HAZARD IDENTIFICATION AND RISK ASSESSMENT AT A SELECTED PETROL STATION IN KLANG VALLEY

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Field of Study: Process Safety

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ABSTRACT

The demand for energy by sector shows that the transportation is the major consumer of energy. With average increment of 5.4% per year, the registration of new vehicle in Malaysia has steadily increased from 2010-2015 (JPJ, 2017). In delivering this primary energy sources to the consumer, petrol station is the primary method in many parts of the world including Malaysia. Due to the nature of handling flammable materials and the incidences which happened at petrol station locally or globally, risk management including fire and explosion at petrol station has started to bring more attention than before.

Quantitative Risk Assessment (QRA) which widely being used in chemical processing plant either downstream or upstream is an effective planning tool. It can help to predict the potential major accident occurrences, so the appropriate preventive and mitigating measures can be implemented. In this study, QRA had been conducted on a selected petrol station which was located at Klang Valley with specified objectives. The three main objectives for this study are hazard identification from a checklist, risk evaluation using qualitative and quantitative risk assessment by using ALOHA software and assessment of practices among selected government agencies in giving inputs and approving the petrol station development.

Site visit and checklist used has found that the hazards were derived from various categories namely waste and general management, electricity at work, hazardous chemical exposure and fire safety. In general, poor management for these categories could lead to fire and explosion incidents. The results from the QRA study had revealed that the overall individual risk per annum (IRPA) for the petrol station is 7.25 x 10^{-4} which was

not within the risk acceptance criteria (1 x 10^{-6} frequency per year). Three scenarios has been established to estimate the risk associated to the petrol station such as leakage during offloading of petroleum product from road tanker due to hose or fittings failure, leakage at dispenser area due to failure in safeguarding systems and underground fuel storage tank explosion due to overpressure. The level of concern (LOC) distance for the most significant risk which were flash fire and pool fire, were found beyond the petrol station as shown in the individual risk contour.

Survey among the selected government agencies concluded that there is positive process which currently been implemented in evaluating and approving the Development Planning for petrol station projects. However, holistic planning which combines all aspects is deemed necessary so the impact of the associated risk from the operational of petrol station can be identified and minimised during the planning stages.

ABSTRAK

Permintaan tenaga menunjukkan sektor pengangkutan merupakan pengguna utama tenaga. Dengan peningkatan sebanyak 5.4% setiap tahun, jumlah pendaftaran kenderaan baru telah meningkat antara tempoh 2010 – 2015 (JPJ, 2017). Di dalam membekalkan keperluan tenaga yang utama ini, stesen minyak merupakan kaedah utama di dunia termasuklah Malaysia. Disebabkan oleh bahan mudah terbakar dan juga kejadian kemalangan yang telah berlaku di stesen minyak di dalam dan luar negara, pengurusan risiko termasuklah kebakaran dan letupan di stesen minyak semakin mendapat perhatian berbanding sebelum ini.

Penilaian risiko kuantitatif (QRA) yang telah dipraktikan dengan meluas di dalam industri pemprosesan kimia sama ada huluan and hiliran yang mana ia merupakan kaedah perancangan yang berkesan. Ia dapat membantu dalam meramal kemalangan besar yang berpotensi untuk berlaku supaya langkah-langkah pencegahan dan pengurangan yang bersesuaian dapat diwujudkan dan dilaksanakan. Di dalam kajian ini, QRA telah dijalankan di sebuah stesen minyak yang terletak di Lembah Klang berdasarkan objektif yang telah ditetapkan. Tiga objektif utama kajian ini adalah pengenalpastian bahaya daripada senarai semak, penilaian risiko kualitatif dan kuantitatif dengan mengunakan perisian ALOHA dan juga penilaian soal selidik di kalangan beberapa agensi kerajaan yang terlibat dalam memberikan ulasan teknikal dan meluluskan projek pembangunan stesen minyak.

Lawatan tapak dan senarai semak yang telah digunakan menunjukkan risiko bahaya adalah berpunca daripada beberapa kategori iaitu pengurusan sisa dan am, elektrik di tempat kerja, pendedahan kepada bahan berbahaya dan keselamatan kebakaran. Secara amnya, kelemahan-kelemahan di dalam kategori ini boleh menyebabkan kepada

kebakaran dan letupan. Hasil daripada kajian QRA telah menunjukkan bahawa keseluruhan risiko tahunan pada tahap individu (IRPA) adalah 7.25 x 10^{-4} yang mana ianya tidak berada di dalam kriteria yang diterima (1 x 10^{-6} frekuensi tahunan). Tiga senario telah dikenalpasti untuk menganggarkan risiko yang berkaitan dengan stesen minyak. Risiko yang mempunyai jarak yang membimbangkan (LOC) di stesen minyak ini ialah api denyar *(flash fire)* dan api kolam *(pool fire).* Jarak ini telah dipaparkan di dalam kontur risiko individu.

Kesimpulan daripada soal selidik yang telah dijalankan di kalangan agensi kerajaan terpilih mendapati terdapat kaedah pemprosesan yang positif dalam penilaian dan pemberian ulasan-ulasan teknikal dan proses kelulusan Kebenaran Merancang pembangunan stesen minyak. Walau bagaimanapun, perancangan holistik yang merangkumi kesemua aspek adalah diperlukan supaya impak risiko dari pengoperasian stesen minyak dapat dikenal pasti dan diminimakan bermula di peringkat perancangan.

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Mohamad Saufi Bin Supar

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LIST OF SYMBOLS AND ABBREVIATIONS

AIHA	:	American Industrial Hygiene Association
ALARP	:	As Low As Practicable
ALOHA	:	Area Locations of Hazardous Atmospheres
API	:	American Petroleum Institute
BLEVE	:	Boiling Liquid Expanding Vapour Explosion
CCPS	:	Center for Chemical Process Safety
CNG	:	Compress Natural Gas
CO	:	Carbon Monoxide
CODO	:	Company Owned Dealer Operated
CO_2	:	Carbon Dioxide
DODO	:	Dealer Owned Dealer Operated
DOE	:	Department of Environment
DOSH	:	Department of Occupational Safety and Health
E&P	:	Oil Industry International Exploration and Production
ETA	:	Event Tree Analysis
FTA	:	Fault Tree Analysis
HAZID	:	Hazard Identification Studies
IQR	:	Interquartile Range
IRPA	:	Individual Risk Per Annum
ISO	:	International Standards Organization
KFC	:	Kentucky Fried Chicken
Kg	:	Kilograms
kW/m^2	:	Kilowatts per metre square

LEL	:	Lower Explosive Limits
LOC	:	Level Of Concern
LOPA	:	Layer of Protection Analysis
LPG	:	Liquefied Petroleum Gas
NO	:	Nitrogen Oxide
NO_2	:	Nitrogen Dioxide
OSH	:	Occupational Safety and Health
OHSAS	:	Occupational Health and Safety Assessment Series
PHA	:	Process Hazard Analysis
PM	:	Particulates Matter
QRA	:	Quantitative Risk Assessment
RON	:	Research Octane Number
SCE	:	Safety Critical Equipment
SIL	:	Safety Integrity Level
SPSS	:	Statistical Package for the Social Sciences
RTD	:	Road Transport Department
VCE	:	Vapour Cloud Explosion
VOC	:	Volatile Organic Compound
α	:	Cronbach's alpha

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CHAPTER 1: INTRODUCTION

1.1 Background of study

The primary sources of energy supply in Malaysia are crude oil and petroleum products as well as natural gas. Taken together, the industrial, residential and commercial sectors make up 51.7% of petrol demand in Malaysia (Nineth Malaysia Plan, 2006). In terms of demand by source, petroleum products are the main energy consumed, growing at the rate of 4.5% annually during the 8th Malaysia Plan (2000-2005) period and 6.1% per annum during the 9th Malaysia Plan (2006-2010).

The demand for energy by sector also shows that the transportation is the major consumer of energy, accounting for 40.5% of the total final commercial energy in 2005. (Nineth Malaysia Plan, 2006). According to statistics from Road Transport Department (RTD) of Malaysia, the registration of new vehicle in Malaysia is increased on average 5.4% per year from 2010 to 2015 (JPJ, 2017). Figure 1.1 showed the number of passenger vehicles registered from 2010 to 2015 in Malaysia.

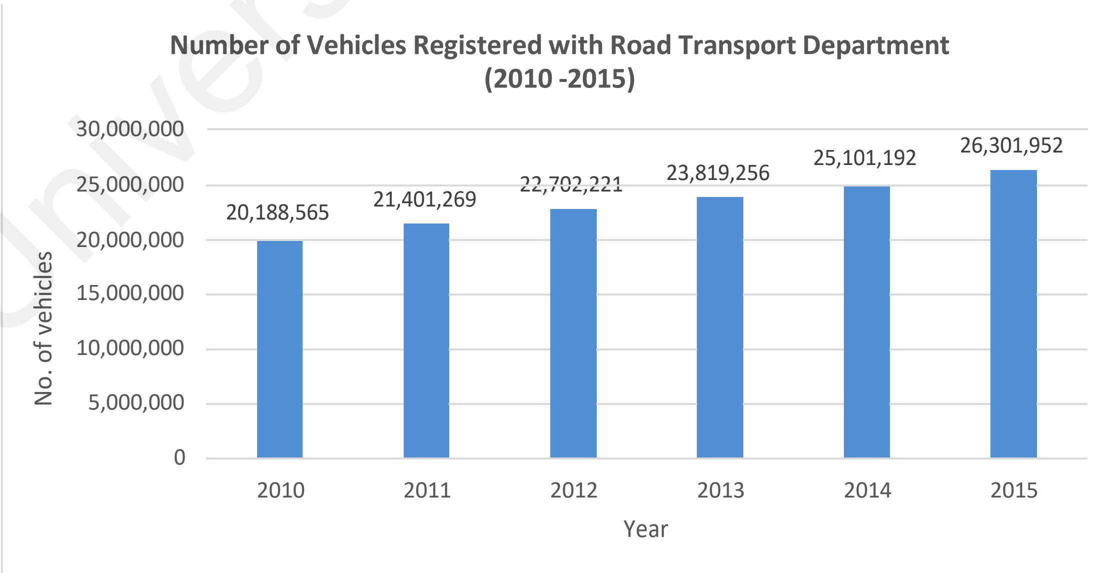

Figure 1.1: Graph of Number of Vehicles Registered from 2010 to 2015

In delivering this primary energy sources to the customer, petrol station is the primary method in many parts of the worlds including Malaysia. Petrol station is defined as land used to sell motor vehicle fuel and lubricants. It may include the selling of motor vehicles accessories or parts, food, drinks and other convenience goods, servicing or washing motor vehicles and installing accessories or parts of motor vehicles. According to statistic, as of August 2013, there were 3291 petrol stations, 332 mini stations and 200 petrol service station selling NGV in Malaysia (MPC, 2014). This service industry brings good opportunity to the business partner for the investment. Companies like PETRONAS, SHELL, PETRON, BHP and CALTEX are opening more petrol stations from year to year due to increasing energy demand (Francis Dass, 2016).

Hazardous chemical typically stored in petrol station are unleaded petrol, premium unleaded petrol, diesel and compress natural gas (CNG). Due to the nature of the handling these flammable and hazardous material, it may pose fire and explosion hazards if ignited. Characteristic of these materials which contains volatile organic compound (VOC) are volatile, highly flammable, explosive and may release vapour even at very low temperature (Wyckoff & Wyckoff, 1960). While the compressed natural gas (CNG), which use by the natural gas vehicles (NGV) is the natural gas compressed into very high pressure of usually 3000 - 3600 psi (Ahmad, 2004). Thus, it is very important to have an overall understanding when dealing with risk associated to the operational of petrol station which can help to reduce and ultimately eliminate from the impacts of major hazards.

Among the major hazards identified from the operational of petrol station are fire, explosion and toxic release which comes from the tank filling process by road tanker, hazards when storing and handling and finally while fuel dispensing and transferring process. (Zhu, 2014). However, the most common incident in petrol station is due to fire (Cruz & Okada, 2008). However, explosion is more significant in terms of its damage potential which often lead to fatalities and damage to properties (Khan & Abbasi, 1998).

For the past few years, many incidents involving petrol station has been reported by media which happened all over the world including Malaysia. Such incidents have resulted not only on property damaged but also causing injuries and fatalities. The recent major accident occurrence is explosion and fire incident at Accra, Ghana in 2015 due to the release of fuel from the underground tank during a flood. 250 people were killed while taking a shelter at the station (VibeGhana, 2015). Similar incident also happened in Malaysia at Gua Musang, Malaysia in April 2014 due to the hose leakage during fuel transfer which resulted in 11 injuries (Syed Azhar & Zulkifle, 2014).

The hazards due to static electricity also could happen at petrol station. The latest incident in Malaysia caused severe burns to a woman due to explosion from the usage of mobile phone during refuelling. This incident occurred on 28 June 2016 in Setapak, Malaysia. Initial checks by the Fire and Rescue Department showed that there was no fire following the explosion. On 17th July 2016, the woman died at the Kuala Lumpur Hospital (Asyraf, 2016).

The Quantitative Risk Assessment is widely being used in chemical processing plant (midstream and upstream) as the planning tool. Furthermore, risk assessment has been used rigorously worldwide in estimating of risk chemical storage regards to flammable and toxicity. Thus, risk assessment should also be adopted and used for the downstream in answering the incidents that had happened in the past to avoid similar occurrence in future. The importance of addressing this issue has brought attention to some researchers which then they had considered the petrol station as a hazardous and risk area not just onsite but also offsite by Srivastata *et al.* (2005), Walmsley (2012), Cornilier *et al.* (2012).

This study will focus on the operation and maintenance of a petrol station located at Klang Valley where QRA will be a useful tool to identify and estimate the risk of fire and explosion from the overall layout such as toilet, underground storage tanks, petrol pumps and retail area. The risk control measure will be established from the result of this analysis with the aim to minimize the risk to as low as practicable (ALARP) level. The steps in conducting QRA are outlined in the Methodology section.

1.2 Problem statement

The hazards associated to petrol station does bring impacts to people, environment, asset and reputation. Nevertheless, the consequences of disaster resulted from the incident are very huge. The rapid growth of urbanisation has created greater demand for vehicles, which results in more fuel consumption. Thus, petrol station has become more important nowadays, but meanwhile it is a hazardous facility which require special attention starting from the site selection up until the operational and maintenance phases as to protect relevant stakeholders involve especially nearby community vicinity to the petrol station.

There are many researchers whom has conducted research in the area of process safety including risk assessment on the major installation such as chemical plant, nuclear plant, transportation and major hazard installation but fewer on the non-major hazard installation such as petrol station. However, there is no specific methodology that has been used and introduced in petrol station cause the chemical substances in the station is below than then threshold limit according to the requirement. (Mohd Shamsuri, 2015). In Malaysia, studies conducted previously on petrol station is mainly on the site potentiality of petrol stations based on traffic counts which relates to demand analysis and economic consideration.

Thus, an effective risk assessment framework should be developed to highlight the hazards and risk so the operational of petrol station will be in inherently safer. Ultimately, the holistic approach can be implemented which integrate all elements from site selection, land use suitability, commercial consideration, safety of the people and last but not least the environmental protection.

1.3 Scope of study

This study will cover the operation and maintenance of petrol station which includes dispenser area, retail area and other supporting facilities. The selected petrol station in this study is located at Shah Alam, Selangor which is nearby commercial and residential area. Study will also cover the planning and approval aspect by government which involve various technical agencies.

