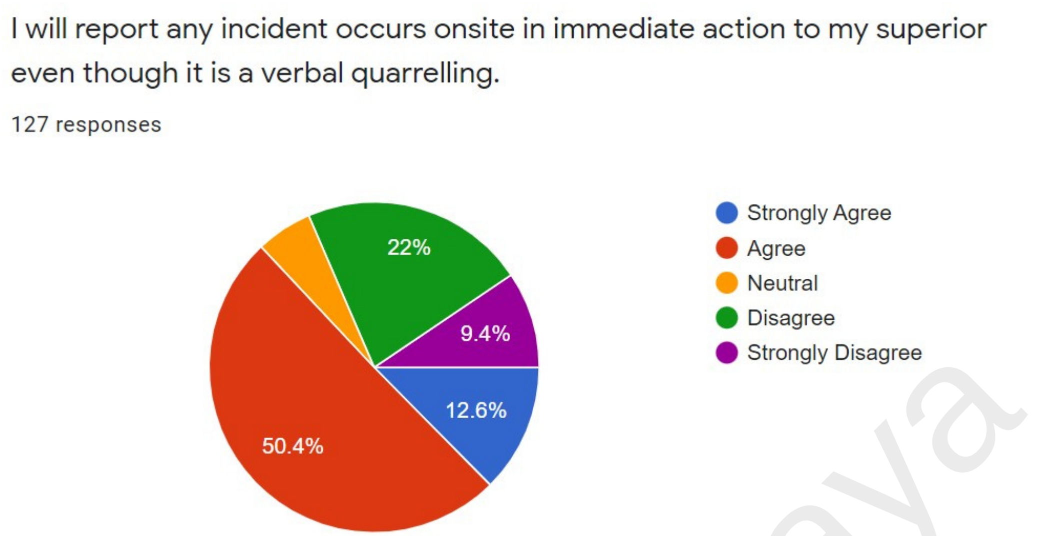


Figure 4.8: Question 8 and result obtained from respondents from the survey.

Reporting an incident to the management will allow the team to conduct an investigation on the root cause of the problem and implement a solution. The question aims to obtain the data on how efficiently construction personnel informs any incident to the management. Hiding an incident will lead to a bigger cause for an accident which might be more severe and in some cases might lead to fatality. Figure 4.8 shows that 12.6% of the respondent have strongly agreed and 50.4% agree that they will inform the management of any incident even though it is verbal quarreling. The data shows majority will report the incident to the management and it is a good practice that can resolve an issue from the early stage of the dispute. Then 5.5% of the respondent choose to be neutral, which this group will be depending on the situation and severity of the incident to be highlighted to the management. This might risk the workers as the issue gets along, it might be severe in the future. On the other hand, 22% of the respondent and 9.4% have strongly disagreed and disagree respectively. The opinion of this group of people is that small issues should not be brought up to the management, instead to resolve it in the site itself to prevent and misunderstanding among workers and management side.

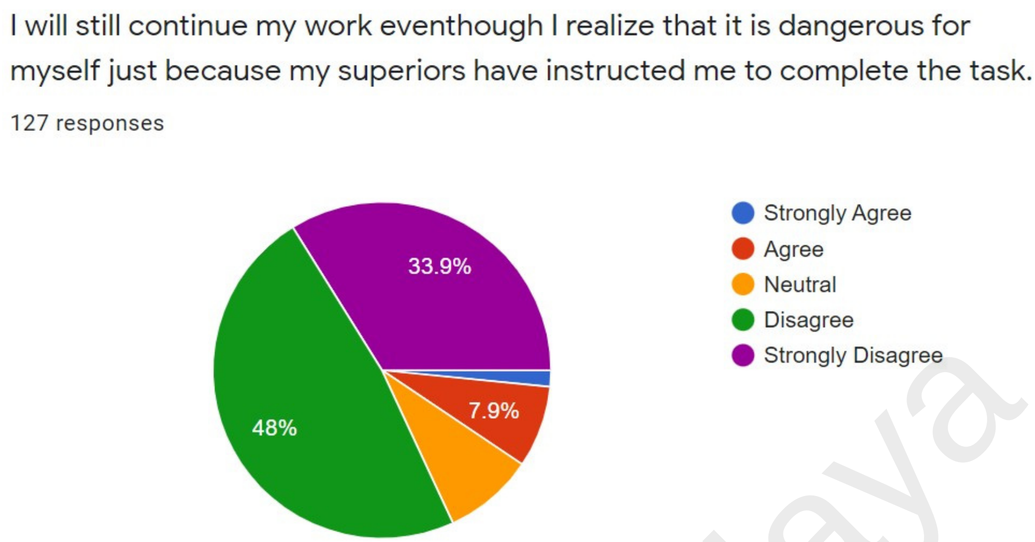


Figure 4.9: Question 9 and result obtained from respondents from the survey.

In some construction sites, the workers will just obey the order from the superior the complete the task without thinking about the risk that they might face during the task execution which might also endanger their life. The question aims to obtain the data to analyze the awareness of the construction personnel toward work safely culture. Figure 4.9 shows that it can be seen that 48% of the respondent have disagreed and 33.9% have strongly disagreed with the statement. Based on the obtained data, it shows that majority of the personnel can think and act without just blindly following the orders and executing the task. Through this, accidents can be reduced where the worker has the knowledge and awareness of the associated risk of the task to be conducted. Whereas 8.7% of the respondent closed to being neutral, as their opinion is, the task execution is depending on the situation that they can evaluate before executing even though they realize the presents of the risk which can be harmful. Then there is 7.9% and 1.6% of respondents have responded agreed and strongly agree to the statement. In their point of view, the risk is present is everywhere, therefore appropriate analysis and control measures should be applied and the task should be executed regardless of how risky is the situation for themselves.

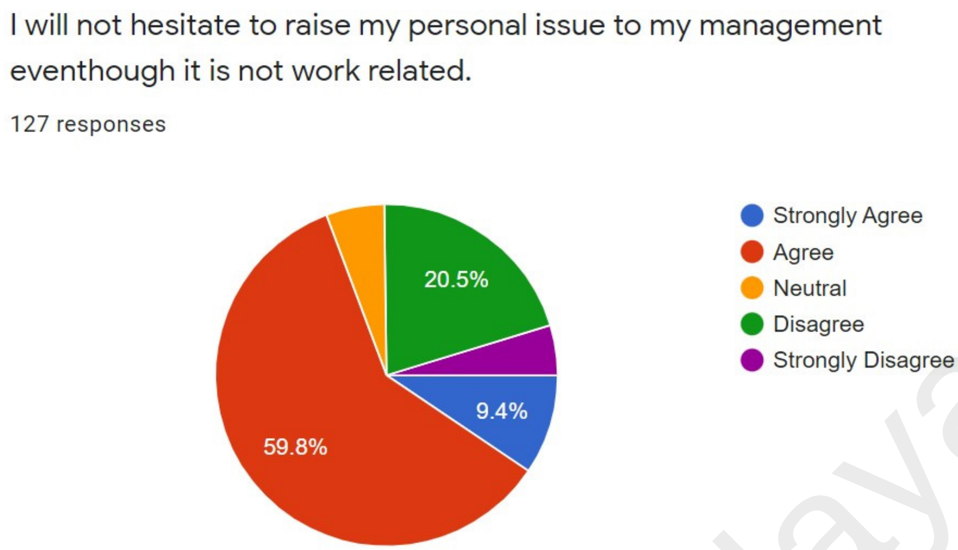


Figure 4.10: Question 10 and result obtained from respondents from the survey.

Safety in work does not only involves physical but also mental fitness. If a site safety supervisor does have some personal issues and loses focus on the construction site, that safety personnel might miss out on some important point during toolbox briefing and be unable to advise the corrective measure for hazards existing onsite which might lead to accidents. Hence personal issues play an important role in ensuring a safe working environment. Therefore, this question aims to obtain information on whether the personnel is willing to raise the personal issues to the management or decide to keep it up themselves. Figure 4.10 shows that 9.4% have chosen to strongly agree and 59.8% choose to agree to the statement that they will raise the personal related issue to the management. In this study, it is revealed that, through this, the management might relieve you from high-risk tasks and provide you some space to overcome your problem. Then 5.5% of the respondent choose to be neutral, where, in their opinion, it is depending on the situation on which matter to be raised to management where privacy is a concern. Whereas 20.5% and 4.7% of the respondent have chosen to disagree and strongly disagree to raise the personal issues to the management because it is not work-related and should be resolved outside of the organization which is also a valid point depending on the individuals' preferences.

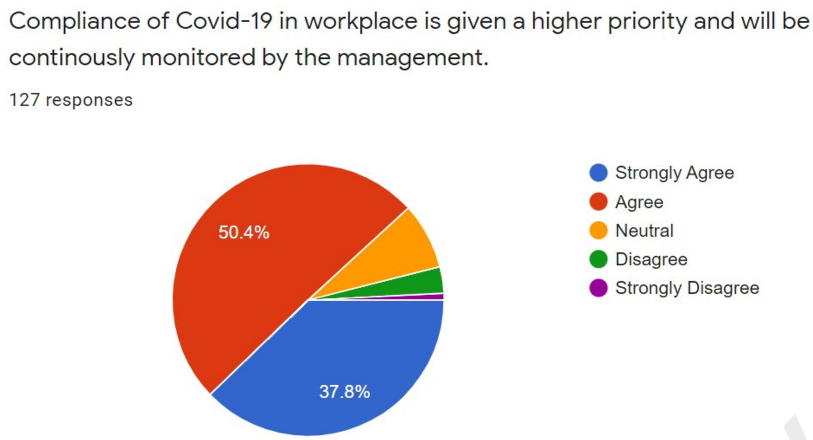


Figure 4.11: Question 11 and result obtained from respondents from the survey.

The pandemic of COVID-19 has given a devastating impact on the construction industry where the workers and machinery were idling during the lockdown and movement control order period led to the closure of many companies by abandoning the ongoing construction projects. Hence to prevent this, strict compliance is required to break the infection chain that prevents the spread. SOP for COVID-19 have been mentioned focusing on several aspect hat required to complied by construction sites (CIDB, 2021). The question aims to obtain the data for the compliance of COVID-19 cases that have been taken into consideration as one of the risks on the construction site. Figure 4.11 shows that 37.8% of the respondent have strongly agreed and 50.4% agreed that COVID-19 compliance is given a higher priority and continuously monitored by the management. This shows a good practice is carried out in the effort of flattening the infection curves especially involving the construction clusters. Then 7.9% of the respondent chooses to be neutral, as they have an opinion that, their management's compliance was not consistent and only partial monitoring is been carried out. On the other hand, 3.1% and 0.8% of the respondent have disagreed and strongly disagree respective to the statement of the questionnaire. This action might lead to non-compliance to COVID-19 SOP, which will risk the entire construction workers and management staff getting infected. Eventually, it will affect the business by stopping work and completing sanitization work.

4.2 Site Observation

Conducted site visit reveals several finding which is a good practice that can be maintained by an organization, whereas certain can be improved in terms of safety to reduce the associated risk under laying within the hazard. Through this study, site observation for gas pipeline activities leads to the identification of hazards, rectified the flaws, proposed and implemented the control measure. Observation to identify and analyze the risk and implemented control measures on particular activities are highlighted in this study. Later, these elements will be adapted to the HIRARC table for the implementation of a more comprehensive HIRARC on the construction site.

4.2.1 Confined Space Practice

According to the Industrial Code of Practice for Confined Space (ICOP 2010), every confined space activity requires, Permit to Work (PTW), mechanical retrieval equipment such as tripod, air blower, and gas testing conducted by Authorized Gas Tester and Entry Supervisor (AGTES) to ensure safe work system in confined space is achieved. During the conducted site observation, the entire requirement complies on site. In gas pipeline construction, trenching, welding pit, and valve chamber as shown in figure 4.12 is considered as confined space.

Figure 4.12: example of a valve chamber considered as a confined space.

Initial ventilation is required to ensure hazardous gas is removed from the valve chamber. Once initial ventilation is completed, as shown in figure 4.13, AGTES personnel conduct gas checking before allowing permitted personnel to enter the valve chamber for installation and paint application works. To get into the chamber, trained personnel in a confined space is required. This training can be obtained from the National Institute of Occupational Safety and Health (NIOSH). Authorized Entrant (AE) will enter the chamber to perform the task, whereas Standby Person (SP), will monitor from outside, just in case of any emergency.

Figure 4.13: Safe confined space work practice.

As a result of the observation, the confined space procedure and existing HIRARC strictly complies with every aspect that is required to be fulfilled. Continuous ventilation using a blower is always ensured by the AGTES personnel on-site. So the current practice can be continued until the necessity of further improvement is required. All the personnel is well trained. PTW file record with health declaration form for (AE) is well kept according to the date of the activity performed. A safe confined space working environment is well established.

4.2.2 Pipeline Welding Works

Pipeline welding works is a process of joining two or more pipes together. Based on the conducted observation, the risk associated with the above-ground is the inhalation of welding fumes and exposure to spark and hot surfaces. Figure 4.14 shows the welding activity for the pipeline that produces the spark and hot metallic particles that can cause fire outbreaks without proper supervision. Besides that, the welding work emits dense welding fumes that pass through the intense heat of the air, nitrogen, and oxygen in the atmosphere may combine to form a dangerous nitrous oxide that can be harmful to inhalations.

Figure 4.14: Pipeline welding activities.

On the other hand, welding works also can cause electrical shock due to the higher voltage involved so that fusion takes place between the electrode and pipe material. The amount of electric current that passes through the body and the severity of the shock depends upon the following factors such as increased voltage will result in greater current flow low voltages may have some consequences if the resistance is low.

Several control measures can be implemented to minimize the identified hazards. Based on the conducted observation, compliance to the personal protective equipment (PPE) is well complied. As shown in figure 4.14, the welder wears a fire retardant coverall that prevents the burn to the skin and clothes. A respiratory mask with a filter fitted prevents the welding fumes inhalation. Welding mask prevents direct eye contact with the welding flame and protects the face and eyes from sparks and hot metallic debris. Leather gloves can withstand a high amount of heat and protect the hand from heat and also prevent electrical shock by providing insulation. Improvements can be done by placing a tray to capture the dripping sparks from directly contacting the ground which might cause fire breaks if the grass or leaves are too dried.

In term of implementation of improvement, the safety checklist is updated by adding an element of tray beneath the welding spark area, the close supervisor is made mandatory by placing a fire watcher to close the monitor before the welding work start by eliminating any flammable material from the site, during welding is to ensure the tray is placed accordingly, a fire extinguisher is made available and upon welding completion, there is no any traces of hot material, debris or active spark dust which can cause fire break. If there is any existence of such particles, damp soil or water will be used to remove them completely to ensure workplace safety from possible fire hazards.

Besides that, the welding generator must be properly grounded. The site safety supervisor (SSS) is responsible to ensure the welding generator is inspected before bringing and suing onsite. The cables and welding rod clamp must be in a good condition without any damage to the insulation which can cause electric shock when coming in contact with wet grounds. A checklist on the items to be inspected before and after usage is placed at the generator set where both SSS and site supervisor are required to verify before the operational use.

During the conduct of this study, it is discovered that some of the workers are not familiar with properly using the fire extinguisher. Activities such as welding and shrink sleeve installation deal with the hot work application. Some personnel is trained to be fire watchers are well versed in identifying fire hazards and usage of the fire extinguisher, whereas some workers are lack knowledge in hot work-related emergencies. The objective of the site observation is conducted is to improvise and create a safe work environment. In this context, new site instructions have been implemented to the site safety supervisor is to brief on the first aid and fire extinguisher usage on weekly basis. The demonstration will also be done from time to time. Each of the workers will be selected randomly to ask about the steps involved in using the first aid box and fire extinguisher. As shown in figure 4.15, the site safety supervisor briefs the workers on the fire hazards and methods to use the fire extinguisher and first aid box. It is essential that, during an emergency, every worker from each team must be able to handle and control the situation without any hesitation.

Figure 4.15: Fire extinguisher and first aid box usage briefing.

Besides the focus on the site and workers for the safe workplace, this study suggested and implemented a method to ensure the management team such as project manager, project engineers, and site safety supervisor be trained and take the responsibilities to ensure the improvements and implementation done continuously. In this case, the site safety supervisor is sent to the first aider and fire watcher training to obtain the knowledge and provide implementation on site. Upon such implementation, the site safety supervisor is required to check the first airbox and on weekly basis and update a report to the management on the availability of the resources as shown in Figures 4.16 and 4.17 to always be kept tracked.