1.4 Objectives

The objectives of this study are:

a) To identify the hazards involved during operation and maintenance of petrol station.

b) To determine and evaluate the probability of risk from occurring during operation and maintenance of petrol station.

c) To assess practises by selected government agencies in giving inputs and approving the petrol station development.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

Disaster always refer to the high impacts incidents which involved high death in human, environment and asset such as Bhopal, Chernobyl , Mexico City, and Sungai Buloh in Malaysia (Papazoglou, 1984 and Ibrahim, 2002). Nuclear technology, pollution, warfare and industrial accidents are example. Hazards contributed from human activity and interaction with environment, social and technological systems are kind of technological hazard. These hazards can be caused during transportation, production, storage or time of disposal also. Influence area, level of effects and duration of effects are different based on surrounding environment such as land use, type of soil and weather condition. All these consequences may lead to undesirable and sometimes catastrophic circumstances.

Every industry has put lots of efforts to prevent accident. There are many of petrochemical industries have high potential for loss and there have been cases, where loss measured in both human and financial terms has catastrophic. It is true to say that there have been other cases where because of effective action taken at the time, the full potential loss has been largely avoided. Effective measure has been possible due to the existence of pre-planned and practiced procedures for handling major emergencies utilizing the combined resources of the industrial concern and outside services. Thus, the requirement to study the risk assessment fundamental and evolution of the method must be done parallel with the evolving industry, technology and also availability of knowledge in the world.

2.2 Hazard Identification and Risk Assessment

The most important step in risk analysis is Hazard Identification because unless hazards are identified, consequence and likelihood reduction cannot be implemented (Sutton, 2010). Hazard identification and risk assessment are sometimes merged into one general category which is called Hazard Evaluation (Crowl, 2011). Crowl suggested that the hazard evaluation study is performed at the initial design stage so that an early modification can be easily implemented.

There are several methods that are widely used in hazard identification such as What If Analysis, Failure Mode and Effect Analysis (FMEA, Hazard and Operability Study (HAZOP), Event Tree Analysis (ETA) and Fault Tree Analysis (FTA). All of these studies are conducted based on previous incident experience with the participation of highly experience team and disciplines in order to produce comprehensive hazard identification. This will also provide a precise risk estimation that pose from the process or plant (Khan et. al, 1998).

Figure 2.1 depicts the commonly use procedure for hazard identification and risk assessment. Upon description of the process is available, the hazards are identified. Then, the various scenarios by which an accident can occur are then determined. Concurrent study of both probability and the consequence of an accident will be then followed. This information is collected into a final risk assessment. The study is considered as completed if the risk is acceptable which the process can be operated. Otherwise, the system must be modified and the process will be restarted from the beginning (Crowl, 2002).

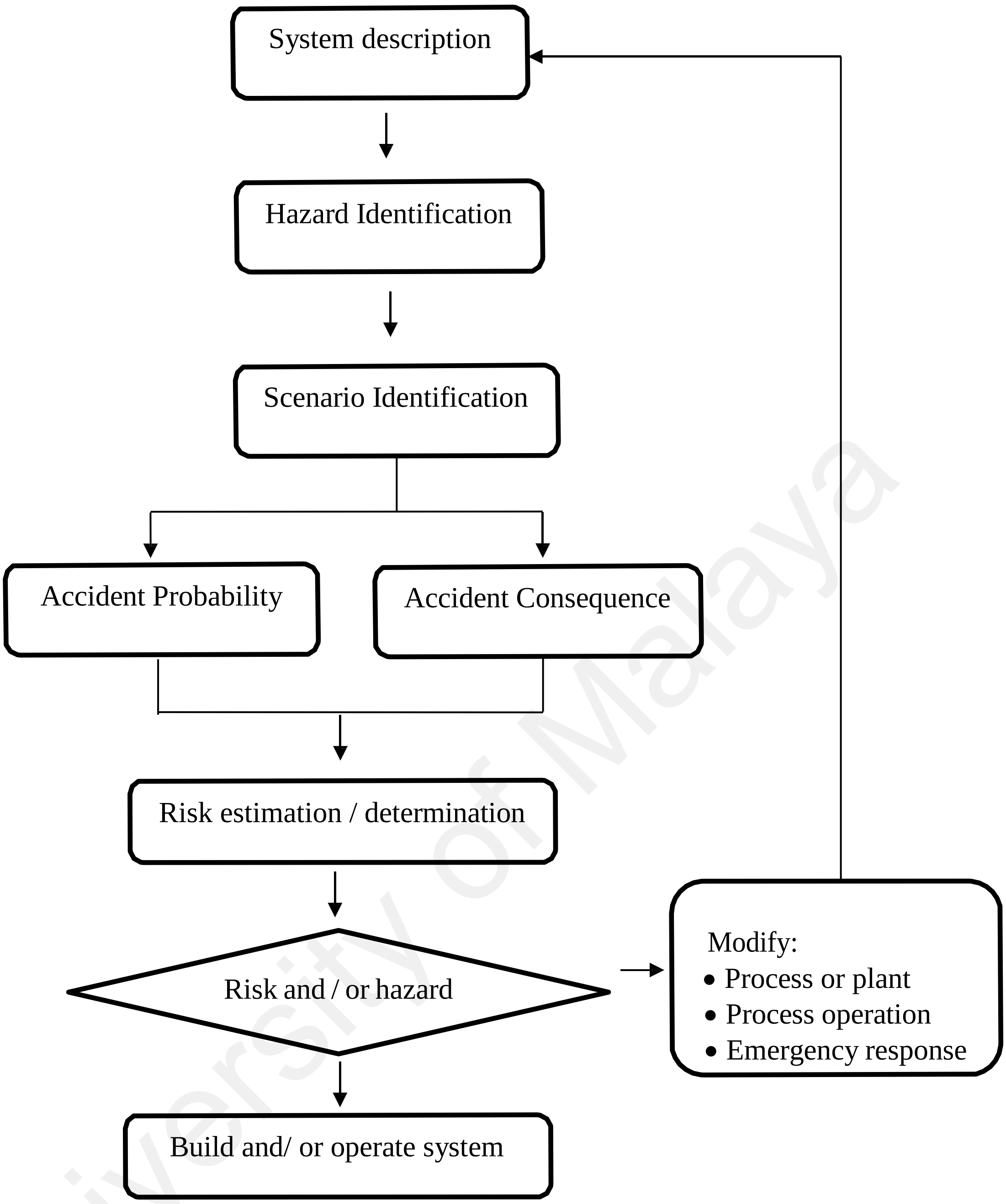

Figure 2.1: Hazard Identification and Risk Assessment Procedure (Source: Crowl, 2002)

2.3 Risk assessment and history

Risk assessment is defined as the process of gathering data and synthesizing information to develop an understanding of the risk of a particular installation (DOE, 2004). While Center for Chemical Process Safety (CCPS, defined risk assessment is the process which the results of a risk analysis are used to make decisions, either through a relative ranking of risk reduction strategies or through comparison with risk target (CCPS, 1989). For example, before proceeding with the construction of major hazardous installation at some particular location, the project proponent may wish to determine and allocate resources to minimise the probabilities of incident. In another instance, local authorities who will approve that project would want to know whether the risk posed by such installation to the surrounding development and human population would be acceptable (DOE, 2004).

Risk has been used as an early as 1940's during the World War II (WWII) on the risk of storing the explosive away from the barrack of army (Shamsuri et al., 2017). Then in 1960s emerge the Probabilistic Reactor Analysis (PRA) which is focusing only on safety or nuclear reactor but not on the risk itself. In 1970s, the concept of Quantitative Risk Assessment (QRA) has been established in answering the 3 main questions: -

a) What can go wrong?
b) How likely is it?
c) What are the consequences?

Risk assessment also stated as overall process of estimating the magnitude of risk and deciding whether or not to the risk is tolerable (ISO 14001: 1994, OHSAS 18001: 1999, and HSE: 2000). Those code and standards refer to the foundation of risk assessment which is subset of risk management. Risk management model consists of; -

a) Hazards identification
b) Risk assessment or analysis
c) Risk control

However, the risk management model is very subjective and continual improvement can be done from time to time. The process is circular process in one loop (Shamsuri et al., 2015). The steps may vary from one researcher to another. Different researcher will have different perspective on risk management thus the steps involved might be different from one to another researcher. William and Heins (1989) introduced 6 steps while Franks P.J et al, 1995 contains only 5 steps (Prichett et al., 1996). Therefore, the risk management model / framework may vary from one organisation to the other because it depends on the gold and target of the organisation to achieve. Processes involved in each organisation also give a huge influence in determining the model of the risk management.

The importance of risk assessment has increased in the recent year in estimating the risk related to various hazardous activities. It could be either quantitative or qualitative after considering the objectives of the analysis (Han & Weng, 2011). Qualitative risk assessment is an initial exercise to assess the risk pose by a proposed installation and it gives the risk ranking of the identified hazards by using risk ranking or risk matrices whereas quantitative risk assessment is an estimation of the risk level in absolute terms.

2.4 Risk Assessment Techniques

There are many risk assessment techniques that widely been practiced by industry worldwide. Each of these techniques has its own approach and requirements thus, it places different burdens on the expertise of the users. Table 2.1 below provides guidance on what technique are suitable within the Process Hazard Analysis and their intended purposes. However, the methodology employed when using the technique can vary greatly and as such the information in the following table is for guidance only.

Table 2.1: Risk Assessment Techniques

Name	Description
Failure Modes and Effect Analysis (FMEA)	Identifies equipment failure modes and resulting consequences or hazards. Also identifies single point failures and requirements for redundancy or safety systems.
Facility Siting Review	A method for determining the suitable location of buildings in process plants. May use methodology defined in API Recommended Practice 752, Management of Hazards Associated with Location of Process Plant Buildings.
Hazard and Operability Analysis (HAZOP)	Focused on the identification of hazards related to the operation of components of a system.
Hazard Identification (HAZID)	Uses specialist checklist to identify hazards at a details level following a step by step assessment of the issue in question.
Human Factor Analysis	Analysis of human capabilities, limitations and needs in designing machine operation and work environment.
Layer of Protection Analysis (LOPA)	A method for the analysis of safeguards in place to manage a particular hazard. Often linked to a reliability or Safety Integrity Level (SIL) assessment.
Qualitative Risk Assessment	Apply simple risk matrix to assess risks. Usually include a hazard identification process.
Quantitative Risk Assessment	Uses a computer models of the system in question to generate numerical assessment of individual and societal risk. Usually only applied when detailed hazard analysis is required for decision making purposes.
Reliability Analysis	An assessment of the probability of defined failure modes occurring for a particular equipment item or system. Often supports other forms of analysis such as QRA.
Safety Integrity Level (SIL)	Method for determining the required reliability of a control or safeguarding system.
Structured What-If Technique (SWIFT)	A general purpose method for system/ higher level identification of hazards. Fast and simply applied using questioning checklist which ask a competent team 'what if…"

Source: Petronas Technical Standard, Guideline Process Hazard Analysis (2009)

2.5 Qualitative and Quantitative Risk Assessment

Risk assessment can be either qualitative or quantitative and it includes incident identification and consequence analysis. A time, a qualitative assessment is performed as an initial preliminary study to get an overview of the risk level before quantitative assessment is conducted.

2.4.1 Qualitative Risk Assessment

Risk ranking and risk index are outcomes from qualitative risk assessment. It uses descriptive scales or to describe the magnitude of potential consequences and the likelihood that those consequences will occur. These scales can be adjusted to suit the circumstances and different descriptions may be used for different risks. Qualitative risk methods are used to set priority for various other purposes, including further analysis. Table 2.2 shows an example of simplified or basic technique to categorise risk based on expert individual or team judgement while Table 2.2 is example of general risk matrix evaluation which is more in details.

Table 2.2: Basic Qualitative Risk Assessment Matrix for Risk Ranking

LIKELIHOOD or FREQUENCY	**CONSEQUENCE SEVERITY**		
	High	***Medium***	***Low***
High	High	High	Medium
Medium	High	Medium	Low
Low	Medium	Low	Low

Source: DOE (2004)

Table 2.3: Risk matrix

Severity / Probability	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)	High	High	Serious	Medium
Probable (B)	High	High	Serious	Medium
Occasional (C)	High	Serious	Medium	Low
Remote (D)	Serious	Medium	Medium	Low
Improbable (E)	Medium	Medium	Medium	Low

Source: RISTIĆ (2013)

2.4.2 Quantitative Risk Assessment

Quantitative risk assessment involves the calculation of probability and consequences using numerical data. As such, accurate quantification or risk can give opportunity to be more objective and analytical than the qualitative approach. Generally, quantification of risk involves generating a number that represent the probability of a selected outcome, such as fatality.

a) Individual Risk

Individual risk is the probability or frequency at which one particular person being fatally injured when standing at a certain point and distance from a major hazardous installation when major hazard occurs. It is normally used to indicate how significant the imposition of risk as compared with the background risk an individual is exposed to. Individual risk is usually represented on a map as contours, providing graphic picture of the geographical risk distribution.

b) Societal risk

Societal risk or sometimes known as group risk is the relationship between the number of fatalities amongst a group of people near a major hazardous installation and the probability or frequency of such number of fatalities occurring. This risk indicator is useful when deciding on the suitability of a proposed major hazardous installation to be built in a certain location that can affect large number of people. The individual risk to, say the employees, may be very low and acceptable, but because of the large number of individuals either working or living near the site of the proposed installation, the societal risk may be very high and unacceptable.

There are many benefits on implementing QRA as outlined in Table 2.4 below

Table 2.4: Strength of Quantitative Risk Assessment

No	QUANTITATIVE ADVANTAGE	PRESENT METHOD COMPLIANCE
1.	Results are substantially based on independently objective processes and metrics	All components are based on mathematical computations
2.	Great efforts put into asset value determination and risk mitigation	Employs rich knowledge database for risk mitigation and includes a mechanism for valuing asset impact
3.	It includes a cost/benefit assessment	Provides a range of measures for users to select to mitigate risk
4.	Results can be expressed in management-specific language	Can produce reports based on statistical computation of degree of control implementation.

2.4.3 Standard use in Quantitative Risk Assessment in Malaysia.

In relation to QRA, many countries and society has developed their own codes and standard in conducting QRA. In Malaysia the regulatory agencies such as Department of Environment (DOE) and Department of Occupational Safety and Health (DOSH) have established their guidelines and dedicated regulation to address QRA as Table 2.5 below:

-

Table 2.5: Related government regulation and guidelines on risk assessment

Agencies	Guidelines/ Regulations	Law
DOSH	Occupational Safety and Health (Control of Industrial Major Accident Hazards) Regulations, 1996 (CIMAH)	Occupational Safety and Health Act, 1994
DOE	Guidelines for Risk Assessment,	Environmental Quality Act, 1974

There are other international codes and standard that applicable for QRA which have some differences according to their design principle. Some related examples are ISO 28000, ISO31000 and ISSOW. In Petroleum and Petrochemical Industry in Malaysia, all companies will conduct the QRA by referring to Petronas Technical Standard on Quantitative Risk Assessment, other than codes of engineering practices and other society like American Petroleum Institute, (API).

2.5 Overview of Petrol Station in Malaysia

Petrol station or also called petrol service station is defined as facility to sell vehicle fuel and lubricants. It may include other services like selling of motor vehicles accessories or spare parts, drinks, food, other convenience goods, vehicles servicing or washing and other support facilities like fast food. Though this is considered as downstream in petroleum industry, it does bring a good opportunity and value for investment to the business partner. It was reported that PETRONAS targeted a roll out between 25 to 30 new petrol stations nationwide in 2014 with the investment of RM2 million per station. Their goal is to achieve 35% market share from the current 30% which ultimately be the market leader in Malaysia (Petronas Dagangan, 2014).

The current petrol station in Malaysia is normally setup with two types of petrol dealer program depending on the interest and requirements. The first program is Company Owned Dealer Operated (CODO) and the second program is Dealer Owned Dealer Operated (DODO). Under the CODO program, the company owns all asset onsite whereas the dealer has the ownership on fuels and convenience store products as well as inventory. Dealers would undertake signing of the License Agreement with the company for a period between 1 to 3 years and subsequently be the holder of all operating licenses. Dealers also need to pay the license fees to the company. The second program which is DODO where the petrol stations are built and owned by dealers which they own the land, building and some equipment.