* Picture Taken on Actual Construction

Figure 4.16: Site safety supervisor inspecting first aid box onsite.

Implementation and execution of such weekly-based inspection methods eliminate the possibilities of over-left expired medicines, prevent misuse of first air box by placing consumable medicines and avoid issues of missing items. As shown in figure 4.17, regular inspection of fire extinguishers prevents from overlooking low pressure and expired validity fire extinguishers which might turn into a bigger hazard during a fire emergency.

Figure 4.17: Site safety supervisor inspecting fire extinguisher on site.

4.2.3 Pipe Lifting Operation

Lifting operation in gas pipeline construction is to load and unload pipe from the storage area. As shown in figure 4.18, upon receiving the pipe stock from the client, the pipe will be loaded from the storage yard and will be transported to be unloaded onsite. The lifting procedure and traffic management plan are well complied with during the execution of this activity. It reflects a good practice to ensure a safe workplace.

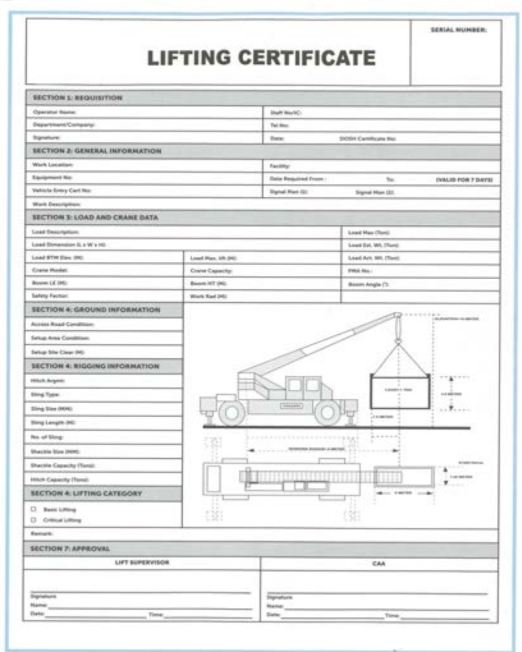
Figure 4.18: Pipe loading and unloading activities.

Hazard identified during the pipe loading and unloading is pipe falling and rolling over. Pipe falling will cause fatality if the worker does not maintain sufficient clearance from the pipe lifting area. Besides that, insufficient knowledge on how to hook the pipe and positing the tag line might cause the pipe to swing and hit the workers while lifting activity is been carried out. Besides that, without proper guidance, workers might not be able to position themselves especially during pipe lifting, and also the most critical action is standing below the suspended load. Position under the suspended is highly prohibited during lifting operations. As a control measure, workers are ensured to attend training to qualify them for the lifting operations. This study revised the lifting procedure by implementing mandatory lifting supervisor recognized by NIOSH is required for any lifting operation to be carried out. Previously, basic lifting and rigging should be sufficient, but due to the improvement and site observation study conduct, the updated procedure requires a lifting supervisor for any lifting operations to ensure proper lifting method is applied for a safe work system.

On the other hand, the safety supervisor and lifting supervisor are instructed to check on the lifting belt to ensure the appropriate belt is used according to the recommended weight of the load. A faulty lifting belt might fail and tear apart while lifting operation and causes the load to hit the ground or impact on the nearby workers. As shown in figure 4.19, based on the conducted site visit, it is discovered that the lifting belt inspection is done regularly and a new lifting belt is frequently changed and made available onsite with the loaded certificate. This shows a good practice is adapted during pipeline construction on the emphasized lifting operations.

A further study conducted on-site practices and implementation of trained personnel, scheduled inspections, briefing, and site demonstration. Another implementation considered is the lifting plan. The lifting plan will be prepared by the project engineer who works together with the lifting and site safety supervisor to come up with a comprehensive form, as shown in figure 4.20 that is required to be filled up upon conducting any lifting operation onsite. The lifting form consists of several factors such as working load, ground information, and lifting category that ensure the lifting supervisor check and ensure the surrounding crane park location be safe and withstand the load to be lifted. Benefits from this implementation make the site personnel aware of the lifting aspects and take responsibility by placing the signatory in the form which will be documented in projects health, safety, environment, and quality (HSEQ) records.

Figure 4.20: Lifting belt inspection and new belt standby onsite.



LIFTING CERTIFICATE

SERIAL NUMBER:

SECTION 1: REQUISITION

Operator Name: | Staff No/IC:

Department/Company: | Tel No:

Signature: | Date: | DOSH Certificate No:

SECTION 2: GENERAL INFORMATION

Work Location: | Facility:

Equipment No: | Date Required From : | To: | (VALID FOR 7 DAYS)

Vehicle Entry Cert No: | Signal Man (1): | Signal Man (2):

Work Description:

SECTION 3: LOAD AND CRANE DATA

Load Description: | Load Max (Ton):

Load Dimension (L x W x H): | Load Est. Wt. (Ton):

Load BTM Elev. (M): | Load Max. lift (M): | Load Act. Wt. (Ton):

Crane Model: | Crane Capacity: | PMA No.:

Boom LE (M): | Boom HT (M): | Boom Angle (°):

Safety Factor: | Work Rad (M):

SECTION 4: GROUND INFORMATION

Access Road Condition:

Setup Area Condition:

Setup Site Clear (M):

SECTION 4: RIGGING INFORMATION

Hitch Argent:

Sling Type:

Sling Size (MM):

Sling Length (M):

No. of Sling:

Shackle Size (MM):

Shackle Capacity (Tons):

Hitch Capacity (Tons):

SECTION 4: LIFTING CATEGORY

☐ Basic Lifting

☐ Critical Lifting

Remark:

SECTION 7: APPROVAL

LIFT SUPERVISOR | CAA

Signature | Signature

Name: | Name:

Date: Time: | Date: Time:

Figure 4.19: Lifting form to be approved before lifting activity

4.3 Fault Tree Analysis

4.3.1 Excavation and Trenching.

Fault tree analysis (FTA) is conducted on the selected high-risk activity involved in gas pipeline projects. The value of probability (P) and reliability (R) is an assumed value based on the event of occurrence and experience gained by an individual upon the conduct of the particular activity.

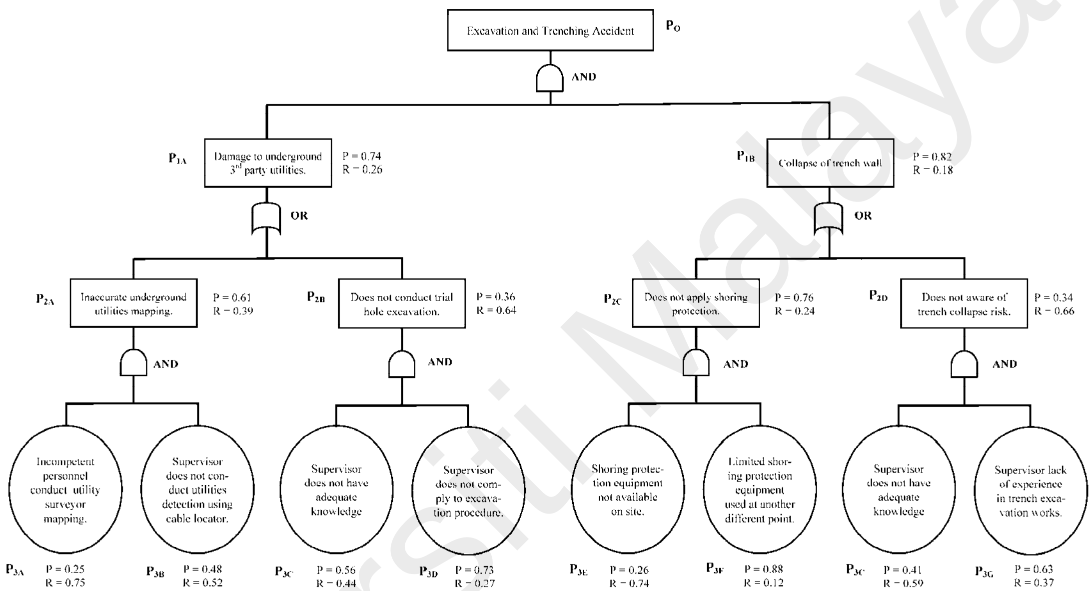


Figure 4.21: fault tree conducted for excavation and trenching accident occurrence.

The probability of the excavation and trenching accidental can be calculated by using the Boolean Manipulation, provided that, once FTA is completed with the major even that contribute to the top event. Therefore, the top event denoted as P_o can be calculated using Boolean Manipulation based on the applied logic gates which stand OR (+) and AND (•). Solving probabilities equations (Eqn) to obtain the percentage of main event occurrence.

$P_o = P_{1A} \bullet P_{1B}$ Eqn (1)

$P_{1A} = P_{2A} + P_{2B}$ Eqn (2)

$P_{1B} = P_{2C} + P_{2D}$ Eqn (3)

$P_{2A} = P_{3A} \bullet P_{3B}$ Eqn (4)

$P_{2B} = P_{3C} \bullet P_{3D}$ Eqn (5)

$P_{2C} = P_{3E} \bullet P_{3F}$ Eqn (6)

$P_{2D} = P_{3C} \bullet P_{3G}$ Eqn (7)

Substitute eqn (4) & (5) into (2)

$P_{1A} = P_{2A} + P_{2B}$

$P_{1A} = (P_{3A} \bullet P_{3B}) + (P_{3C} \bullet P_{3D})$ Eqn (8)

Substitute eqn (6) & (7) into (3)

$P_{1B} = P_{2C} + P_{2D}$

$P_{1B} = (P_{3E} \bullet P_{3F}) + (P_{3C} \bullet P_{3G})$ Eqn (9)

Substitute eqn (8) & (9) into (1)

$P_o = P_{1A} \bullet P_{1B}$

$P_o = [(P_{3A} \bullet P_{3B}) + (P_{3C} \bullet P_{3D})][(P_{3E} \bullet P_{3F}) + (P_{3C} \bullet P_{3G})]$

$P_o = (P_{3A}P_{3B} + P_{3C}P_{3D})(P_{3E}P_{3F} + P_{3C}P_{3G})$

$P_o = ((0.25)(0.48) + (0.56)(0.73))((0.26)(0.88) + (0.26)(0.63))$

$P_o = (0.528)(0.487)$

$P_o = 0.258 \text{ x } 100\% = 25.80\%$

Based on the obtained Po = 0.258, it can be calculated that, the probability of accident to occur while excavation and trenching is 25.80% during the construction of gas pipeline installation. Hence, this activity is classified as high-risk activity in the HIRARC development. As shown in figure 4.22, cable location is detected using a cable locator before excavation. Detected utilities will be marked on the alignment and depth based on the detection. Changes have been done to the construction procedure, where detailed drawing analysis and cable location detection are to be conducted by the supervisor and witnessed by the project engineer and client before any excavation task.

Figure 4.22: Underground utility detection before excavation works.

Once the alignment and depth are identified, trial hole excavation is conducted to verify the alignment and depth of existing utilities. This excavation is a slow process, where probing is necessary while excavation is being carried out. Most of the excavation involved will be manually excavated, whereas actual trench excavation is mechanical by using backhoe and excavators. Probing is performed at a particular depth before the manual or mechanical excavation takes place. As shown in figure 4.23, if the probing depth is 600mm, then the excavation depth will be 300mm. This is to prevent damages to the existing utilities. Trial hole excavation will reveal any markers, signage, and indication of buried underground services.

Figure 4.23: Existing utilities indication slab.

On the other hand, soil collapses are also one of the major causes of accidents in trench excavation. Trench or pit protection is done to the excavated area to prevent the soil collapse until the completion of gas pipeline installation works is completed. As shown in figure 4.24, a sheet pile and steel plate will be used to protect the trench wall from collapsing.

Figure 4.24: Sheet pile installed to prevent soil collision with warning tape.

4.3.2 Horizontal Directional Drilling (HDD)

Horizontal directional drilling (HDD), is a trenchless pipeline installation method, which uses underground boring without involving any trenching excavation. Even though there is no trenching taking place, but accidents still occur. Figure 4.25 shows, FTA is used to analyze the major event that contributes to the top event of HDD.

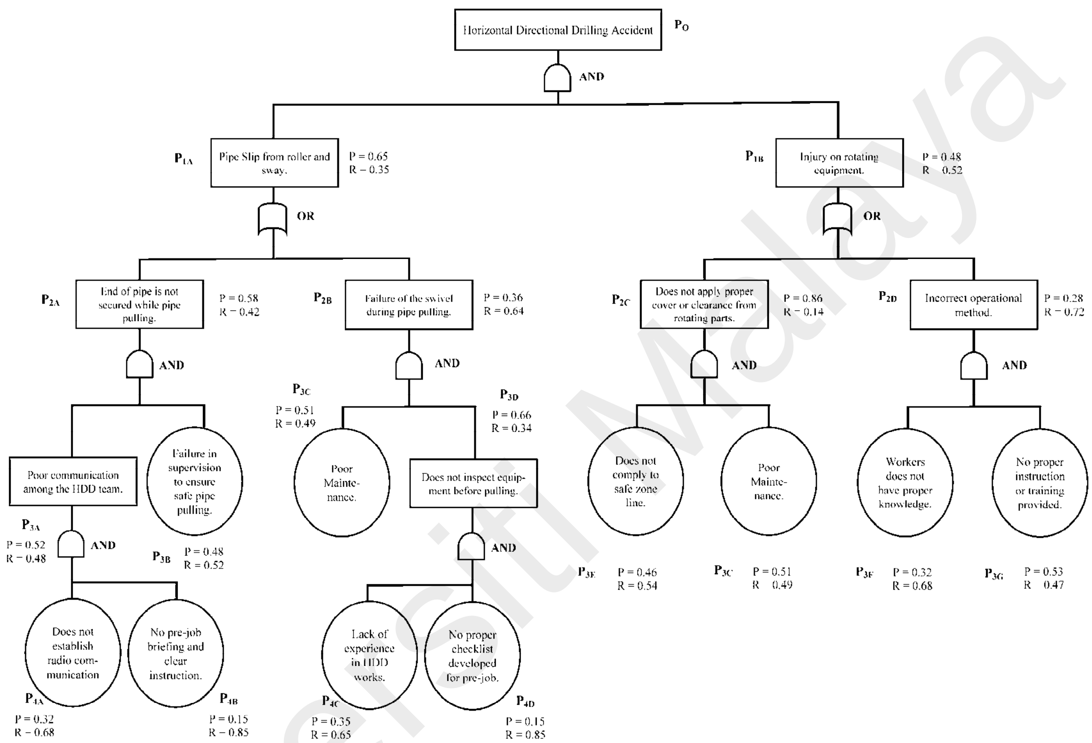


Figure 4.25: Fault tree conducted for excavation and trenching accident occurrence.

The probability of the horizontal directional drilling (HDD) accidental can be calculated by using the Boolean Manipulation, provided that, once FTA is completed with the major even that contribute to the top event. Therefore, the top event denoted as P_o can be calculated using Boolean Manipulation based on the applied logic gates which stand OR (+) and AND (•). Solving probabilities equations (Eqn) to obtain the percentage of main event occurrence.