2.6 Risk Assessment in Petrol Station Activities

Nowadays, over 40 years of risk assessment has been used frequently in decision making in 3 main industries which are petroleum and chemical process, nuclear power plant, space flight (Garrick and Christie, 2002). Risk analysis is an important tool in handling large amount of hazardous materials at the petrochemical industries as there are many major accidents occur globally due to the loss of hazardous material containment. These incidents resulted in casualties and also adverse effect to environment and damage to properties which worth more than billions of dollar (Greenberg & Cramer, 1991).

However, seldom researchers use QRA in the downstream especially petrol station though it is considered as a hazardous and risk area not just onsite but also offsite by Srivastava *et al.* (2005), Walmsley (2012), Cornilier *et al.* (2012). Therefore, due to less researchers on this area and a new paradigm of research should focus mainly in downstream petroleum industry such and as petrol station. This will benefit in clarifying on the severity and impacts of fire to human and environment even though it is not considered as major hazard installation under the legislation. Table 2.6 below summaries the previous studies conducted on risk assessment for petrol station. Mostly studies were conducted on the new framework of risk assessment, monitoring on the real-time contamination and exposure which could harm to the surrounding area, replenish case study in quantify earlier detection before become disaster. However, fewer research done on the consequences of the substances storage which could pose hazard not just onsite but offsite.

Table 2.6: Method used in Petrol Station Researches

Year	Summary/ Methods	Result/ Finding
2001	Experimental study: investigate into the distribution of hydrocarbon concentration in underground tank	Delivery rates of up to 200 l/min so far permissible that volume with explosive atmosphere are formed in underground storage tanks (Frobes, 2001).
2007	Remote real-time monitoring and control of contamination in underground storage tank systems of petrol products	System can diagnose the leakage and start remediation by a specific soil venting process. (Sacile, 2007)
2007	Modeling system: COPERT and CALINE4	A consequence, the population living in the vicinity (of the examined urban location) is exposed to an additive concentration ranging from 3 to 6 mgm3, increasing the leukemia risk caused by benzene alone from. (Karakitsios et al., 2007)
2007	Laboratory study case study on the bioremediation of diesel oil contaminated soil.	Bioremediation strategies enhanced the natural of bioremediation of the contaminated soil and treatment nutritional amendment. (Mariano, et al, 2007)
2008	Develop an algorithm for the petrol station replenishment	Algorithm best usage to distributor to acquire a loading and routing optimization computerized module which has been integrated within their enterprise resource planning system (Cornillier et al., 2008)

2010	Investigation and experimental on One-hundred-and-five Radiello; passive samplers (RAD130.Cartridge Adsorbent and RAD120 Diffusive Bodie, Sigma Aldrich, Inc., St. Louis, Missouri (US)) were used to measure VOCs in the urban are.	the spatial influence of petrol stations on their surroundings based on the fact that the concentration ratio of n-hexane and benzene found in the air of the petrol stations is different from that found in city air (mainly determined by motor vehicle exhaust). (Morales Terrés et al., 2010)
2011	Develop safety and risk assessment framework by using actual field data related to hazard contributing factors at PFS.	Top most hazard contributing use recorded was carelessness. Risk calculated due to carelessness at PFS is 49.28%. Second most significant factor was slips, tips & falls. It achieves risk value of 28.70. Third top most risk oriented contributor was miscellaneous cases. (Ahmed et al., 2011)
2014	Investigate and experimental if pressures and flow rates occurring in road- tanker petrol-station systems during the delivery of petrol.	Gas displacement pipe will be discharged to the atmosphere when the storage-tank system is opened in order to connect the hoses. Extent depends on the flow resistances in the gas displacement system and the resulting excess pressure in the venting system. (Frobese, 1998)

Source: Shamsuri *et al.* (2015)

2.7 Petrol Station Incident

The major hazards of petrol station are toxic release, fire and explosion. The most common accident is due to fire (Cruz & Okada, 2008). However, explosion is more significant due to its damage potential which often lead to fatalities and damage to properties (Khan & Abbasi, 1998). Table 2.7 showed the list of major accident in petrol station.

Table 2.7: List of major accident in petrol station

Year	Location	Factor	Event	Death or injuries
1978	Nijmegen, Netherlands	Fuel leakage	Fire	No casualties
1989	Aspropyrgos, Greece	Fuel leakage	Fire and explosion	No casualties
1991	Alpignano, Italy	Welding	Explosion	1/1
1997	Bursa, Turkey	Fuel leakage	Explosion	No casualties
1997	Upland, United States	Residual fuel vapours	Explosion	1/1
1998	Cambridgeshire, United Kingdom	Multiple vehicle collision	Explosion	1/not available
2000	Ontario, United States	Tank cleaning process	Fire and explosion	Not available
2000	Charleston, United States	Ignition of fuel vapours	Fire	Not available/1
2002	Chincha, Peru, Brazil	Bus crashed into fuel pumps	Fire and explosion	35/20
2003	Ankara, Turkey	Fuel leakage and domino effect	Fire and explosion	3/186
2003	Karachi, Pakistan	Explosion of fuel tanks	Fire and explosion	Not available/14
2005	Genes, Italy	Fire starts in a gas cartridge storage area	Fire and Explosion	1/10
2014	Gua Musang, Malaysia	Hose leakage during fuel transfer	Fire and explosion	Not available/11
2015	Accra, Ghana	Release of fuel from the underground tank during a flood	Fire and explosion	250/not available
2016	Setapak, Malaysia	Usage of mobile phone during refuelling	Explosion	1/not available
2016	Gua Musang, Malaysia	Fire ignited due to child played with lighter	Fire	Severely burnt

Source: (1) ARIA (2008); (2) Syed Azhar and Zulkifle (2014); (3) VibeGhana (2015); (4)Asyraf (2016)

2.8 Fuel characteristics

Petroleum is a mixture of volatile hydrocarbon with various molecular weights which recovered by oil drilling and extraction of fossil fuel such as coal. Fractional distillation was used in separating components of petroleum into different categories. The most common types of petroleum products sold at petrol station are petrol and diesel.

One of the products derived from fractional distillation of crude oil is petrol which is volatile liquid. At a low temperature up to below -400^{0}C, flammable vapour is released which could result in fire or explosion at certain proportions of air if ignited even in a composition of 1%-8% petrol vapour in the air. Petrol vapour is denser than air due to its difficulties in dispersion where it tends to remain at the bottom of the area. This vapour could accumulate any enclosed or poorly ventilated area without leaving any traces of the liquid itself (Nolan, 2014).

During the transfer of fuel into storage tanks or vehicles, petrol spills could result to the occurrence of flammable situation due to the release of flammable vapour into the atmosphere. Contamination could also cause a flammable situation. Furthermore, petrol tends to float on water surface as it has lower density. The flow could carry on several distances through drain, watercourses or groundwater which leads to a fire or explosion some distance away from the release of petrol (Gardiner *et al.*, 2010). In a petrol station in Malaysia, the widely used petrol are RON 95 and RON 97 type. Both characteristics of petrol were mentioned in Table 2.8.

Second product is diesel which is also have similar characteristic which can also result in fire and explosion hazards if exposed to certain factors. However, unlike petrol, it has lower flash point which vary between 52 and 96^{0}C as well as required less refining which resulted in heavier, thicker and oiler properties (Speight, 2015). Table 2.8 mentioned the detailed characteristics of diesel as well as petrol.

Table 2.8: Characteristics of fuel

Fuel / Properties	Petrol RON95	Petrol RON97	Diesel
Mixture description	Complex mixture of hydrocarbons consisting of paraffins, cycloparaffins, aromatic and olefinic hydrocarbons with carbon numbers predominantly in the C4 to C12 range. Includes benzene at 0.1 - 5% v/v	Complex mixture of hydrocarbons consisting of paraffins, cycloparaffins, aromatic and olefinic hydrocarbons with carbon numbers predominantly in the C4 to C12 range. Includes benzene at 0.1 - 5% v/v	Complex mixture of hydrocarbons consisting of paraffins, cycloparaffins, aromatic and olefinic hydrocarbons with carbon numbers predominantly in the C9 to C25 range.
Appearance	Yellow. Clear, bright liquid	Red. Clear, bright liquid	Colourless to yellowish liquid
Odour	Hydrocarbon	Hydrocarbon	May contain a reodorant
Boiling range	25 - 220^{0}C	25 - 220^{0}C	170 – 390^{0}C
Flash point	-40^{0}C	-40^{0}C	> 55^{0}C
Upper or lower flammability or explosion limits	1 – 8%(V)	1 – 8%(V)	1 – 6 % (V)
Auto-ignition temperature	>250^{0}C	>250^{0}C	>220^{0}C
Density	Typically 0.40 g/cm^3 at 15^{0}C	Typically 0.40 g/cm^3 at 15^{0}C	0.8 – 0.89 g/cm^3 at 15^{0}C
Flammability	Extremely flammable	Extremely flammable	Not applicable
Chemical stability	Stable under normal use conditions	Stable under normal use conditions	Stable under normal use conditions
Conditions to avoid	Avoid heat, sparks, open flame and other ignition sources	Avoid heat, sparks, open flame and other ignition sources	Avoid heat, sparks, open flame and other ignition sources
Sensitivity to static discharge	Yes, in certain circumstance products	Yes, in certain circumstance products can ignite	Yes, in certain circumstance products can ignite

	can ignite due to static electricity	due to static electricity	due to static electricity
Fire fighting measures	Foam, water spray or fog	Foam, water spray or fog	Foam, water spray or fog

Source: SHELL (2014)

2.9 Potential major hazard at petrol station

The operation of a petrol station involves receiving and storing different types of fuel in adequate volume which are stored in underground storage tanks and then dispensing the fuel according to the request of consumers. Since fuel is a complex mixture of flammable, toxic and carcinogenic chemical, various hazards at the petrol station could be found which may cause injury or even death (Rodricks, 1992). Some of the hazards may even result in multiple deaths. These hazards could be divided into the following categories:

a) Fire and explosion hazards

The most concern major hazards at the petrol station are fire and explosion. Multiple factors could cause these incidents, one of which was failure of pipework and tank. Failure of pipework and tank could lead to various outcomes, some of which can pose a significant threat of damage to people and properties in the immediate vicinity of the failure location. The hazard associated area will depend on the mode of the pipework failure, ignition time, environmental condition at failure point and meteorological condition. Some of the failures were time independent occurrences such as external mechanical interference, earthquake or overpressure whereas others were time dependent such as corrosion or ruptures (Jo & Ahn, 2002).

Upon loss of containment caused by line leak or failure, hydrocarbon fire could occur. A jet fire is a hydrocarbon fire which could occur at the premise. In the presence of ignition source with immediate ignition, jet fire could result in the release of heat radiation but the fuel would undergo rapid dispersion without immediate ignition (Shelley, 2008).

Table 2.9 showed the level of hazardous thermal radiation for various exposure times while the thermal radiation intensity's damages were illustrated in Table 2.10.

Table 2.9: Hazardous thermal radiation levels for various exposure times

Exposure time (seconds)	Probit value	Mortality rate* (%)	Thermal radiation (kW/m^2)
5	2.67	1	27.87
	5.00	50	55.17
	7.33	99	109.20
15	2.67	1	16.57
	5.00	50	32.80
	7.33	99	47.39
20	2.67	1	9.85
	5.00	50	19.50
	7.33	99	38.60
30	2.67	1	7.27
	5.00	50	14.39
	7.33	99	28.47

Source: Tsao and Perry (1979)

Table 2.10: Damage due to incident thermal radiation intensity

Incident thermal radiation intensity (kW/m^2)	Type of damage
37.5	Can cause heavy damage to process equipment, piping, building etc.
32.0	Maximum Flux level for thermally protected tanks
12.5	Minimum energy required for piloted ignition of wood.
8.0	Maximum heat flux for un-insulated tanks.
4.5	Sufficient to cause pain to personnel if unable to reach cover within 20 sec. (First Degree Burn).

1.6	Will cause no discomfort to long exposure.
0.7	Equivalent to solar radiation.

Source: Dow Chemicals (1981)

Other hydrocarbon fire that could occur was a pool fire. A pool fire occurs when a spilled liquid formed a pool which then ignited before evaporation of fuel occurred. Due to lack of well aeration, the flame temperature for pool fire was low thus produced low level of thermal radiation and smoke. The impact from a pool fire was a structural damage within the flame but the effect will be delayed compared to a jet fire which gave immediate damage (Suardin, 2008).

Furthermore, flash fires with flammable cloud range could also occur at a petrol station. Flash fires occurred when flashing or non-flashing liquids of pressurized flammable chemicals were released from an overfilling storage tanks which resulted in the formation of vapour clouds. Delayed ignition resulted in the formation of vapour cloud where it moved away from the point of source in the presence of wind. However, if the ignition took place in a confined area, it would result in the occurrence of vapour cloud explosion (VCE). Flash fires could also initiate a pool fire when the liquid pools' clouds were ignited (Woodward, 2010).

Other than that, VCE could be formed when a vapour cloud fire is generated with the presence of pressure. The amount of overpressure depend of the reactivity of gas, the strength of the ignition source, the degree of confinement of the vapour cloud, the number of obstacles in and around the cloud and the location of the point of ignition with respect to the escape path of the expanding gases. There are two types of explosion of VCE which are called deflagration and detonation. Deflagration is the type of explosion where the flame front swelled and moved slowly than the pressure wave whereas detonation is explosion with the fast moving flame front that matched the pressure wave. Overfilling could also result in VCE (Abbasi & Abbasi, 2007).

Aside from that, the generation of fire and explosion from a single accident could result in secondary and higher order accidents in other units (Khan & Abbasi, 2001a). This is known as a "domino effect". Domino effect causes tremendous damage to people and properties but the concern is relatively low as it rarely happened (Lee *et al.*, 2006). For instance, a liquefied petroleum gas (LPG) explosion accident related to domino effect occurred at Mexico City in 1984 which caused 650 death and 6400 injuries. The cause of this incident was the release of gas from the rupture of 8 inch pipe connecting sphere. A cloud was then formed and covered an area of 200 m x 150 m. After a while, the cloud moved towards a flare tower which was caught on fire that resulted in the formation of boiling liquid expanding vapour explosion (BLEVE). Due to this, the failure of vessel kept occurring one after another, with most exploding vessels causing nearby vessels to fail (Abbasi & Abbasi, 2007). Based on this incident, the domino effect is prompted by flame, overpressure and missile effect as stated in Table 2.11.

Table 2.11: Accidental events related to domino effect

Domino Factor	Accidental Event
Heat radiation and Fire impingement	Pool fire, Jet fire, Flash fire, Fireball, VCE
Overpressure	Condensed phase explosion, Confined explosion, Physical explosion, BLEVE, VCE
Fragment projection	Condensed phase explosion, Confined explosion, Physical explosion, BLEVE

Source: The MathWorks (2004)

b) Health hazards

Concerns regarding the health risks from the exposure of fuel vapours to people have increased drastically (Lynge *et al.*, 1997). The main cause of this was benzene and 1-3 butadiene which could be found in fuel. The exposure of benzene would result to numerous blood cancers including acute myeloid leukaemia and acute non lymphocytic leukaemia (Jakobsson *et al.*, 1993).

There are different routes of exposure for fuel. Inhalation, ingestion and dermal contact are the example of these routes. Every route gives different health hazards for fuel such as inhalation could result in asphyxiations. The fuel could be released in the form of liquid spills or vapour losses where the effect is dependent on the distribution of fuel across the surrounding area. Thus, the minimization of exposure should be conducted to eliminate or reduce the health risks (Asante-Duah, 2002).

c) Environmental concerns

Fuel is considered one of the environmental concerns' chemicals which have the ability to contaminate the water, air and land resulted from the petrol station's process, design and equipment standards. Leaks and spills of fuel are the most common cause of contaminations. Due to this incident, the management had taken additional precautionary measures and develop higher standards for safety and environmental matters (Terrés *et al.*, 2010).