$P_o = P_{1A} \bullet P_{1B}$ Eqn (1)

$P_{1A} = P_{2A} + P_{2B}$ Eqn (2)

$P_{1B} = P_{2C} + P_{2D}$ Eqn (3)

$P_{2A} = P_{3A} \bullet P_{3B}$ Eqn (4)

$P_{3A} = P_{4A} \bullet P_{4B}$ Eqn (5)

$P_{2B} = P_{3C} \bullet P_{3D}$ Eqn (6)

$P_{3D} = P_{4C} \bullet P_{4D}$ Eqn (7)

$P_{2C} = P_{3E} \bullet P_{3C}$ Eqn (8)

$P_{2D} = P_{3F} \bullet P_{3G}$ Eqn (9)

Substitute eqn (4) & (6) into (2)

$P_{1A} = P_{2A} + P_{2B} = (P_{3A} \bullet P_{3B}) + (P_{3C} \bullet P_{3D})$ Eqn (10)

Substitute eqn (6) & (7) into (3)

$P_{1B} = P_{2C} + P_{2D} = (P_{3E} \bullet P_{3C}) + (P_{3F} \bullet P_{3G})$ Eqn (11)

Substitute eqn (10) & (11) into (1)

$P_o = P_{1A} \bullet P_{1B}$

$P_o = [(P_{3A} \bullet P_{3B}) + (P_{3C} \bullet P_{3D})][(P_{3E} \bullet P_{3C}) + (P_{3F} \bullet P_{3G})]$

$P_o = (P_{3A}P_{3B} + P_{3C}P_{3D}) (P_{3E}P_{3C} + P_{3F}P_{3G})$

$P_o = ((0.52)(0.48) + (0.51)(0.66)) ((0.46)(0.51) + (0.32)(0.53))$

$P_o = (0.586)(0.404)$

$P_o = 0.237x\ 100\% = 23.70\%$

Based on the obtained Po = 0.122, it can be calculated that the probability of an accident to occur is 12.20% during the construction of gas pipeline installation using the HDD method. Before the commencement of the HDD, the steel pipe will be welded according to the designed profile and will be placed on a roller as preparation for pipe pulling as shown in figure 4.26. Once the boring is ready, the pipe will be connected to a pulling head attached to the swivel to pull the pipe into the borehole to complete the process.

Figure 4.26: Pipe placed on roller ready for pulling process.

Once the pipe is ready for pulling, the swivel will be connected with the pulling head to commence the pulling process. HDD team will test the swivel rotation to prevent malfunction or failure to rotate that might cause the pipe to get twisted and sway by creating a reaction force that can cause fatality if any workers are working nearby the pipe area. As illustrated in figure 4.27, the main function of the swivel is to prevent the pipe from rotating during the pulling process. The pulling rod connected to the machine will rotate together with the reamer cutting through the soil followed by the swivel and the pipe. Hence before the pipe pulling, the swivel will be well tested by the HDD team to ensure the swivel rotates without getting stuck as shown in figure 4.28. Additional grease or lubricant will be applied to ensure the smoothness of the swivel to rotate.

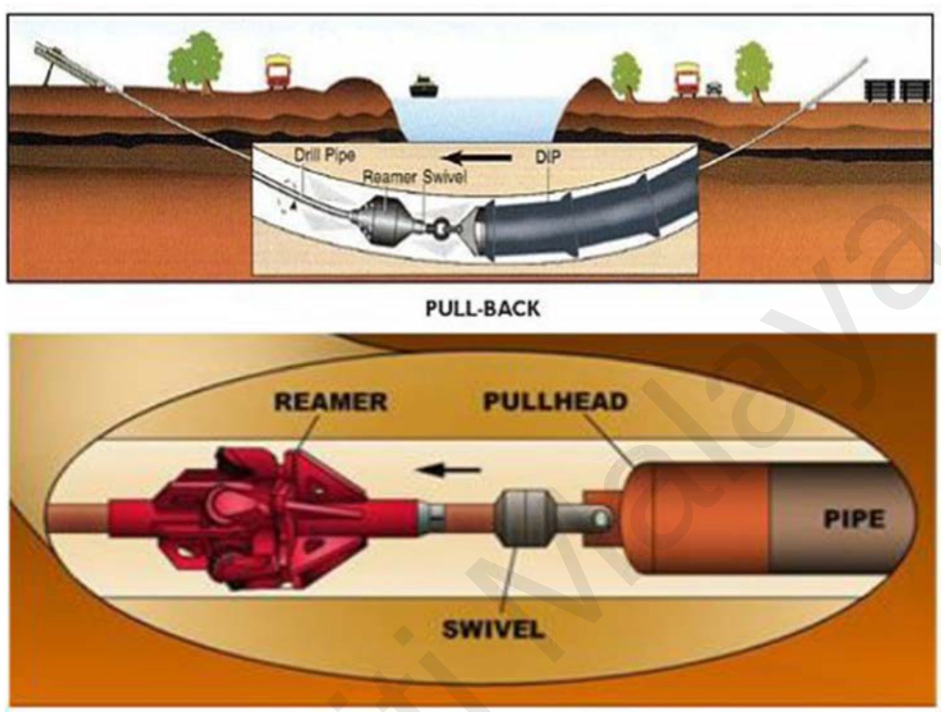


Figure 4.27: Illustrates the reamer, swivel, and pipe configurations.

Figure 4.28: Testing swivel before attaching to rod for pipe pulling.

4.4 Proposed HIRARC

Information and data acquired through this study are gathered, analyzed, and documented in the HIRARC table form. Then the risk is analyzed through the severity and likelihood to identify the risk which indicates low (1-4) that can be considered as acceptable or as low as negligible but control measure is necessary to ensure the mitigation of the risk during any task conduct. Then, the risk at medium (5-12) indicates that approach is necessary for controlling the hazards by applying temporary measures and to be recorded as a documented risk assessment which also includes the date of completion, High risk (15-25) indicates the immediate action is required to control the hazard as mentioned in the hierarchy of control in term of elimination, substitution, engineering controls, administrative controls and personal protective equipment (PPE).

The formation of the HIRARC based on this study is mainly analyzed using experienced personnel in the same field and also based on the opinion exchange on an event that takes place in different locations and companies. On the same discussion, ideas and suggestions are exchanged on how they managed to overcome several issues on facing the particular hazards with the proposed control measure. Besides that, the effectiveness of the implementation of the control measure is also required to be given attention to ensure the continuity of the improvements.

The advantages of the HIRARC analysis is well organized in the tablet form to be referred to as a guideline and easy for future improvement to be revised on a particular section for the betterment. In terms of referring for the risk rating, HIRARC is way easier for construction personnel compared to another method of risk analysis. On the other hand, the disadvantage of the HIRARC is the evaluation of risk will vary depending on the opinion, information obtained, and evaluation consideration that is taken into consideration.

Hazard Identification			Risk Analysis				Risk Control	
Work Activity	Hazard	Which can cause /effect	Existing Risk Control (If Any)	(L)	(S)	(R)	Recommended Control Measure	Person In Charge (PIC)
Loading and Unloading Pipe Stock Pipe.	Machinery movement.	− Body injury, permanent disability, and fatality. − Workers hit by crane or loader truck while loading and unloading pipe. − Crane and loader truck hit by a public vehicle while working at the roadside.	− Place warning signage safe cones and to slow down and direct traffic movement. − Comply to TMP − Wear reflector vest.	2	3	6	− Place flagmen to manage the traffic movement while road closure and divert. − Consult TMO for a suitable and appropriate location to park the crane and loader truck to load and unload the stock pipe. − Signalmen to monitor and instruct the crane and loader truck in and out from the construction site.	− SSS − SHO − TMO − SS
	Pipe swings and falls while lifting.	− Body injury, permanent disability, and fatality due to worker hit by swing pipe. − Damage third-party properties.	− Use tag-line to control pipe movement. − Workers are prohibited under and within the pathway of the load while lifting operation. − Competent crane operator.	4	4	8	− Mandatory training for all the personnel for basic rigging and slinging training. − The lifting supervisor must prepare a lifting plan before lifting operation. − Only lifting gear that is inspected by the lifting supervisor and SSS can be used for the lifting operation.	− SSS − SHO − SS − LS

	Machinery topples during lifting operation.	− Body injury, permanent disability, and fatality due to worker hit by swing pipe. − Damage third-party properties.		4	4	8	− The lifting supervisor must prepare a lifting plan before lifting operation. − SSS and TMO must verify the site for the crane parking location. − Ensure loading and unloading is safe from overhead cables.	− SSS − LS − TMO
Trial Pit Excavation	Potential Damage to third-party underground utilities such as electrical cable, water pipe, fiber cable, and gas pipeline.	− Service disruption to consumers. − Liability claim and a lawsuit from utility owner.	− Conduct pipe or cable detection and utility mapping. − Refer to the construction drawing	1	2	2	− Confirm the utilities using the sonde test and above-ground observation before excavating. − Invite the utility owner to withness the excavation. − Mark the utility alignment using a wooden peg as a reference during excavation.	− SSS
	Electrical shock to construction personnel while probing the existing utilities.	− Injuries, permanent disabilities, and fatality to construction workers.		2	2	4	− Use a rubber isolated probe for probing. − Request the utility owner to conduct leakage detection while the interval of excavation.	− SSS
	Poisonous snakes, insects, and infectious diseases in the pit.	− Workers fall ill and are unable to perform the task assigned. − Disease breakout point and cause massive infection.	− Inspect the site for biological hazards. − Comply with COVID-19 SOP all the time.				− Perform site clearance before commencing work and leave it for at least 2-3 days for the poisonous animals to escape the site due to abnormal conditions.	− SSS − SHO − PE − SS