2.10 Hazard contributing factors

Many studies have been conducted to determine the causes of hazards-prone accidents. In the study by Dodsworth *et al.* (2007) and Powell and Canter (1985), they had highlighted that the root causes of accidents are human factor and failure of technical component. The following causes are mentioned in detail below:

2.10.1 Human factor

Human factor could be divided into human errors and negligence. The example of human errors was carelessness. Carelessness happened when workers failed to give attention in avoiding hazard. This behaviour cannot be eliminated without the workers' own effort to improve (Reason, 2008). According to Ahmed *et al.* (2012), the case of carelessness could occur due to the following violation committed by the workers:

a) Inability to obey work instructions
b) Inability to obey disciplinary rules and regulations
c) Inability to utilize methods of safe work
d) Inability to fully concentrated in performing work
e) Inadequate skills in performing work
f) Inappropriate behaviour in the utilization of tools
g) Inability to focus in conducting task
h) Lack of attitude towards safety
i) Performance of "shortcuts"

During operation and maintenance of petrol stations, carelessness is the main factors that could cause harm to people. The most common cases are slips, trips and falls. Injuries of these cases could be on legs, arms and heads. For example, fallen tools at height could result in injuries to workers and public. Luckily, petrol station is one-storey facility so the probability of falls to occur is low. However, falls could occur when workers were changing the light source using a ladder which might be in a bad condition.

On the other hand, slippery occurred when there was a leakage of oil in the working area or forecourt. This contributed to slips, trips and falls. On other situation where a worker monitored the level of the tanker lorries after unloading by climbing a ladder, slippage took place which resulted in serious injuries of legs and arms (Ahmed *et al.*, 2012). The management have been urged to constantly remind the workers on the outcome of carelessness to prevent such cases from occurring.

On the contrary, negligence occurred when workers failed to take proper care in performing work or others. One of the examples from negligence is housekeeping. Housekeeping is the cleaning of all area of facility including equipment and materials to eliminate any hazardous materials and situation. Although housekeeping is unable to control risk at petrol station, it is able to prevent fire, tripping and contact hazards. For instance, stacking items in appropriate shelves contributed to the prevention of tripping hazards and the construction of clear pathway in case of fire. In the case of cleaning display boards at the retail outlet, electrical shock could occur which may result in the generation of fire (Ahmed *et al.*, 2010).

2.10.2 Failure of technical components

Argyropoulos *et al.* (2012) suggested that there were various failure causes for tank accidents. The most common initiating events or failure were presented and explained in Table 2.12.

Table 2.12: Immediate causes of accidents

Causes of accidents	Factors
Operational errors	Tank overfilling
	Drain valves left open accidentally
	Vent closed during loading or loading
	Oil leaks due to operator errors
	High inlet temperature
	Drainage ducts to retention basin obstructed
Equipment or Instrument failure	Floating roof sunk
	Level indicator
	Discharge valve rupture
Lightning	Poor grounding
	Rim seal leaks

	Flammable liquid leak from seal rim
	Direct hit
Static electricity	Rubber seal cutting
	Poor grounding
	Fluid transfer
	Improper sampling procedures
Maintenance errors	Welding or cutting
	Non explosion-proof motor and tools used
	Circuit shortcut
	Transformer spark
	Poor grounding of soldering equipment
	Poor maintenance of equipment both normal and blast proof
Tank rupture or crack	Poor soldering
	Shell distortion or buckling
	Corrosion
Piping rupture or leak	Valve leaking
	Flammable liquid leak from a gasket
	Piping failure
	Pump leak
	Cut accidentally
	Failure owing to liquid expansion
Miscellaneous	Earthquake
	Extreme weather
	Vehicle impact on piping
	Open flames or smoking flame
	Escalation from another unit (domino)
	Accident caused by energy or fuel transportation lines
	Arson (intentional damage)
Safety supporting systems	Electric power loss
	Insufficient tank cooling
	Fire fighting water loss
	Fire fighting water in piping freezing

Source: Argyropoulos *et al.* (2012)

2.10.2.1 Operational errors

These errors consisted of

i. tank overfilling where the metering system or human error failed to reach level in the loading procedure

ii. fuel release due to accidental opened drain valves

iii. Closed vent valve during loading or unloading in fixed roof tanks

iv. Oil leaks due to errors by operators

v. Import of a product with high inlet temperature

vi. Blockage of drainage ducts to retention basin.

The causes above led to leakage of fuel in the retention bund and creation of an air vapour mixture that could be easily ignited on the occasion of an ignition source, leading to a pool fire even in the whole bund area.

Cause (iii) led to tank buckling, owing to under pressure in it, and subsequent tank failure and fuel release, while cause (v) led to temperature increase in the tank and possible release of fuel vapour.

2.10.2.2 Equipment or instrument failures

The failures comprise of

i. the sinking of floating roof resulting in the bursting of a fire that may comprise the entire upper surface of the tank

ii. the level indicator failure that can lead to tank overfilling

iii. the discharge valve failure

iv. a rusted vent valve that did not open, with consequences described in table 2.

In a petrol station, the damage of electrical equipment could occur from electrical faulty which then led to the formation of fire that engulfed the whole equipment. The main electrical components of petrol station are:

i. electrical fixtures

ii. switch boards

iii. electrical panel

iv. control panel

v. sky links

vi. electrical hooters

vii. dispenser units

viii. generators

ix. electrical wiring

x. electrical heaters

Since hazards involving electricity did not gain any recognition, the management should educate the workers regarding this type of hazards to prevent accident associated with electricity from occurring.

2.10.2.3 Lightning

It was the most prominent accident initiator due to:

i. poor grounding of the tank which stopped fully absorption of a direct strike

ii. leakage of rim seal or flammable liquid which created the lightning strike into a fire

iii. wall of tank was directly strike that led to its failure and subsequent fuel leakage.

2.10.2.4 Static electricity

It was caused by:

i. generation of spark from rubber seal cutting of floating roof which led to tank roof fires

ii. poor grounding of fixed roof tanks which led to its channelling to tank shell, thus, occurrence of vapour ignition

iii. generation of spark from the transfer of fluid during the process of unloading tank

iv. generation of spark from inappropriate conduct of sampling method such as unsuitable gloves

2.10.2.5 Maintenance errors

These errors contributed to:

i. generation of unshielded sparks during the process of welding or cutting
ii. utilization of explosive motor and tools
iii. circuit shortcut
iv. generation of sparks from transformer
v. poor grounding of soldering equipment
vi. poor maintenance of normal and blast proof equipment

2.10.2.6 Tank rupture or crack

This incident was due to:

i. poor soldering
ii. distortion of shell or buckling
iii. corrosion of roof and shell

2.10.2.7 Piping rupture or crack

The detection of this incident was by:

i. presence of hole in pump or valve
ii. flammable liquid outflowing from the gasket
iii. failure of piping material
iv. inexperienced contractor
v. failure of pipe owing to liquid expansion

The problems above could lead to the formation of pool fire with the presence of ignition source and specific volume of liquid discharge.

2.10.2.8 Miscellaneous

This section comprised of disaster such as:

i. earthquakes
ii. extreme weather
iii. vehicle impact on piping
iv. open flame or smoking
v. domino effect
vi. past accident of petrol station
vii. act of sabotage or arson

2.10.2.9 Supporting safety systems failures

The failure involved

i. loss of electricity
ii. destruction of total tank caused by lack of cooler
iii. loss of water supply for fire fighting
iv. presence of frozen water in the fire extinguishing's pipes

In brief, the management should serve its role in promoting good safety practices in workers on grasping self-responsibility and sufficient skills. In contrast, proper maintenance of technical components and good housekeeping promoted good safety managements (Chadha, 2007).

2.11 Components of petrol station

A petrol station is an essential vendor facility of fuel and other lubricants for vehicles. In the 2010s, the most commonly used fuels were petrol and diesel (Afolabi, 2011). Some cars might use electric energy or gasoline but it is not common in Malaysia due to less utilization of electric cars compared to petrol-utilizing cars. Most of petrol stations are built with the following components:

a) Fuel system

This includes dispenser, tanks and tanker lorries. A fuel dispenser is a pump for transferring petrol or diesel into the vehicles tank where the financial cost was calculated for every litre of fuel (Gresak *et al.*, 2004). In Malaysia, different types of fuel and dispensers use separate pipes. However, in a more developed country, a single pipe is used for every dispenser. This pipe comprises of a set of smaller pipes for every type of fuel. During refuelling, the releases of vapour into atmosphere would occur but this could be prevented by vapour recovery systems that embedded in fuel tanks, dispensers and nozzles as well as exhaust pipe. The vapour was accumulated, liquefied and released back into the lowest grade of fuel tank by the systems. Thus, no vapour was released to the atmosphere (McAvey *et al.*, 2015).

The dispenser pumps are used by elevating of nozzle followed by pressing of a lever underneath it to automatically release a switch for the transfer of fuel. Separate nozzles are used for different fuel types where permanent damage could occur to the vehicles' injection pumps if different fuel types were inserted. Diesel dispenser pump differs from petrol dispenser.

The nozzle of diesel dispenser pump is huge with the diameter of 23.8 mm and secured by a lock mechanism or a flap that can be lifted so it is impossible to make a mistake of refuelling diesel in petrol vehicles due to the difference in nozzle's size and separate dispenser (Redmond, 2007).

A fuel tank is a safe container that stores flammable liquid such as petrol and diesel. It is normally bitumen coated single skinned mild steel tanks. Fuel tanks vary in complexity and sizes which would best meet the daily sales volume. The most widely used tank's sizes are 18000, 27000 and 45000 litres. In this study, the size of tank used is 27000 litres. Typically, a petrol station contains multiple fuel tanks which are stored underground where underground pipes transferred the fuel to the dispenser pumps. Direct access of fuel tanks must always be made available through a service carnal directly from the forecourt. Fuel is usually unloaded into underground tanks from tanker lorries which are designed liquefied loads, dry bulk cargo or gases on roads. The transfer took place through a separate valve located on the petrol station's area (Reese, 1993).

b) Forecourt

A forecourt is the area for the refuelling of vehicles where fuel dispensers are located. As a preventive measure, concrete plinths were used for the placement of the dispensers with additional elements such as metal barriers. A drainage system and fire protective system are provided at the fuel dispensers' area for emergency situation such as spill and fire. The presence of spilled liquid in the forecourt could be removed through the channel drain equipped with a petrol interceptor to prevent pollution distribution of hydrocarbon especially during rainy season. The role of a petrol interceptor is to capture the polluted hydrocarbon and then discharging the liquid into a sewer or ground (Mwania & Kitengela, 2013)

A forecourt is usually arranged in the form of tollgate, echelon or square. All of these arrangements depend on the availability of space in the premises of a petrol station (Ahmed *et al.*, 2011). Figure 2.2 shows different arrangement of forecourt.

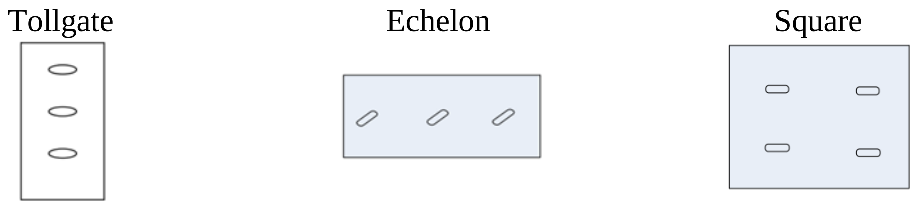

Figure 2.2: Arrangement of forecourt (Source: Ahmed *et al.* (2011)**)**

Figure 2.3 shows the typical example of forecourt layout for most petrol stations in Malaysia.

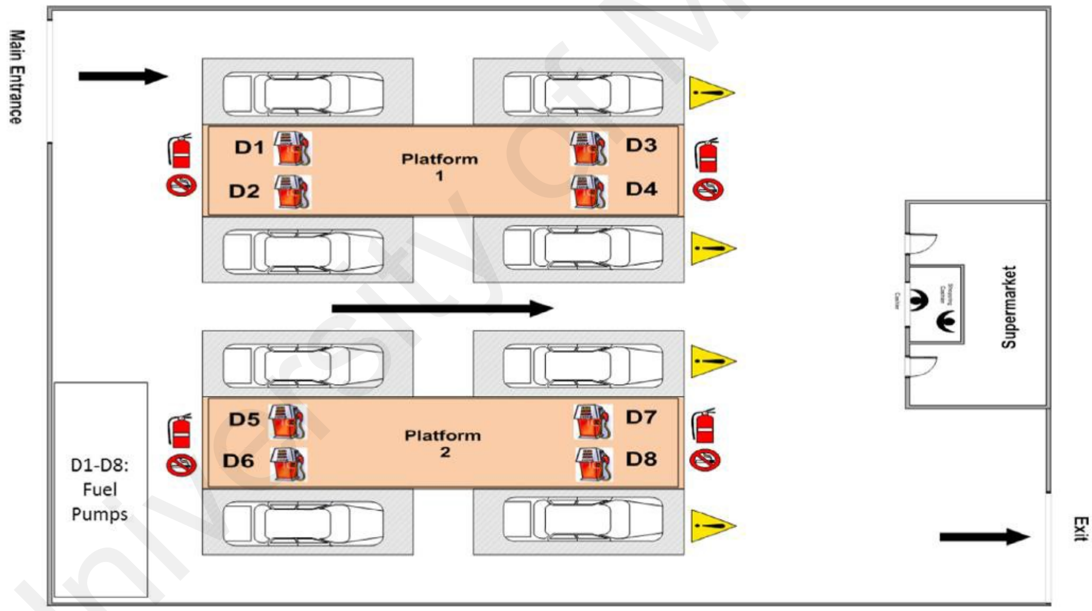

Figure 2.3: Layout of forecourt at petrol station (Source: Galankashi et al., 2016)

c) Signage

This includes the safety signs which indicate the danger of specified area of petrol station as well as fire fighting measures such as fireproofing, water-draw systems, and relief systems. These considerations address the various ways to prevent leaks or releases that may lead to a fire. In general, there are three primary methods to apply water for cooling or extinguishing fire which are water deluge, fixed monitors, and water spray.

Additionally, portable equipment such as ground and trailer-mounted monitors can be used but should not be considered a primary means of water delivery. This is mainly because of the potentially extended setup times, logistics, and requirement of human intervention that is not necessarily reliable (Webb, 1996). Table 2.13 showed the water application methods for fires

Table 2.13: Water Application Methods for Fires

Method	Advantages	Disadvantages
Water Deluge	Rapid activation	Problems with wettability
	Can be automatic	Possible water spray supplement for legs
	Lack of plugging	Effectiveness with jet fires
Fixed Monitors	Ease of activation	Exposure to operators
	Can be automatic	Wind
	Effective for jet fires	Large water demand
		Monitors may be changed unknowingly
Water Spray	Rapid activation	VCE damage
	Wettability and run down	Plugging
	Can be automatic	Effectiveness with jet fires
Portable Equipment	VCE damage not an issue	Prolonged setup times
	Specific application to area	Manual
	Portability for multiply hazards	Exposure to operators

Source: Webb (1996)

d) Allied facilities

The allied facilities include restaurant, car wash, prayer areas as well as toilets. Since a petrol station was used at a pit stop for resting, these facilities were provided to accommodate the consumers’ needs. In the recent years, restaurant like Kentucky Fried Chicken (KFC) could easily be found on the premise of a petrol station. Besides that, a convenience store is incorporated in a petrol station. Snack, candy, drinks and some toiletries items like toothbrush are sold at this convenience store.

Other than consumers that bought items in the store, consumers which came for refuelling are also required to pay at the register located inside the convenience store. The cash register system is able to control the dispenser and turn the pump on and off as instructed by the clerk. The fuel tank's status and quantities of fuel were monitored by a separate system where sensors embedded in the fuel tank fed the data directly into an external database or the back room (Withrow, 2000). The example of overall layout of the petrol station is presented in Figure 2.4.

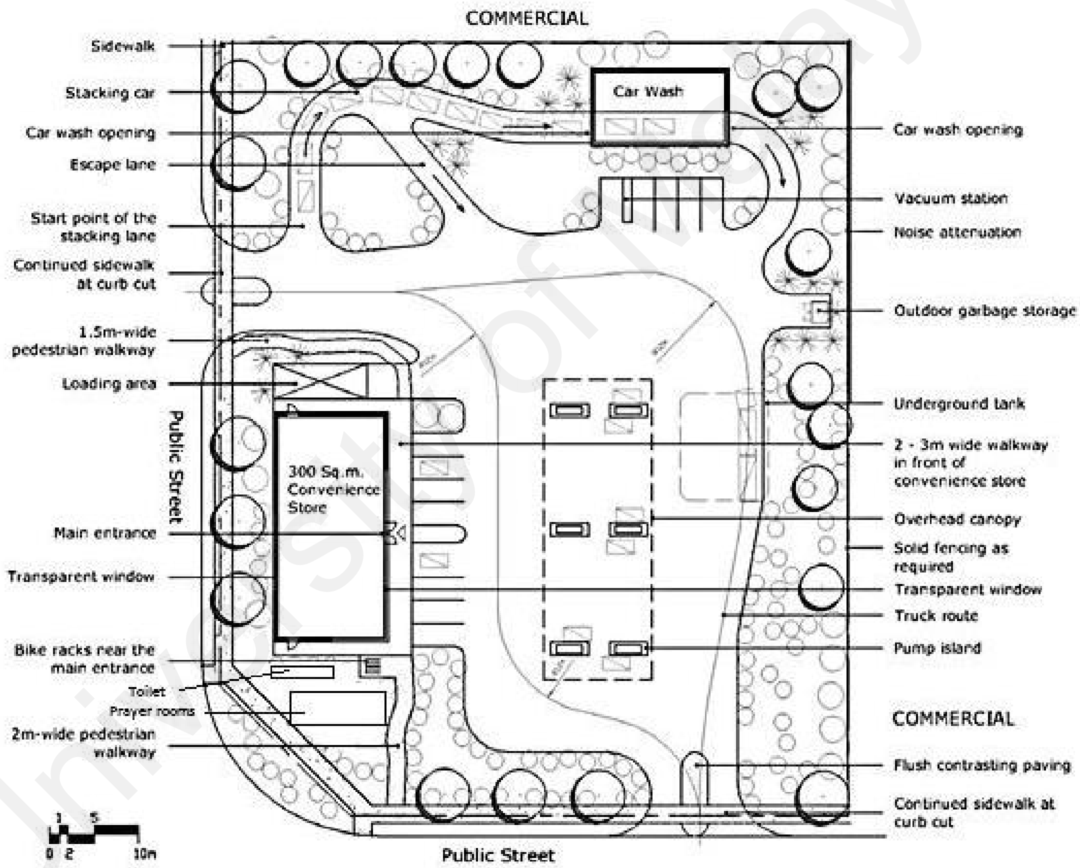

Figure 2.4: Layout of petrol station

CHAPTER 3: METHODOLOGY

3.1 Introduction

This chapter is focused on the methodology in conducting the research. It started with hazards identification process, risk and consequences assessment and last but not least on the risk estimation. The study is involved both qualitative and quantitative risk assessment. The method of risk assessment can be classified as qualitative and quantitative (Khan & Abbasi, 1998). Table 3.1 showed the examples of risk assessment methods used qualitatively and quantitatively in process safety (Tamil Selvan & Siddqui, 2015).

Table 3.1: Qualitative and Quantitative Tools

Qualitative	Quantitative
Checklist	Fault tree analysis
Site survey	
Site inspection	Event tree analysis
Safety audit	
Site observation	Probabilistic risk assessment
HAZID	
What if	Quantitative risk assessment
HAZOP	

Source: Tamil Selvan and Siddqui (2015)

This study began by conducting screening methodology which was identifying hazards at the petrol station using a checklist. Based on the checklist, qualitative risk assessment will be conducted followed by quantitative risk assessment. The probability of risk to occur will be determined using Aerial Locations of Hazardous Atmosphere (ALOHA) software version 5.4.6, February 2016.

A questionnaire based on a 4-point Likert-type scale (1 = strongly disagree, 4 = strongly agree) is also distributed among the selected government agencies which were involved in giving technical inputs before Development Order will then be approved by Local Authorities. The purpose of the questionnaire is to have some basic understanding on each agency roles and responsibilities in the petrol station development. The responses are then analysed using Statistical Package for Social Sciences (SPSS) software, version 25.

3.2 Preliminary hazard identification

Site visit was conducted as preliminary approach to do the hazards identification. Overall layout and related procedure on operation and maintenance manual are referred to get better understanding on petrol station operation. Checklist was also used to further identify the hazards in relation to the daily operation of petrol station.

3.2.1 Site visit

A site visit was conducted to fully understand the whole operation of the petrol station. This includes observation on the process of unloading and loading of fuel from the tank lorry, the outline of the underground fuel tank and the layout of the petrol station.

3.2.2 Checklist

A safety checklist which covers a general workplace safety and health hazards related is used. This checklist is adapted from other research which helps the operator to control associated risk with regards to the operation and maintenance of petrol station (Dana *et al.*, 2013). This checklist was divided into several categories as follows which the details is appended at appendix of this report.

a) Site perimeter

b) Electricity at work

c) Hazardous chemical exposure, management and communications

d) Tanker filling operation

e) Fuel dispensing area

f) Operator console and retail area

g) Fire safety

h) Exit

i) Waste management

j) HSE communication and record keeping

k) General management

3.3 Estimate failure frequency and event probability

The quantitative risk analysis attempted to estimate the risk in form of the probability (or frequency) of a loss and evaluate such probabilities to make decisions and communicate the results.

The probability concept can be used to characterize the 'uncertainty' associated with the estimation of the frequency (or probability) of the occurrence of the undesirable events and the magnitude of severity (consequences). Uncertainties associated with the quantitative results play a decisive role in the use of the results when evidence and data are scarce (Morgan *et al.*, 1992). Event trees per sequence of events were developed along with associated frequencies and probabilities to determine the overall event frequencies as mentioned below:

3.3.1 Failure frequency

In this study, the common failure frequencies of systems component were demonstrated from Oil Industry International Exploration and Production (E&P) Forum Database (E&P, 1992). This helped in reducing variance arose out of analysis judgement in estimating failure frequency.

The equation below expressed the overall frequency for a particular set of equipment (CCPS, 2003)

$$F_t = \sum FN$$

Where, F_t = total failure frequency/per year/per unit

F = individual item frequency/per year

N = number of items or length of piping unit.

Table 3.2 showed the cumulative frequencies for all sizes of holes up to full bore for piping and other equipment acquired from the E&P Forum Database for leaks.

Table 3.2: Common equipment release frequencies per year

			Hole Size Probability		
Equipment Item	**Size**	**Overall**	**Small Leaks**	**Medium Leak (represented by 2")**	**Rupture (6" and above)**
Valves	6" – 10"	2.30 x 10^{-4}	0.65	0.30	0.05
	12" – 14"	2.30 x 10^{-4}	0.60	0.34	0.06
Process Piping	6" – 10"	3.60 x 10^{-5} /m	0.82	0.15	0.03
	12" – 14"	2.70 x 10^{-5} /m	0.60	0.25	0.15
Flanges	6" – 10"	8.80 x 10^{-5}	0.95	0.15	0
	12" – 14"	8.80 x 10^{-5}	0.90	0.10	0
Pressurized Tanks	-	1.50 x 10^{-4}	0.22	0.67	0.01
Pumps	-	2.63 x 10^{-4}	0.82	0.14	0.04

Source: E&P (1992)

3.3.2 Event Probability

Event probability was constructed by utilizing event tree analysis. Event tree analysis (ETA) is used to model the evolution of an event from the initial release through to the final outcome such as jet fire, fireball, flash fire and vapour cloud explosion (VCE). This may depend on factors such as whether immediate or delayed ignition occurs, or weather that can result in flash fire or explosion. The probability of ignition depends on the availability of flammable mixture, the temperature where the ignition source of flammable mixture was reached and the type of ignition source or energy (Frank & Lees, 1996). The probability of the ignition for oil leak was mentioned in Table 3.3.

Table 3.3: Generic Overall Ignition Probabilities

	Overall Release Frequency / Year		
	Small	**Medium**	**Large**
Oil leak	0.01	0.07	0.30

Source: Cox *et al.* (1990)

Ignition can be either immediate or delay depending on the time of ignition after release (Frank & Lees, 1996). The following assumption was summarized in Table 3.4 with the distribution of overall ignition probability of immediate and delayed ignition.

Table 3.4: Immediate and Delayed Ignition Probability Distribution

Release rate category	**Release rate category (Kg/s)**	**Immediate ignition**	**Delayed ignition**
Small	<1	0.1	0.9
Medium	1-50	0.5	0.5
Large	>50	0.6	0.4

Source: Cox *et al.* (1990)

Several factors contribute to the probability of explosion such as location of leak sources, gas concentrations, location of ignition source, ventilation area and equipment congestion. Table 3.5 demonstrated the probability of explosion.

Table 3.5: Probability of explosion

Release rate category (Kg/s)	**Probability of explosion given ignition**
<1	0.04
1-50	0.12
>50	0.3

Source: Cox *et al.* (1990)

3.4 Estimate and evaluate effect and consequence of event

Hazardous material like gas and liquid can pose a potential risk to life, health and properties if they released. Therefore, it is crucial to estimate dispersion manner of a hazardous material release under the various scenarios. Consequence analysis is performed by using Area Locations of Hazardous Atmospheres (ALOHA) software. ALOHA is a program used in evaluating and quantifying the risk associated to chemical release together with emergency planning and training. With an ALOHA program, the key hazards related to a petrol station such as toxicity, flammability, thermal radiation and overpressure can be determined (EPA, 2007). Table 3.6 shows different sources and scenarios that were estimated and evaluated by ALOHA.

Table 3.6: ALOHA sources and scenarios estimates and evaluation

Source	Toxic scenarios	Fire scenarios	Explosion scenarios
Direct			
Direct release	Toxic vapour cloud	Flammable area (Flash fire)	Vapour cloud explosion (VCE)
Puddle			
Evaporating	Toxic vapour cloud	Flammable area (Flash fire)	Vapour cloud explosion (VCE)
Burning (Pool fire)		Pool fire	
Tank			
Not burning	Toxic vapour cloud	Flammable area (Flash fire)	Vapour cloud explosion (VCE)
Burning		Jet fire or Pool fire	
BLEVE		BLEVE (Fireball and Pool fire)	
Pipeline			
Not burning	Toxic vapour cloud	Flammable area (Flash fire)	Vapour cloud explosion (VCE)
Burning (Jet fire)		Jet fire	

Source: EPA (2007)

ALOHA software has the ability to model chemical releases from four types of sources which was direct, puddle, tank and pipeline where tank is the most applicable in this study due to the existence of underground storage tanks. It is also used in predicting the effect of explosion to the surrounding. This was done by interpreting ALOHA’s threat zone plot from the assessment of the surrounding of the explosion site. Large object such as trees and buildings in the path of the pressure wave could affect its strength and direction of travel. For example, if many buildings surround the explosion site, the actual overpressure threat zone was expected to be smaller than ALOHA predicted result. However, the blast could cause structural damage to those building which then produced more hazardous fragments (EPA, 2007). Table 3.7 showed the summary of the threat zones for each event modelled by ALOHA which outline the criteria for individual risk.

Table 3.7: Summary of threat zones for individual risk

		Distance to	**Risk probability**
Event effects	**Threat zone**	**(Model by ALOHA)**	
Toxic effect	Red	4000 ppm = AEGL-3	Potentially lethal
	Orange	800 ppm = AEGL-2	Severe health
	Yellow	52 ppm = AEGL-1	Health effect
Flammable area for Vapour cloud	Red	12000 ppm = LEL	Potentially lethal
	Orange	7200 ppm = 60% LEL	Flame pocket – potentially lethal severe injury
	Yellow	1200 ppm = 10% LEL	Injury
Jet fire or Pool fire radiation	Red	10.0 kW/m^2	Potentially lethal within 60 seconds
	Orange	5.0 kW/m^2	2^{nd} degree burns within 60 seconds
	Yellow	2.0 kW/m^2	Pain within 60 seconds
Overpressure or Explosion	Red	8.0 psi	Destruction of building
	Orange	3.5 psi	Severe injury
	Yellow	1.0 psi	Shatters glass

Source: Crowl and Louvar (2001)

3.5 Estimate event impacts and evaluate risks

The impacts of event and risk evaluation were estimated through individual and societal risk (CCPS, 2009 and DOE, 2004)

a) Individual risk

It is the probability of death resulted from accidents at a petrol station. It is expressed as a probit analysis which relate to the effects of accident to the degree of damage it cause on human beings. The following probit expression is used to estimate fatalities related to thermal radiation:

$$Y = -36.38 + 2.56 \ln(I^{(4/3)}.\ t)$$

Where t is exposure time and I is the thermal radiation intensity (Ronza *et al.*, 2006). According to Aven (2015), the risk of death or serious injury should not exceed 1 in 10000 per year. If risk reached between these limits, it must be made "as low as reasonably practicable" (ALARP). It is usually expressed as individual risk per annum (IRPA).

b) Societal risk

It is expressed as the cumulative risk to group of people who might be affected by major accident. It is usually expressed as an F-N curve where F is the expected frequency per year and N is the number of casualties in the area of all possible dangerous incidents at a petrol station.

3.6 Comparison with risk acceptance criteria

All the risks were summarized by combining the probability and consequences of all incident outcomes based on established incidents scenarios to provide a measure of risk. The risk of all selected incidents were individually estimated and summed to give an overall measure of individual risk. The results were then displayed in ISO-risk contours of individual risk form.

According to Department of Environment (DOE), the risk acceptance for individual risk contours for both worker and the public in the tolerable region should not exceed the value of 1 x 10^{-5} and 1 x 10^{-6} per year respectively. Thus, the measure of risk obtained shall not exceed the standard limits. Figure 3.1 shows the maximum individual risk criteria for both worker and the public as per As Low As Reasonably Practicable (ALARP) principle.

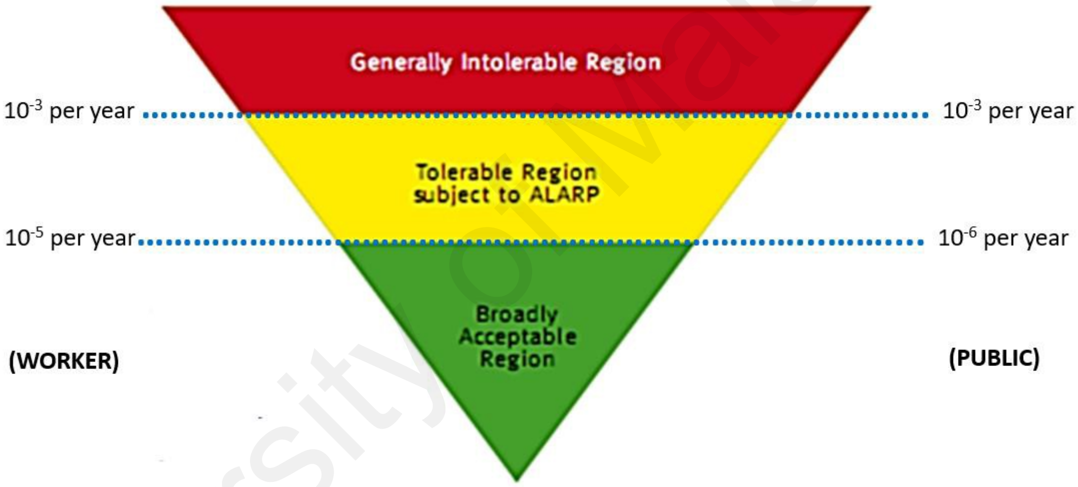

Figure 3.1: ALARP principle (Source: DOE, 2004)

3.7 Risk reduction measure

The most important risk contributing factors were identified to ensure that control and mitigation measure in reducing and eliminating the major hazards were established. The matters in consideration were:

a) Processes involve (e.g. loading and unloading of fuel from road tanker etc.)

b) Equipment (e.g. changes or modification of equipment such as nozzles, petrol pumps etc.)

c) Standard operating procedures (e.g. establishment of safe operation procedure including normal and abnormal condition.

d) Emergency response plans (ERP) etc.