			− Immediate report of any infection to the HSEQ department.				− Check with the surrounding communities is there any disease breakthrough such as COVID-19, dengue, and hantavirus. If any, re-schedule the task for some time, and executing is a safer area first. − Study on the history and record of the land to be excavated. If it dumping area, post-mining, and surrounded by chemical factories, extra precautions should be considered before the excavation works to be conducted.	
	The collapse of the trial hole trench wall.	− Injuries, permanent disabilities, and fatality by bury the construction workers. − Damages to other buried utilities and third part properties.	− Slope protection	4	4	8	− Install shoring protection while excavation. − Apply bench cutting method for a wide area. − Fully supervised by a standby person from the top of the pit to observe any earthwork crack.	− SSS

	Presents of toxic and flammable gaseous.	− Breathing difficulties and faint in trial pit hole. − Unconscious and fatality. − A fire break or explosion occurs.		4	4	16	− Conduct initial ventilation by placing a sufficient blower. − Obtain authorization from AGTES personnel before going into the pit. − Record gas check for PEL and LEL at every hour interval or after break time. − Maintain internal PTW for confined space.	− SSS, − AGTES
	Machinery topples while excavation.	− Injuries, permanent disabilities, and fatality to construction workers and machine operators. − Damage or puncture of types of equipment operating nearby.	− Competent operator to operate the machinery.	4	4	8	− Identify suitable machine park areas before excavation. − Apply hard rock or crusher run stones for soft ground machine placement. − Use steel plates to prevent the machinery and machinery support to sink.	− SSS
Tench Excavation	Potential Damage to third-party underground utilities such as electrical cable, water pipe, fiber	− Service disruption to the consumer. − Liability claim and a lawsuit from utility owner.	− Conduct pipe or cable detection and utility mapping. − Refer to the construction drawing	1	2	2	− Confirm the utilities using the sonde test and above-ground observation before excavating. − Invite the utility owner to withness the excavation.	− SSS − SS

	cable, and gas pipeline.						− Mark the utility alignment using a wooden peg as a reference during excavation.	
	The collapse of the trench wall.	− Injuries, permanent disabilities, and fatality by bury the construction workers. − Damages to other buried utilities and third part properties.	− Slope protection	4	4	8	− Install shoring protection while excavation. − Apply bench cutting method for a wide area. − Fully supervised by a standby person from the top of the pit to observe any earthwork crack.	− SSS − ES
	Machinery movement.	− Workers hit by excavator or tipping truck while shifting temporary trench soil. − Excavator and tipping truck hit by a public vehicle while working at the roadside.	− Place warning signage safe cones and interlocking barriers to slow down and direct traffic movement. − Comply to TMP − Wear a reflective vest.	2	3	6	− Place flagmen to manage the traffic movement while road closure and divert. − Consult TMO for a suitable and appropriate location to park the tipping truck to load and unload the excavated soil. − Signalmen to monitor and instruct the tipping truck in and out from the construction site.	− SSS − SHO − SS
	Machinery topples while excavation.	− Injuries, permanent disabilities, and fatality to construction workers and machine operators. − Damage or puncture of equipment operating nearby.	− Competent operator to operate the machinery.	4	4	8	− Identify suitable machine park areas before excavation. − Apply hard rock or crusher run stones for soft ground machine placement.	− SSS − SHO − SS

							− Use steel plates to prevent the machinery and machinery support to sink.	
	Trench continuous fill up by underground water.	− Slip and fall due to swampy pit. − Electrical shock due to puncture or damaged cable immersed in water. − The noisy environment is due to the continuous running of a water pump. − Body injury, permanent disability, and fatality.		1	2	2	− Pump out the water before starting the excavation work. − Wear ear protection. − Wear appropriate PPE such as high knee safety boots, coverall, and rubber gloves. − The full supervisor is required while the conduct of the work	− SSS − SS
	Presents of toxic and flammable gaseous.	− Breathing difficulties and faint in trial pit hole. − Unconscious and fatality. − A fire break or explosion occurs.		2	2	4	− Conduct initial ventilation by placing a sufficient blower. − Obtain authorization from AGTES personnel before going into the pit. − Record gas check for PEL and LEL at every hour interval or after break time. − Maintain internal PTW for confined space.	− SSS, − AGTES
Lower in/ Pipe installation works	Pipe swings and falls while lifting.	− Body injury, permanent disability, and fatality due to worker hit by swing pipe.	− Use tag-line to control pipe movement.	4	3	12	− Mandatory training for all the personnel for basic rigging and slinging training.	− SSS − SHO − SS − LS

		− Damage third-party properties.	− Workers are prohibited under and within the pathway of the load while lifting operation. − Competent crane operator.				− The lifting supervisor must prepare a lifting plan before lifting operation. − Only lifting gear that is inspected by the lifting supervisor and SSS can be used for the lifting operation.	
	Machinery topples during lifting operation.	− Body injury, permanent disability, and fatality due to worker hit by swing pipe. − Damage third-party properties.		3	3	9	− The lifting supervisor must prepare a lifting plan before lifting operation. − SSS and TMO must verify the site for crane and excavator parking location. − Ensure loading and unloading is safe from overhead cables.	− SSS − LS − TMO
	Machinery movement.	− Workers hit by excavator or tipping truck while shifting temporary trench soil. − Excavator and tipping truck hit by a public vehicle while working at the roadside.	− Place warning signage safe cones and interlocking barriers to slow down and direct traffic movement. − Comply to TMP − Wear a reflective vest.	2	3	6	− Place flagmen to manage the traffic movement while road closure and divert. − Consult TMO for a suitable and appropriate location to park the excavator and crane for pipe lifting. − Signalmen to monitor and instruct the tipping truck in and out from the construction site.	− SSS − SHO − SS − TMO

	The collapse of the trench wall.	− Damages to third-party utilities. − Damage to equipment placed near trenching. − Body injury, permanent disability, and fatality due to the worker slipping and falling during the collapse.	− Place shoring protection.				− Third-party utilities to be secured using appropriate anchoring tool to ground. − Place shoring protection to prevent collapse and other utilities. − Tag-line to control pipe swing to prevent hitting other utilities underground. − Workers, equipment, and machinery to be placed in an appropriate buffer zone from trenching at least one meter.	− SSS − SHO − SS − ES
Tie-In Welding Works	Expose to welding fumes.	− Occupational asthma. − Pneumonia − Throat and Lung Irritation.	− Adverse health effect.	4	4	8	− Use N99 Welding Respirator Mask − Use blower for force ventilation to remove welding fumes from trench pit.	− SSS − SHO − SS − AGTES
	Expose to light-arc rays.	− Eye injury. − Visual impartment.	− Use/wear a welder helmet. − Use safety shade glasses.	2	2	4	− Use a barrier to block the welding flashlight from workers. − Frequent interval to workers assisting the welding works. − Break interval for welders upon completing each joint of the welding.	− SSS − SHO − SS

	Electrical Shock	− Body injury, and fatality due to electrocution to worker and welder during welding due to welding cable leakage. − Body injury, and fatality of electrocution due to improper grounding of the welding generator.	− The welding machine was properly earthed. − Inspect welding machine cable. − Wear coverall.				− Welding cable should be inspected by a competent person on the insulations and the clamp holders. − Insulation boots and leather gloves are required during welding. − The circuit breaker in the welding generator is mandatory and is required to be inspected before welding commence. − Schedule maintenance sticker to be displayed on-site to ensure the generator set is well maintained.	− SSS − SHO − SS − EI
	Welding and Grinding Sparks.	− Body injury, permanent disabilities, and fatality due to thermal burns and explosions. − Fire breaks and burn down equipment and construction materials. − Chaos and panic to the public when firing breaks and visible of flame and thick smokes.	− Place fire extinguisher. − Wear coverall	2	2	4	− A fire extinguisher is well inspected and placed nearby the welding area. − Firewatcher to be placed to monitor the hot work activities. − Flammable materials to be removed from the site before welding works commence. − Place fire-resistant blankets and sand buckets nearby the welding area.	− SSS − SHO − SS − FW − AGTES