3.8 Background of case study

The location of the selected petrol station is in Shah Alam, Selangor which provides services to the population at its vicinity. There are two more petrol stations at this area which one of it is located next to this petrol station while the other one is within xxx meter. Surrounding area comprises of residential and commercial area which this area considers as prime area due to highly populated area.

Nearest receptor area are the flats, landed property, primary school, government hospital and also the higher learning institution which is in the close proximity to this petrol station. The commercial area nearby is always attracts many visitors especially during weekend which cause traffic congestion at this area. Figure 3.2 illustrated the location of the petrol station.

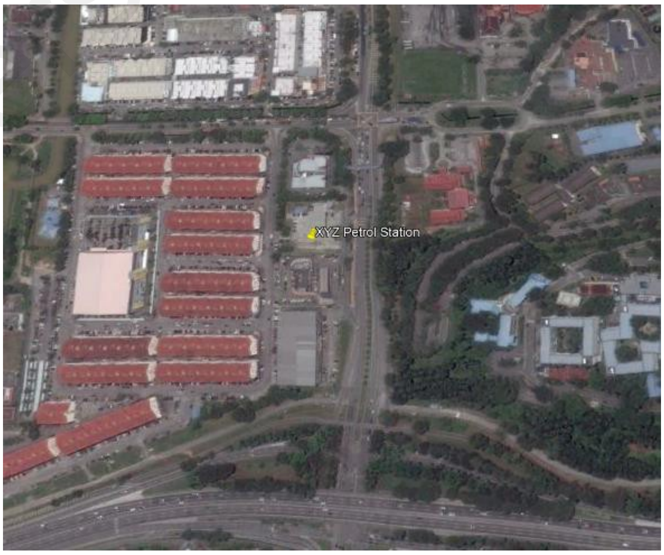

Figure 3.2: Location of petrol station (Source: Google Earth)

In general, the land use in this area is occupied with commercial, residential, public amenities and higher learning institution as per Table 3.8 below

Table 3.8: Surrounding Land Use within 1 km from Study Area

Radius (meter)	Landuse
0 – 300	Commercial, higher learning institution
300 – 500	Commercial area, Sekolah Jenis Kebangsaan Tamil, , Government Hospital, Residential area (Flat, Condominium, Double Storey and Bungalow house)
500 - 1000	Private School, Sekolah Kebangsaan Residential area (Flat, Condominium, Double Storey and Bungalow house) and industrial area

3.8.1 Meteorological data

The meteorological data is crucial in using the ALOHA software because it uses the information to evaluate the effect of weather conditions on various scenarios. As for example, strong wind might give severe effect to the surrounding areas since the expected outcome would be widely spread across the area (EPA, 2007).

Over the course of a year, the temperature of Shah Alam typically varies from with minimum and maximum temperature varies from 23°C to 33°C as illustrated in Figure 3.3 respectively. Wettest month which is the highest rainfall is November (281.9 mm) while driest month is June (124.5 mm) as per Figure 3.4.

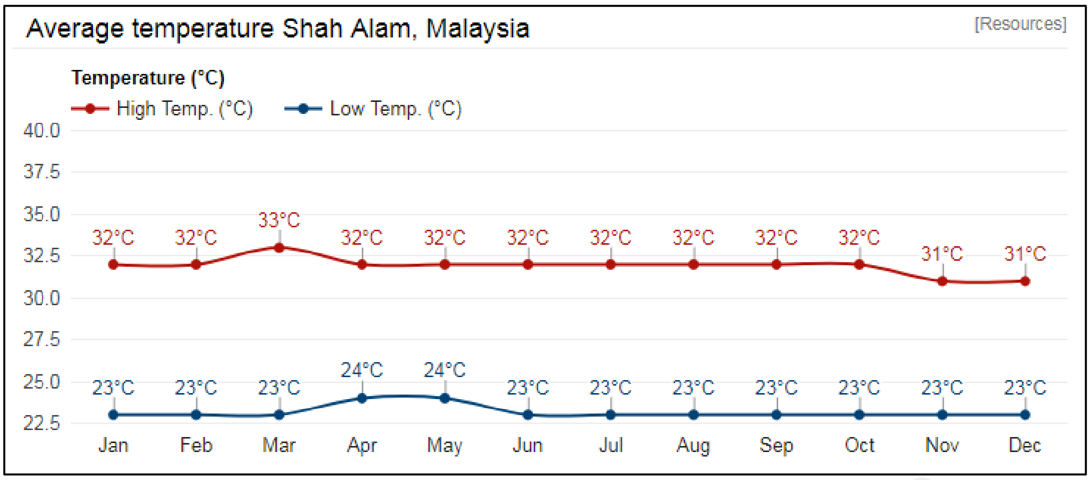

Figure 3.3: Average high and low temperature for Shah Alam
(Source: https://www.weather-my.com/en/malaysia/shah-alam-climate**)**

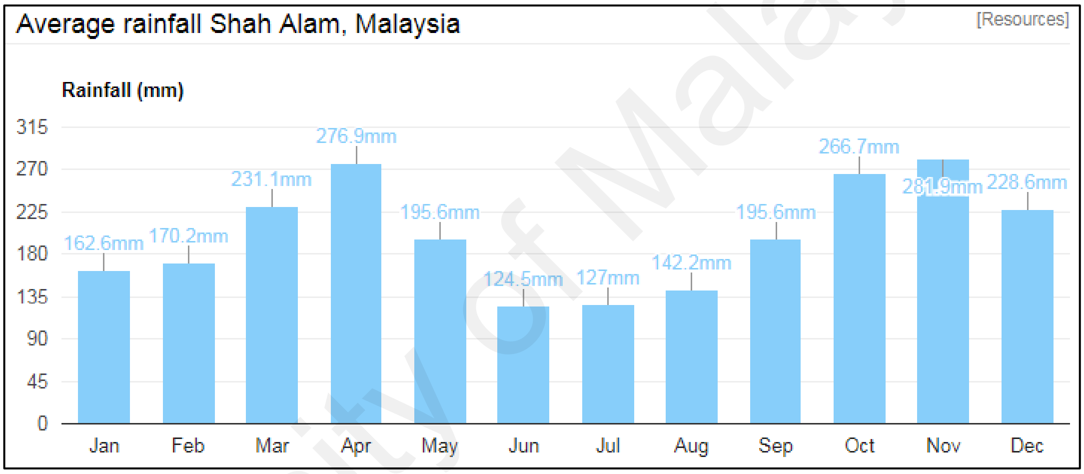

Figure 3.4: Average precipitation and rainfall days for Shah Alam
(Source: https://www.weather-my.com/en/malaysia/shah-alam-climate**)**

As for the wind speed of the location, they vary from 0 m/s to 3.4 m/s (calm to light breeze) and maximum recorded wind speed in recent years is 20 m/s – 40 knot.

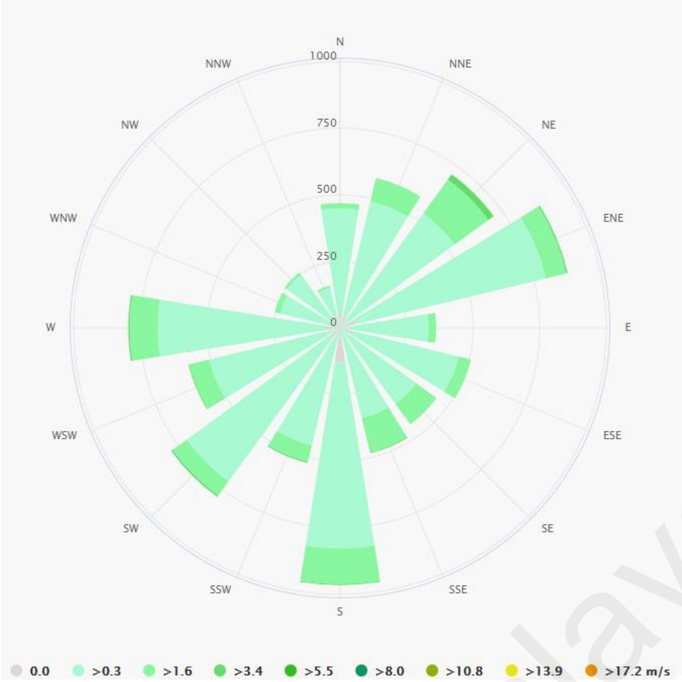

Figure 3.5: Wind rose for Shah Alam
(Source: https://www.meteolube.com/en/weather/forecast/modelclimate/shah-alam_malaysia_1732903)

3.7.2 Petrol station system information

ALOHA require several input data for the modelling calculation of consequences and effects. One of them is the information of petrol station gas system such as pipeline dimension and tank dimension which was obtained from the facility management. This information is listed in Table 3.9.

Table 3.9: XYZ Petrol Station System Information

Parameter	**Value**
Tank	
Diameter (vertical)	0.712 m
Length (vertical)	1.77 m
Volume (vertical)	615 kg
Diameter (horizontal)	5.33 m
Length (horizontal)	2.42 m
Volume (horizontal)	27,000 kg
Internal temperature	26-36^{0}C
Circular opening diameter	600 mm

(Source: XYZ petrol station operation and maintenance manual)

3.8 Questionnaire to selected government agencies

As to gauge the current implementation by related government agencies which involved in giving the technical input to Local Authority who will approve the Development Plan for petrol station, a questionnaire survey was distributed to selected government agencies. This questionnaire was based on a 4-point Likert-type scale (1 = strongly disagree, 4 = strongly agree) where the responder chose the best options for each question. The questionnaire were developed based on brief overview of the following Act, Regulations and other statutory requirements which relates to this selected government agencies:-

a) Local Authorities
b) Department of Occupational Safety and Health (DOSH)
c) Department of Environment (DOE)

The aim of this questionnaire is to assess the current implementation by these government departments. The questionnaire was written in both English and Malay for the ease of understanding. Further analysis was performed after the data collection by using SPSS software version 25. Appendix B to D present the questionnaire used for this survey.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Introduction

Previous chapter has outlined the method of this research project which started with hazards identification through site visit and using checklist. Next step was followed by qualitative risk assessment and followed by quantitative risk assessment (QRA) using ALOHA software. The last part is the questionnaire which were distributed to some selected government agencies to get some understanding on their involvement in petrol station development.

4.2 Hazard identification

Site visit is the primary focus for the hazard identification and at the same time and have better understanding on the operational and maintenance of selected petrol station. For this purpose, checklist was used to assist on getting systematic hazard identification. This checklist is categorised into ten categories which evaluation is made as ‘yes’ and ‘no’ depending on its existence or implementation at the petrol station. Safety score for each category in the checklist where poor safety score implied that the category could be classified as hazards. Score of 100 was given for each ‘yes’ whereas each ‘no’ was given as a score of 0. The final score of each category was calculated with the following equation:

$$\frac{\sum [\text{no of ‘Yes’ x 100 + no of ‘No’ x 0}]}{\text{No of applicable items}}$$

For this checklist, the non-applicable items were ignored and not used in the calculation as they did not serve any purpose for the final score of a category (Fourcade *et al.*, 2011). The rating of the score was shown in Table 4.1 while Table 4.2 summarized the safety score for each category which served as an indicator for the safety level of the facility.

Table 4.1: Rating of category's score

Score	Rating
0 – 59%	Poor
60 – 69%	Fair
70 – 79%	Good
80 – 89%	Very good
90 – 100%	Excellent

Source: Fourcade *et al.* (2011)

Table 4.2: Summary of the safety score for the checklist's categories

Category	Item	Safety score (%)	Rating
1	Site perimeter	80	Very good
2	Electricity at work	63	Fair
3	Hazardous chemical exposure, management and communications	64	Fair
4	Tanker filling operation	80	Very good
5	Fuel dispensing area	91	Excellent
6	Operator console and retail area	80	Very good
7	Fire safety	67	Fair
8	Exit	75	Good
9	Waste and general management	50	Poor
10	HSE communication	75	Good
	Average safety score	**73%**	Good

From the table, safety scores assessed has wide variation from the lowest 50% (poor) to 91% (excellent) on the highest score. These differences might due to ignorance either from management or the employees side to implement basic HSE practices at the work site. The lowest score was 50% which is waste and general management and report at common area where an organisation is lacking of. The next issues of interest are on the electrical safety, hazardous chemical exposure and fire safety. This served as an indicator that all safety measures should be taken at the initiative of the management as its absence would result in higher likelihood of accidents in the facility (Reason, 2016).

On the contrary, the fuel dispensing area which achieved the highest safety score was due to the fact that they were the compulsory safety code and practices and reflect to the brand of the company which engineering and HSE department of the company always focus at. Although, the safety score varied greatly with the range of poor to excellent, the average safety scores indicated that the safety level of the facility was generally good with the score of 73%. This showed that the facility was operated safely even though there was some area which need to be taken care of for continual improvement.

In conclusion, the safety level of the facility was relatively good with some areas need to be improved. Three categories which recorded fair score which were related to electricity, hazardous chemical exposure and fire safety has raised concern as these hazards pose moderate probability of catastrophic accidents. For example is the electrical hazards which may create sparks that could ignite the fuel from the nearby dispenser or tank (Marshall, 1996).

4.3 Qualitative Risk Assessment

Based on the hazard identification and risk assessment flow chart which has been discussed in Chapter 2, the qualitative risk assessment is conducted using the HAZID (Hazard Identification) method. Risk ranking for each hazard is given based on the Risk Assessment Matrix by XYZ company as appended in Table 4.3. A complete hazard register is appended in Table 4.4 which only discussed the related hazard during the operation and maintenance period of petrol station. The related hazard during construction stage are excluded for the purpose of this research project.

Table 4.3: Risk Assessment Matrix

IMPACT		Severity	**1** Insignificant	**2** Minor	**3** Moderate	**4** Major	**5** Catastrophic
		People	Slight injury	Minor injury	Major injury	Single fatality	Multiple fatality
		Asset	Slight damage	Minor damage	Local damage	Major damage	Extensive damage
		Environment	Slight impact	Minor impact	Localised impact	Major impact	Massive impact
		Reputation	Slight impact	Limited impact	Considerable impact	Major national impact	Major international impact
LIKELIHOOD	**E** Almost certain	Happen several times per year at location	E1	E2	E3	E4	E5
	D Likely	Happens several times per year in company	D1	D2	D3	D4	D5
	C Possible	Incident has occurred in our company	C1	C2	C3	C4	C5
	B Unlikely	Heard of incident in industry	B1	B2	B3	B4	B5
	A Remotely likely to happen	Never heard of in industry	A1	A2	A3	A4	A5

Low risk (accept) Medium risk (manage) High risk (mitigate or reduce Very high (mitigate or reduce)

Source: XYZ Company

Table 4.4: Qualitative Risk Assessment for Operational and Maintenance of Petrol Station

No	**Hazard**	**Activity**	**Possible Source**	**Control**	**Top Event**	**Recovery**	**Consequences**	**P**	**E**	**A**	**R**	**Final rating**	**Final risk**	**Reference**
1	Diesel	• Receiving • Storage • Supply	Dipping point	• IQ Box • Non-return valve	LOC	• Concrete paved • Oil spill kit • Oil interceptor • Corrective maintenance	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates	-	E1	-	E1	E1	Medium	**Risk rating** <u>Likelihood</u> E- Multiple incident occur at PS.