							− Cover the ground and other utilities surrounding the pit with a metal sheet or fire-retardant blanket to prevent damages, puncture, and explosion.	
	Exposure to high-level noise of noise from welding generators and other machinery.	− Hearing impairment. − Reduced communication effectiveness. − Stress and fatigue for a prolonged time of activities.	− Wear earplugs or earmuffs.	1	2	2	− Monitor noise exposure (dB) and install barrier within the welding generator set and other machinery to reduce the sound level. − Install ekzos silencer. − Replace with less noise equipment. − The frequent interval for both welders and workers or execute the job by alternate turn basis. − Place the machinery and equipment as far as possible from the work area.	− SSS − SHO − SS
	Poisonous snakes, insects, and infectious diseases in the pit.	− Workers fall ill and are unable to perform the task assigned. − Disease breakout point and cause massive infection.	− Inspect the site for biological hazards. − Comply with COVID-19 SOP all the time. − Immediate report of any infection	1	1	1	− Perform site clearance before commencing work and leave it for at least 2-3 days for the poisonous animals to escape the site due to abnormal conditions. − Check with the surrounding communities is there any disease breakthrough such	− SSS − SHO − PE − SS

			to the HSEQ department.				as COVID-19, dengue, and hantavirus. If any, re-schedule the task for some time, and executing is a safer area first. − Study on the history and record of the land to be excavated. If it dumping area, post-mining, and surrounded by chemical factories, extra precautions should be considered before the excavation works to be conducted.	
Above Ground Welding Works	Expose to welding fumes.	− Occupational asthma. − Pneumonia − Throat and Lung Irritation.	− Adverse health effect.	2	2	4	− Use N99 Welding Respirator Mask − Use blower for force ventilation to remove welding fumes and ensure good ventilation during welding.	− SSS − SHO − SS
	Expose to light-arc rays.	− Eye injury. − Visual impartment.	− Use/wear a welder helmet. − Use safety shade glasses.	2	2	4	− Use a barrier to block the welding flashlight from workers and the public. − Frequent interval to workers assisting the welding works. − Break interval for welders upon completing each joint of the welding.	− SSS − SHO − SS

	Electrical Shock	− Body injury, and fatality due to electrocution to worker and welder during welding due to welding cable leakage. − Body injury, and fatality of electrocution due to improper grounding of the welding generator.	− The welding machine was properly earthed. − Inspect welding machine cable. − Wear coverall.	2	2	4	− Welding cable should be inspected by a competent person on the insulations and the clamp holders. − Insulation boots and leather gloves are required during welding. − The circuit breaker in the welding generator is mandatory and is required to be inspected before welding commence. − Schedule maintenance sticker to be displayed on-site to ensure the generator set is well maintained.	− SSS − SHO − SS − EI
	Welding and Grinding Sparks.	− Body injury, permanent disabilities, and fatality due to thermal burns and explosions. − Fire breaks and burn down equipment and construction materials. − Chaos and panic to the public when firing breaks and visible of flame and thick smokes.	− Place fire extinguisher. − Wear coverall	1	1	1	− A fire extinguisher is well inspected and placed nearby the welding area. − Firewatcher to be placed to monitor the hot work activities. − Flammable materials to be removed from the site before welding works commence. − Place fire-resistant blankets and sand buckets nearby the welding area.	− SSS − SHO − SS − FW − AGTES

							− Cover the ground and other utilities surrounding fire-retardant blanket to prevent damages, puncture, and explosion. − Install barrier to prevent the public from watching the activity with bare eyes.	
	Exposure to high-level noise of noise from welding generators and other machinery.	− Hearing impairment. − Reduced communication effectiveness. − Stress and fatigue for a prolonged time of activities.	− Wear earplugs or earmuffs.	1	1	1	− Monitor noise exposure (dB) and install barrier within the welding generator set and other machinery to reduce the sound level. − Install ekzos silencer. − Replace with less noise equipment. − The frequent interval for both welders and workers or execute the job by alternate turn basis. − Place the machinery and equipment as far as possible from the work area.	− SSS − SHO − SS
	Poisonous snakes, insects, and infectious diseases within the area.	− Workers fall ill and are unable to perform the task assigned. − Disease breakout point and cause massive infection.	− Inspect the site for biological hazards. − Comply with COVID-19 SOP all the time.	1	1	1	− Perform site clearance before commencing work and leave it for at least 2-3 days for the poisonous animals to escape the site due to abnormal conditions.	− SSS − SHO − PE − SS

			− Immediate report of any infection to the HSEQ department.				− Check with the surrounding communities is there any disease breakthrough such as COVID-19, dengue, and hantavirus. If any, re-schedule the task for some time, and executing is a safer area first.	
Non-Destructing Testing (NDT) using radiography underground piping.	High exposure to radioactive materials.	− Adverse health effects such as cancer and mutations. − Contamination of ground with radioactive traces.	− Radioactive exposure self-monitoring meter. − Only qualified personnel is allowed to carry out the task − Comply with the local authorities' (AELB) license requirement.	3	2	6	− Place a shield within the NDT area to reduce exposure and traces. − Allow buffer of 1-2 days before beginning the activities in that area to allow the traces of the radioactive to deplete. − Wear coverall, leather gloves, and full-face mask to prevent exposure, if the task is required to be carried immediately after the NDT is performed. − Regular medical check-ups to examine health related to the exposure.	− SSS − SHO − SS
Power Brush and Shrink Sleeve Application.	Sharp and high-speed rotating head from the power brush equipment.	− Body injury, permanent disabilities, and fatality due to intact with the high-speed rotating equipment.	− Wear gloves, face shields, goggles, safety shoes.	3	3	9	− Inspection of the power brush head regularly and do not over pressure the power brush metal mesh heat	− SSS − SHO − SS

		− Damage and puncture the rotating part breaks and is intact with nearby equipment. − Tiny metal dust flying and intact the eyes and skin during power brush activity.	− Inspect the condition of the tool before using it. − Rotating tools are guarded with appropriate cover.				which leads to break. Change regularly. − Avoid fault tools and replace them with new ones. If can be fixed, make sure it is done by qualified personnel. − Modification of the tools is prohibited. − Wear coverall, leather or rubber gloves, and a full-face mask to prevent the exposure of tiny metal dust from penetrating the skin.	
Backfilling Works.	Machinery movement.	− Workers hit by excavator or tipping truck while backfilling the trench pit. − Excavator and tipping truck hit by a public vehicle while working at the roadside. − Excavator or tipping truck sunk in soft/excavated soil during backfilling works.	− Place warning signage safe cones and interlocking barriers to slow down and direct traffic movement. − Comply to TMP − Wear a reflectory vest.	2	3	6	− Place flagmen to manage the traffic movement while road closure and divert. − Consult TMO for a suitable and appropriate location to park the excavator and tipping truck during backfilling. − Signalmen to monitor and instruct the tipping truck in and out from the construction site. − Use steel plate, stones, or crusher run to support machinery pathway.	− SSS − SHO − SS − TMO

	Machinery topples during lifting operation.	− Body injury, permanent disability, and fatality due to worker hit by swing pipe. − Damage third-party properties.		3	3	9	− The site supervisor must plan the machinery park during backfilling work on the suitability of machinery operation. − SSS and SS must verify the site for tipping truck and excavator to operate in the backfilling area. − Ensure the machine park and movement area is safe for the machinery to ingress and egress the site during backfilling activities. − Signalmen to monitor and instruct the tipping truck in and out from the construction site. − Place flagmen to manage the traffic movement while road closure and divert.	− SSS − LS − TMO
Horizontal Directional Drilling (HDD) pipe installation works.	HDD Machine movement for Piloting and Reaming- (Bore Hole Cutting)	− Body injury, permanent disability, and fatality due to worker hit by HDD machine or rotating parts. − Body injury, permanent disability, and fatality due to worker hit by the	− Fully supervision by the supervisor on site. − Comply with HDD procedure − Wear a respirator and gloves during handling	3	3	9	− Ensure proper clearance from the machine and the equipment loading area. − Ensure all the rotating part is covered all time during operation. − Site supervisor to monitor and fully supervise the workers.	− SSS − SHO − SS

		HDD rods and reamer roll and fall. − Exposure to Bentonite dust particles.	bentonite dust particles.				− Secure the reamer to the road and ensure workers have sufficient clearance before rotating the reamer. − Do not stake the road up to 3 layers that will lead to roll and drop. − Wear disposable respiratory and gloves all time. Take a turn if the operation is prolonged for long hours.	
	Pipe slip and sway from the roller.	− Body injury, permanent disability, and fatality due to worker hit by the pipe during pulling operational. − Damage to the equipment and machinery is placed nearby the pipe pulling area. − Damage to the HDD machine due to the sway effect by the large force of the pipe.	− Ensure the end of the pipe is secured and no personnel standby side by side of the pipe during pulling. − Use crane or cradle conveyor roller to extent meet the required pitch and angle. − Conduct a job briefing, roles, and responsibilities of each person.	4	3	12	− Workers must stay away from the pulling pipe, and pulling should stop when the roller is about to topple. − Only assigned and instructed personnel is allowed to stay at the pipe pulling area. − Establishing radio communication between the HDD team for clear instruction and full supervision. − Check and verify the swivel function properly while before pipe pulling to prevent the jamming that creates a twist for the pipe and sway.	− SSS − SHO − SS

	Exposure to high-level noise of noise from HDD machines and other machinery.	− Hearing impairment. − Reduced communication effectiveness. − Stress and fatigue for a prolonged time of activities.	− Wear earplugs or earmuffs.	1	2	2	− Monitor noise exposure (dB) and install barrier within HDD machine and other machinery to reduce the sound level. − Install ekzos silencer. − Replace with less noise equipment.	− SSS − SHO − SS
	Potential Damage to third-party underground utilities such as electrical cable, water pipe, fiber cable, and gas pipeline.	− Service disruption to consumers. − Liability claim and a lawsuit from utility owner.	− Conduct pipe or cable detection and utility mapping. − Refer to the construction drawing and HDD Profile.	1	3	3	− Confirm the utilities using sonde test and above ground observation before reaming or bole hole drilling. − Invite the utility owner to withness the HDD works. − Mark the utility alignment using a wooden peg as a reference during piloting activities.	− SSS − SS
Pipeline Valve Chamber Construction	Working in a confined space.	− Body injury, and fatality due to worker trip and fall or collapse in the chamber. − Poor ventilation causes difficulty in breathing. − Lack of monitoring and supervision from outside of the chamber. − Presence of toxic gaseous	− AGTES must perform a gas check before entering the chamber. − Continous force ventilation. − Strictly comply with ICOP 2010, − Ensure PTW is valid before the commencement	4	3	12	− Complete inspection to be done by AGTES to evaluate the confined space and impose the necessity based on the condition. − To ensure all the Authorized Entrant (AE) enter with valid qualification and have declared health status. − The calculation is to be performed to ensure	− SSS − AGTES − SS − PE

		− Presence of venomous animals.	of confined space activity.				sufficient ventilation by using an appropriate blower. − To use mechanical retrieval equipment such as rope and tripod in case of emergency.	
Night work Pipeline Installation Works.	Working near Roadside and exposed to vehicles.	− Body injury, and fatality due to workers due to hit by public vehicles. − Low visibility during night hours. − Vehicle crash into a construction site.	− Provide adequate lighting. − Wear reflectorized safety vest. − Place adequate blinkers and reflective warning signs when working near the roadside.	2	2	4	− Brief the workers on the danger of working at road site before commencing of the work. − Plan the traffic management and place adequate numbers of cones and barriers in the construction sites. − Comply with the TMP and procedure for working at night.	− SSS − SHO − TMO − SS
	Inadequate lighting at the construction site.	− Poor visibility leads to accidents. − Vision strains and discomforts. − Lead to a lack of communication efficiency.	− Provide adequate lighting.	1	1	1	− Appropriate lighting in the working area. − Ensure sufficient power supply for lightings and other machinery operational. − Lighting is inspected and grounded well before use. − Using the correct cable rating for a combination of multiple lights.	− SSS − SHO − SS

CHAPTER 5: CONCLUSION & RECOMMENDATION

5.1 Conclusion

Risk assessment and risk control are conducted based on the identified hazard associated with the task performed. This study demonstrated that hazard identification which was performed using the site observation method based on the work step involved in the pipeline construction reveals that, management has to play a vital role in ensuring the compliances of safety procedure and practices is carried out accordingly. Findings show that the presence of Project Manager and Construction Manager for site inspection through monthly walkabout, reminds the construction personnel such as Safety Officers, Site Safety Supervisors, and Site Supervisors to upkeep the site conditions, materials, and equipment such as first aid box, lifting belt and fire extinguisher in a good condition through frequent inspections. Besides that, construction personnel also must always engage with the co-workers by communicating and providing internal training to create awareness to ensure that they are updated and prepared in case of any emergency. Moreover, improvement in worksite site safety is observed upon implementing frequent site observation by management with site personnel that shows the commitment of both parties can make a significant difference. This study suggests that management walkabout for site observation sessions should be made more frequent from monthly to weekly basis to enhance the safe work culture which should not be only limited to the site but also in terms of discussions that involve previous finding rectification, further improvements, and site safety documentation reviews.

Upon hazard identification, risk assessment is conducted to assess the hazard severity in gas pipeline construction. In this study risk assessment is conducted through survey analysis, site observation, and fault tree analysis. Finding in survey analysis reveals that, compliance of an organization towards safety varies. According to the received responses, most of the respondent agrees that they acquire knowledge, provide training and proper establishment of communication within the management and workers are well versed. Whereas a small number of respondents have stated that, the provided personal protective equipment is not suitable, training does not help for the task conducted, and no proper safety procedure executed on site. Through this, even though the majority of the respondent have provided positive feedback but the transparency by answering the survey is dependant. By this, an organization needs to take full responsibility for the safety concern of their site personnel and co-workers to ensure provide the required welfare to cultivate safe work culture. Besides that, Fault Tree Analysis reveals that a simple cause will contribute to the major event and occurrence of the top event. Finding reveals through FTA shows that lack of knowledge or less awareness for supervisors on trench risk leads to trench wall collapse and lead to an excavation accident. This accident can cause permanent disability or fatality if there are personnel in the trench hole. So the management should be more particular in ensuring competence among all the personnel working on site. This study suggests that briefing should be conducted before commencing work to ensure every personnel understands the flow and scope of work and training should be frequently provided to keep the personnel updated on the latest risk might occur onsite by inputting recent incidence and lessons learned occurred in other places together with new safety procedure implementations.

The risk control measure proposed in this study is based on the hazard identification and risk assessment as reflected in the developed HIRARC. The finding shows that an appropriate risk control method is important to be implemented on the site which is applicable based on the site conditions. For example, the implementation of inviting and witnessing 3rd party utilities owner before work commences, have reduced the number of an incident that causes damage to their assets. Besides that, performing sonde test and marking the utilities before excavation prevents cable damages and these approaches of control measures have improved the excavation safety compared to previous control measures. Through this, safety performance can be improved which reflects good project execution. This study suggests that control measures must be continuously analyzed and improved based on the hierarchy of control in line with the updated requirement by the local authorities and professional bodies. In a conclusion, cultivating a safe working environment is everyone's responsibility to minimize and work towards zero accidental cases in the workplace through proper risk assessment and control measures so that we adopt from the lesson learned from an incident.

5.2 Future Recommendation

Gas pipeline construction is a very wider scope that involves many types of and methods of construction to serve the industrial requirement and demands. This study is limited to onshore pipeline construction only. Future study can be conducted in the following scope to analyze and assess the risk associated and develop multiple comprehensive HIRARC to close the gap of the research as follows:-

1. HIRARC study for offshore pipeline construction.
2. HIRARC study for hot tapping installation works.
3. HIRARC study for internal piping construction for factories, power plants, and gas processing plants.

Besides that, in the gas pipeline works, there are also post-construction works that involve, gas pipeline cleaning, hydro and pneumatic high-pressure testing, pipeline swabbing, drying, and commissioning which will lead to a separate scope of HIRARC study and associated risk assessment for the conducted activities.

In a nutshell, the HIRARC study in gas pipeline construction should not be limited to paper works but needs to be implemented and observed on-site on the efficiency and practicality of the control measure proposed based on the identified hazards and risk control measure. HIRARC study should be a continuous study that is required to be conducted in line with safety development and lesson learned.

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