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
				• Procedure- store product within safe limit		• Inspection • Emergency response plan (ERP)	• Flora and fauna that have direct impact with spillage							Consequences Environment (1) - Release below Tier 2 Threshold Quantities as the product require pressure to spilled out from the dipping point and against gravity. Reputation (1)- Public/ customer nearby awareness may exist as they are at the surrounding incident.
2	Diesel	Supply	Dispenser and piping including T-Joints and fittings	• Flexible connector • Shear valve	LOC	• Dispenser sump • Silicon seal for conduit cable between dispenser to dispenser • Mechanical leak detector (MLD) • Emergency cut-off button • Oil spill kit • Corrective maintenance • Inspection- RFB • ERP	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates • Flora and fauna that have direct impact with spillage	-	E4	-	E3	E4	Very high	**Risk rating** Likelihood E- Multiple incident happened at PS-failure at connector under dispenser. Consequences Environment (4) – Release above Tier 1 Material Threshold Quantities but not affect beneficial use, no significant disruption. Reputation (3) – Possible to receive fine from authority
3	Diesel	Supply	Island/ Line	• Double wall piping • Preventive maintenance	LOC	• Mechanical leak detector (MLD) • Dispenser sum • Oil spill kit • ERP	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates	-	E3	-	E3	E3	High	**Risk rating** Likelihood E- Multiple incident happened at PS-

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
						• Inspection • Inventory control	• Flora and fauna that have direct impact with spillage							failure at connector under dispenser. <u>Consequences</u> Environment (3) – Release above Tier 1 Material Threshold Quantities but not affect beneficial use, no significant disruption. Reputation (3) – Possible to receive fine from authority
4	Diesel	Supply	Nozzle Hose	• Overfill sensor • Swivel joint • Breakaway coupling • Quarterly preventive maintenance by vendor • Nozzle replacement schedule • Weekly pump test by station dealer	LOC	• Oil trap at forecourt • Oil interceptor • Concrete paved • Emergency cut off button • Oil spill kit • Corrective maintenance • Splash guard • Inspection • ERP	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates • Flora and fauna that have direct impact with spillage	-	E1	-	E1	E1	Medium	**Risk rating** <u>Likelihood</u> E- Multiple incident occur at PS- pull away incident. <u>Consequences</u> Environment (1) – Release below Tier 2 Material Threshold Quantities. The flow rate is considered low Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
5	Diesel	Storage	Underground tank	• Located underground • Vent pipe • Double wall, inner wall is	LOC	• STP sump • Fire extinguisher • Fire switch • Monitoring well • Oil spill kit • ERP	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates	-	C4	-	C4	C4	High	**Risk rating** <u>Likelihood</u> C- Happened more than once per year for oil and gas industry

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
				steel, secondary wall in fiberglass • Built in relieve valve inside submersible turbine pump (STP) • Preventive maintenance • Tank replacement every 15 years		• Inspection • Inventory control	• Flora and fauna that have direct impact with spillage							https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/485216/pmho0402bgs_e_e.pdf Consequences Environment (4) – Release above Tier 1 Material Threshold Quantities but not affect beneficial use. Reputation (3)- Possible to receive fine from authority
6	Diesel	Storage Supply	• Pipeline fittings • Submersible turbine pump (STP)	• Double wall piping • Flexible piping (HDPE) • Flexible connector • Preventive maintenance	LOC	• Mechanical leak detector (MLD) • Tank sump • Test tube • Fire extinguisher • Fire switch • Oil spill kit • ERP • Inspection • Inventory control	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates • Flora and fauna that have direct impact with spillage	-	E4	-	E4	E4	Very high	**Risk rating** Likelihood E- Multiple incident occur at PS. Consequences Environment (4) - Release above Tier 1 Threshold Quantities that may be resulting fish kill but no significant disruption or affect beneficial use of stream. Reputation (3)- Possible to receive fine from authority
7	Diesel	Receiving Storage	Vent	• Pressure vacuum valve at vent point	LOC	• Concrete paved • Oil spill kit • Oil interceptor	• Soil, groundwater and surface contamination • Drinking water contamination	-	E1	-	E1	E1	Medium	**Risk rating** Likelihood

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
		Maintenance		• Procedure- safe storage limit		• ERP	• The vapors given off when diesel evaporates • Flora and fauna that have direct impact with spillage							E- Multiple incident occur at PS. Consequences Environment (1) - Release below Tier 2 Threshold Quantities as the product require pressure to spilled out from the dipping point and against gravity. Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
8	Diesel	Receiving	Road tank compartment	• LOPC protection system at road tanker compartment i.e tank and manhole overprotection, manhole cover locks, hatch and manhole cover latches with lockable closed position, positive pressure-vacuum vents in every hatch and overfill protection system.	LOC	• Foot valve • Fire extinguisher • Oil spill kit • Oil interceptor • ERP	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates • Flora and fauna that have direct impact with spillage	-	D4	-	D4	D4	High	**Risk rating** Likelihood D- Incident had occurred within company which contributed to major incident Consequences Environment (4) - Release above Tier 1 Threshold Quantities that may be resulting fish kill but no significant disruption or affect beneficial use of stream. Reputation (3)- Possible to receive fine from authority

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
				• Inspection of road tanker compartment and hose • Road transport guidelines • Trained driver										
9	Diesel	Receiving	• Road tanker hose/ fittings • Filling points	• LOPC protection system at hose i.e crimped type of hose, Kamlock adaptor of hose • Inspection of road tanker hose • Road transport guidelines • Trained driver	LOC	• Foot valve • Fire extinguisher • Oil spill kit • Oil interceptor • ERP	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates • Flora and fauna that have direct impact with spillage	-	E3	-	E3	E3	High	**Risk rating** Likelihood E-Multiple incident occurred at PS (hose leak) Consequences Environment (3) - Release above Tier 1 Threshold Quantities considering the product in one compartment spilled (5400 liter) onto the ground. Reputation (3)- Possible to receive fine from authority
10	Diesel	Maintenanc e	Genset	Periodic inspection and maintenance of genset i.e lubrication, change filter	LOC	• Secondary containment • ERP	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates • Flora and fauna that have direct impact with spillage	-	B1	-	B1	B1	Low	**Risk rating** Likelihood E- http://www.abc.net.au/news/2016-04-19/hydro-confirms-500-litre-diesel-spill-at-meadowank/7338854 Consequences Environment (1) - Release below Tier 2 Threshold Quantities

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
														considering the whole diesel spilled onto the ground (500 liter in average) Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
11	Diesel	Supply	Customer's vehicles	No operational control on customer's vehicles	LOC	• Oil trap at forecourt • Oil interceptor • Concrete paved • Emergency cut-off button • Oil spill kit • Corrective maintenance • Splash guard • Inspection • ERP	• Soil, groundwater and surface contamination • Drinking water contamination • The vapors given off when diesel evaporates • Flora and fauna that have direct impact with spillage	-	E1	-	E1	E1	Medium	**Risk rating** <u>Likelihood</u> E- occurred several times <u>Consequences</u> Environment (1) - Release below Tier 2 Threshold Quantities considering the whole diesel in vehicles compartment spilled onto the ground (70 liter in average) Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
12	Petrol	• Receiving • Storage • Supply	Dipping point	• IQ Box • Non-return valve • Procedure- store product within safe limit	LOC	• Concrete paved • Oil spill kit • Oil interceptor • Corrective maintenance • Inspection • Emergency response plan (ERP)	• Soil, groundwater and surface contamination • Drinking water impacted • The vapors given off when gasoline evaporates and the substances produced when it is burned (CO, NO, PM and	-	E1	-	E1	E1	Medium	**Risk rating** <u>Likelihood</u> E- Multiple incident occur at PS. <u>Consequences</u> Environment (1) - Release below Tier 2

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
							unburned hydrocarbons) contributes to air pollution • Burning gasoline also produce CO_2 – greenhouse gases which lead to climate change							Threshold Quantities as the product require pressure to spilled out from the dipping point and against gravity. Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
13	Petrol	Supply	Dispenser and piping including T-Joints and fittings	• Breakaway coupling • Shear valve	LOC	• Dispenser sump • Silicon seal for conduit cable between dispenser to dispenser • Mechanical leak detector (MLD) • Emergency cut-off button • Oil spill kit • Corrective maintenance • Inspection- RFB • ERP	• Soil, groundwater contamination • Drinking water impacted • The vapors given off when gasoline evaporates and the substances produced when it is burned (CO, NO, PM and unburned hydrocarbons) contributes to air pollution • Burning gasoline also produce CO_2 – greenhouse gases which lead to climate change • Flora and fauna that come direct contact with gasoline spill may be killed • Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change.	-	E4	-	E3	E4	Very high	**Risk rating** Likelihood E- Multiple incident happened at PS- failure at connector under dispenser. Consequences Environment (4) – Release above Tier 1 Material Threshold Quantities but not affect beneficial use, no significant disruption. Reputation (3) – Possible to receive fine from authority
13	Petrol	Supply	Island/ Line	• Double wall piping • Preventive maintenance	LOC	• Mechanical leak detector (MLD) • Dispenser sum • Oil spill kit • ERP • Inspection • Inventory control	• Soil and groundwater contamination • Drinking water impacted • Air pollution (VOC) • Flora and fauna that come direct contact with gasoline spill may be killed	-	E3	-	E3	E3	High	**Risk rating** Likelihood E- Multiple incident happened at PS- failure at connector under dispenser. Consequences

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
							• Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change							Environment (3) – Release above Tier 1 Material Threshold Quantities but not affect beneficial use, no significant disruption. Reputation (3) – Possible to receive fine from authority
14	Petrol	Supply	Nozzle Hose	• Overfill sensor • Swivel joint • Breakaway coupling • Quarterly preventive maintenance by vendor • Nozzle replacement schedule • Weekly pump test by station dealer	LOC	• Oil trap at forecourt • Oil interceptor • Concrete paved • Emergency cut off button • Oil spill kit • Corrective maintenance • Splash guard • Inspection • ERP	• Soil and groundwater contamination • Drinking water impacted • Air pollution (VOC) • Flora and fauna that come direct contact with gasoline spill may be killed • Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change	-	E1	-	E1	E1	Medium	**Risk rating** Likelihood E- Multiple incident occur at PS- pull away incident. Consequences Environment (1) – Release below Tier 2 Material Threshold Quantities. The flow rate is considered low Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
15	Petrol	Storage	Underground tank	• Located underground • Vent pipe • Double wall, inner wall is steel, secondary wall in fiberglass • Built in relieve valve inside submersible	LOC	• STP sump • Fire extinguisher • Fire switch • Monitoring well • Oil spill kit • ERP • Inspection • Inventory control	• Soil and groundwater contamination • Drinking water impacted • Air pollution (VOC) • Flora and fauna that come direct contact with gasoline spill may be killed • Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change	-	C4	-	C4	C4	High	**Risk rating** Likelihood C- Happened more than once per year for oil and gas industry https://www.gov.uk/government/uploads/system/uploads/attachm

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
				turbine pump (STP) • Preventive maintenance • Tank replacement every 15 years										ent_data/file/485216/pmho0402bgs_e_e.pdf Consequences Environment (4) – Release above Tier 1 Material Threshold Quantities but not affect beneficial use. Reputation (3)- Possible to receive fine from authority
16	Petrol	Storage Supply	• Pipeline fittings • Submersible turbine pump (STP)	• Double wall piping • Flexible piping (HDPE) • Flexible connector • Preventive maintenance	LOC	• Mechanical leak detector (MLD) • Tank sump • Test tube • Fire extinguisher • Fire switch • Oil spill kit • ERP • Inspection • Inventory control	• Soil and groundwater contamination • Drinking water impacted • Air pollution (VOC) • Flora and fauna that come direct contact with gasoline spill may be killed • Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change	-	E4	-	E4	E4	Very high	**Risk rating** Likelihood E- Multiple incident occur at PS. Consequences Environment (4) - Release above Tier 1 Threshold Quantities that may be resulting fish kill but no significant disruption or affect beneficial use of stream. Reputation (3)- Possible to receive fine from authority
17	Petrol	Receiving Storage Maintenance	Vent	• Pressure vacuum valve at vent point • Procedure- safe storage limit	LOC	• Concrete paved • Oil spill kit • Oil interceptor • ERP	• Soil and groundwater contamination • Drinking water impacted • Air pollution (VOC)	-	E1	-	E1	E1	Medium	**Risk rating** Likelihood E- Multiple incident occur at PS. Consequences

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
							• Flora and fauna that come direct contact with gasoline spill may be killed • Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change							Environment (1) - Release below Tier 2 Threshold Quantities as the product require pressure to spilled out from the dipping point and against gravity. Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
18	Petrol	Receiving	Road tank compartment	• LOPC protection system at road tanker compartment i.e tank and manhole overprotection, manhole cover locks, hatch and manhole cover latches with lockable closed position, positive pressure-vacuum vents in every hatch and overfill protection system. • Inspection of road tanker compartment and hose	LOC	• Foot valve • Fire extinguisher • Oil spill kit • Oil interceptor • ERP	• Soil and groundwater contamination • Drinking water impacted • Air pollution (VOC) • Flora and fauna that come direct contact with gasoline spill may be killed • Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change	-	D4	-	D4	D4	High	**Risk rating** Likelihood D- Incident had occurred within company which contributed to major incident Consequences Environment (4) - Release above Tier 1 Threshold Quantities that may be resulting fish kill but no significant disruption or affect beneficial use of stream. Reputation (3)- Possible to receive fine from authority

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
				• Road transport guidelines • Trained driver										
19	Petrol	Receiving	• Road tanker hose/ fittings • Filling points	• LOPC protection system at hose i.e crimped type of hose, Kamlock adaptor of hose • Inspection of road tanker hose • Road transport guidelines • Trained driver	LOC	• Foot valve • Fire extinguisher • Oil spill kit • Oil interceptor • ERP	• Soil and groundwater contamination • Drinking water impacted • Air pollution (VOC) • Flora and fauna that come direct contact with gasoline spill may be killed • Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change	-	E3	-	E3	E3	High	**Risk rating** Likelihood E-Multiple incident occurred at PS (hose leak) Consequences Environment (3) - Release above Tier 1 Threshold Quantities considering the product in one compartment spilled (5400 liter) onto the ground. Reputation (3)- Possible to receive fine from authority
20	Petrol	Supply	Customer's vehicles	No operational control on customer's vehicles	LOC	• Oil trap at forecourt • Oil interceptor • Concrete paved • Emergency cut-off button • Oil spill kit • Corrective maintenance • Splash guard • Inspection • ERP	• Soil and groundwater contamination • Drinking water impacted • Air pollution (VOC) • Flora and fauna that come direct contact with gasoline spill may be killed • Fire and burning gasoline also produce CO_2 – a greenhouse gas linked with climate change	-	E1	-	E1	E1	Medium	**Risk rating** Likelihood E- occurred several times Consequences Environment (1) - Release below Tier 2 Threshold Quantities considering the whole diesel in vehicles compartment spilled onto the ground (70 liter in average) Reputation (1)- Public/ customer nearby

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
														awareness may exist at the surrounding incident.
21	Smoke	Supply and maintenance	Genset	• Inspection and maintenance of genset e.g change pump if maximum fuel stop seal has been broken • Exhaust • Emission monitoring	Black smoke from exhaust	• Corrective maintenance	• Localise air pollution (VOC, PM) • Release of greenhouse gases emission (CO_2). • Emit dangerous substances (toxic, persistent/ bioaccumulative, mutagenic, carcinogenic • Fine by authority	-	B3	-	B3	B3	Low	**Risk rating** Likelihood E- Incident has occurred worldwide Consequences Environment (3) – Breach Malaysia standard- Clean Air Regulations 2014 Reputation (3)- Possible to receive fine from authority
22	Air impurities / pollutants (VOC)	Receiving Storage	Storage tank	• Retailer Dealer Agreement and Dealer Licensing Agreement – avoid station dry tank, not less than 3 days sales amount • Underground tank • Vent pipe • Pressure vacuum valve at vent.	Excessive emission	Corrective maintenance on vapour recovery unit	• Formation of ground level ozone and particulate matter which are the main ingredients of smog • Odour to community which trigger public complaint	-	E3	-	E3	E3	High	**Risk rating** Likelihood E- Complaint were received several times for other PS within company Consequences Environment (3) – Breach Malaysia standard- Clean Air Regulations 2014 Reputation (3)- Possible to receive fine from authority
23	Air impurities /pollutants (VOC)	Supply	Customer car	No operational control	Excessive emission	Replacement of splash guard	• Formation of ground level ozone and particulate matter which are the main ingredients of smog	-	E3	-	E3	E3	High	**Risk rating** Likelihood E- Complaint were received several times

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
							• Odour to community which trigger public complaint							for other PS within company <u>Consequences</u> Environment (3) – Breach Malaysia standard- Clean Air Regulations 2014 Reputation (3)- Possible to receive fine from authority
24	Domestic wastewater	• Maintenance • Surrounding	Septic tank	• Maintenance- emptying • Increasing the size of the septic tank	Overflow	Corrective maintenance of septic tank	• Odour (pungent smell and release gas emission from the fermentation (CO_2 and/ or CH_4) • E-coli and other harmful bacteria for any water consumption nearby	-	D3	-	D3	D3	High	**Risk rating** <u>Likelihood</u> D- Incident has occurred at other PS within company. <u>Consequences</u> Environment (3) – Overflow of domestic wastewater resulting in fish kill (eutrophication) but not affect beneficial use. Reputation (3)- Possible to receive fine from authority
25	Contaminated storm water	Raining	• Storm drain • Forecourt • Oil trap at forecourt	• Maintenance of interceptor • Weekly cleaning of interceptor • Monitoring of effluent • Procedures	Excessive discharge of oily water	• Cleaning of interceptor • Corrective maintenance	• Soil and groundwater contamination • Surface water contamination	-	D2	-	D1	D2	Medium	**Risk rating** <u>Likelihood</u> D- Incident has occurred at PS <u>Consequences</u>

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
														Environment (2) – Breach of company limit. Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
26	Storm water	Raining	• Storm drain • Forecourt	• Concrete paved at forecourt area • Premix at drive area • Concrete drain	Excessive discharge of water onto ground	Weep hole area of drain	• Soil erosion • Affect structure stability	-	-	B3	B1	B3	Low	**Risk rating** Likelihood B- https://en.wikipedia.org/wiki/Landslides_in_Malaysia Consequences Asset (3) – Assume the event effect the whole structure of PS (RM 3-4 millions for 4 island type PS) Reputation (1)- Public/ customer nearby awareness may exist at the surrounding incident.
27	Hazardous waste	• Maintenance	• Contaminated with hydrocarbon e.g rags • Unused chemical • E-waste	• Proper container and label • Storage area • Procedure • Record	Spillage	• Fire extinguisher • Fire switch • Oil spill kit • ERP	• Soil and groundwater contamination • Water pollution • Wildlife impact • Fine by authority	-	E2	-	E3	E3	High	**Risk rating** Likelihood E- Multiple cases observed within company Consequences Environment (2) – Breach Malaysia

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
			• Oily waste from interceptor • Used oil from lube bay											standard- Scheduled Waste Regulations 2005 Reputation (3)- Possible to receive fine from authority
28	Domestic waste	Supply	• Office waste • Food waste	• Storage area and proper container • Waste segregation	Improper handling/ disposal	*No further control identified*	• Unhygienic condition leading to aesthetics impacts and biological hazards (mosquito breeding) • Leachate that end up in water bodies	-	C1	-	-	C1	Medium	**Risk rating** Likelihood C- Multiple cases observed within company Consequences Environment (1) – Slight adverse environmental effect.
29	Use of natural resources - electricity	• Receiving activity • Storage • Supply • Maintenance	• Electrical appliances • Light compound	• Energy saving bulb • Cable insulator • Procedure	Over usage of electricity	• Corrective maintenance • Re-assess additional equipment electrical capacity	• Increase carbon footprint • Increase risk of climate change • Higher energy cost	-	D2	-	-	D2	Medium	**Risk rating** Likelihood D- Multiple cases observed within company Consequences Environment (2) – Breach company limit on the maximum usage of electricity which require minimisation and optimisation.
30	Use of natural resources - water	Supply	• Toilet • Cleaning activity	• Rain water harvesting • Install water efficient fixtures inn restrooms	Over usage of water supply	• Corrective maintenance	• Water resources limited creates water shortage	-	D2	-	-	D2	Medium	**Risk rating** Likelihood D- Multiple cases observed within company Consequences

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
				• Signage on water conservation										Environment (2) – Breach company limit on the maximum usage of water which require minimisation and optimisation.
31	Packaging material	Supply	• Plastic • Food container	• Use paper material instead of plasticor biodegradable material	Excessive usage of packaging material	• Use of biodegradable materials • Banned from using plastic	• Depletion of natural resources • Increase amount of waste generated	-	B3	-	-	B3	Low	**Risk rating** Likelihood B- Top event has occurred within industry Consequences Environment (3) – Moderate adverse environmental effect but not significant disruption or loss to beneficial uses.
32	Noise	• Supply • Maintenance	Genset	• Periodic inspection and maintenance of genset i.e lubrication, change filter • Isolation room	Excessive noise generation	• Corrective maintenance • PPE	• Nuisance • Hearing disability	-	C3	-	C3	C3	Low	**Risk rating** Likelihood C- Top event has occurred within company Consequences Environment (3) – Breach Malaysia standard- Noise Guideline Reputation (3)- Possible to receive fine from authority
33	Noise	• Supply • Maintenance	Air compressor	• Periodic inspection and maintenance of	Excessive noise generation	• Corrective maintenance • PPE	• Nuisance • Hearing disability	-	C3	-	C3	C3	Low	**Risk rating** Likelihood

No	Hazard	Activity	Possible Source	Control	Top Event	Recovery	Consequences	P	E	A	R	Final rating	Final risk	Reference
				genset i.e lubrication, change filter • Isolation room										C- Top event has occurred within company <u>Consequences</u> Environment (3) – Breach Malaysia standard- Noise Guideline Reputation (3)- Possible to receive fine from authority
34	Refrigera nt	Supply	• Aircond • Chiller	• Procedure • Contractual agreement with installer	Release of CFC/ HCFC as refrigerant	Change to approved refrigerant	• Ozone depletion	-	B1	-	-	B1	Low	**Risk rating** <u>Likelihood</u> B- Incident has occurred worldwide <u>Consequences</u> Environment (1) – Depletion of ozone layer.

4.4 Top event

Top event has been identified which may cause catastrophic incident after below exercise has been conducted: -

a) observation and result from the checklist during the site visit to the selected petrol station.

b) Top event based on the qualitative risk assessment

Most of the hazards which have final risk of high and very high are related to the hydrocarbon product receiving, storage, supply beside the daily operational and maintenance of petrol station. All the top events identified which have high and very high risk may lead to the catastrophic incident.

4.3.1 Explosion hazard arising from the flammable and/or explosive material

Among the petroleum products handled by the petrol station are petrol, diesel and natural gas which is methane. Fuel poses fire and/or explosion risks as they are highly flammable (Astbury, 2008). Upon loss of containment caused by pipeline leak or failure, vapour would be released as a jet. If an ignition source was present, jet fire could be formed on immediate ignition, thus releasing heat radiation. However, in the case of delayed ignition, the vapour would disperse quickly.

The size of the leaks will be the factor that influence the chemical release. It could range from a pinhole to catastrophic failure. In general, smaller leaks have higher likelihood of accident with lower consequence distances compared to larger leaks (LaChance *et al.*, 2009). Whereby, accumulation of gas could result in the formation of vapour cloud. During the delayed ignition, flash fire occurred within the flammable cloud range (Rigas & Sklavounos, 2005). In the case of large chemical releases, explosion could occur with flash fire due to the accumulation of gas in the congested area of the petrol station. Explosion could also take place in the pressurized fuel delivery systems if the safety valve failed especially during the unloading of fuel from the underground fuel storage tank to fuel dispenser via fuel delivery pump.

4.3.2 Catastrophic equipment explosion

Catastrophic failure of fuel storage tank and dispenser could result in overpressures and explosion. For example, the burst of equipment and piping occurred due to the deterioration of petrol station where a crack was found in the equipment. This was a result of fatigue from vibration, stress corrosion cracking or an inherent manufacturing defect not detected during inspection (Gagg, 2005). On the other hands, a study by United States Environmental Protection Agency (USEPA) found that 83% of underground storage tank in US moderate to severe corrosion problems (US EPA, 2016).

Other factors that may result in explosion are thermal expansion of trapped liquid in piping and internal damage to a fuel dispenser due to a vehicle impact. As a result from the vehicle impact, a spark from the damaged electrical connection or static electricity was generated resulting in fire (Struthers & Webb, 2003). The installation of fuel dispenser includes pressurized fuel delivery systems such as fuel delivery pumps which are equipped with safety valve. In the case of damaged safety valve, the fuel delivery pumps would continue to deliver the fuel to all dispensers including the damaged dispenser that could be on fire which then led to catastrophic problem.

Other than that, vehicle impact may also cause rupture to the fuel piping and associated piping connections located either underneath or inside the dispenser. This would then cause the leakage of fuel that could escape into the environment causing a possible ground contamination problem, like pollution of ground water. However, in this case the ground contamination problem was not considered due to the ALOHA’s limitation.

Based on the top event identified during the qualitative risk assessment, below scenarios were selected for quantitative risk assessment (QRA).

a) Leakage during offloading of petroleum product from road tanker due to hose or fitting failure
b) Leakage at dispenser area due to failure in safeguarding systems
c) Underground storage tank explosion due to overpressure

4.4 Failure frequency and event probability analysis

The probability of event is usually based on the presence of potential ignition source in the facilities. The initiating events leading to hydrocarbon release could occur due to of the following:

a) Spontaneous failure of equipment, i.e;-

   i. Road tanker failure;
   ii. Pipework failure;
   iii. Hose failure;
   iv. Flange failure;
   v. Valve leak; and
   vi. Underground storage failure.

b) External events such as:

   i. External fire from hot work activities,
   ii. Static electricity
   iii. Lightning
   iv. Open fire from smoking
   v. Vehicles collision

Based on the considerations above, representative hydrocarbon release events considered in the assessment are summarized in Table 4.5. Rupture of tank may result in fireballs, flash fires or vapor cloud explosions (VCE). Leaks may cause jet fires, flash fires or VCE. Boiling Liquid Expanding Vapour Explosion (BLEVE) of the petrol tank might be possible though these are mounded tanks due to safeguarding failure.

Table 4.5: Possible event based on identified scenario

Event	Scenario	Potential hazardous event outcomes
Scenario 1	Leakage during offloading of petroleum product from road tanker due to hose or fitting failure	1. Toxic effects 2. Flash fire 3. Explosion 4. Jet fire
Scenario 2	Leakage at dispenser area due to failure in safeguarding systems	1. Toxic effects 2. Flash fire 3. Explosion
Scenario 3	Underground fuel storage tank explosion due to overpressure	1. Toxic effects 2. Flash fire 3. Explosion 4. Fireball 5. BLEVE

Failure frequency and event probability of each identified scenarios were determined as follows:

a) Scenario 1: Hose or fitting failures could lead to four main events which are toxic effects, flash fire, explosion and jet fire. There is possibility of hose or fittings failure during the offloading of petroleum product from road tanker to the underground tank. The typical road tanker has few compartments to store the petroleum product which each of the compartment will have capacity of 5400 litre. Worst case scenario will be the failure of hose and or valve will lead to release of whole compartment to the ground. Figure 4.1 showed the event tree for this scenario.

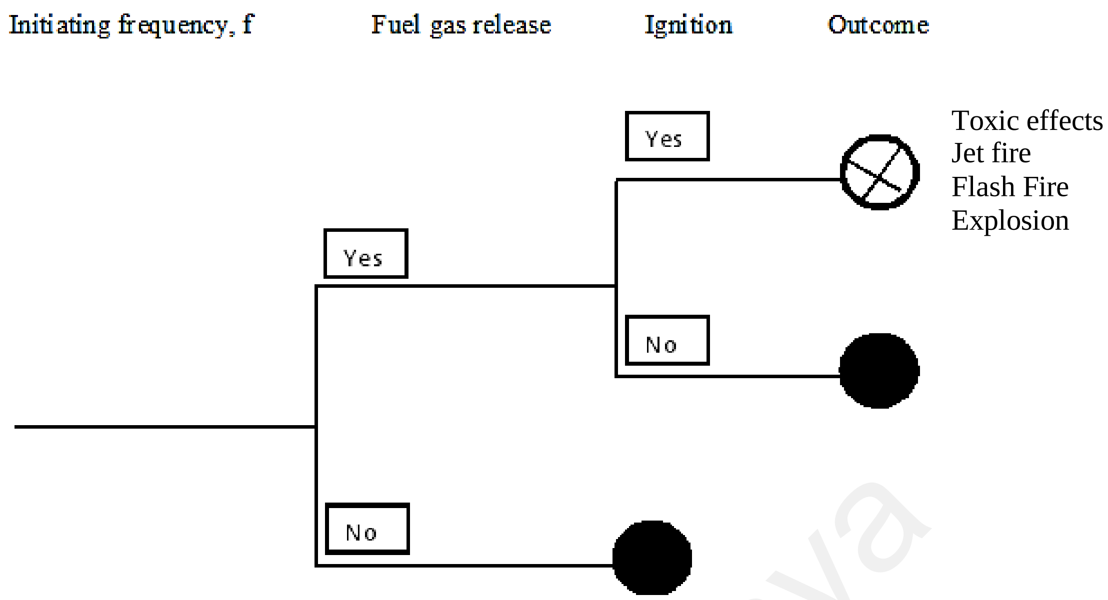

Figure 4.1: Event tree for Scenario 1

The frequencies of each event were calculated based on as the probability of ignition, selected fuel release probability and the overall frequency for the rupture of pipeline which is 2.3 x 10^{-4} per month in accordance to Table 3.2 whereas other probabilities were assumed.

The calculations are demonstrated as follows:

- Hole size probability for small leak = 0.65
- Ignition probability = 0.30 (Table 3.3, Large)
- Ignition Probability Distribution, Immediate = 0.6, Delayed = 0.4 (Table 3.4, Large)
- Probability of explosion = 0.3 (Table 3.5, >50 kg/s)

Therefore,

i) Overall frequency of toxic effect and flash fire per year (when the ignition is delayed)

= overall frequency of valve/ hose failure x hole size probability x delayed ignition x 12 months

= 2.3 x 10^{-4} x 0.65 x 0.40 x 12 = **7.18 x 10^{-4}**

ii) Frequency for jet fire (in case of immediate ignition)

= 2.3 x 10^{-4} x 0.65 x 0.6 x 12 = **1.08 x 10^{-3}**

iii) Probability of explosion

= overall frequency of valve/ hose failure x hole size probability x probability of explosion x 12 months

= 2.3 x 10^{-4} x 0.65 x 0.30 x 12 = **5.38 x 10^{-4}**

b) Scenario 2: Leakage at fuel dispenser caused by failure of safeguarding system. If ignition exists, there is potential of subsequent fire and explosion to occur during unloading of fuel. Figure 4.2 demonstrated the event tree for this scenario.

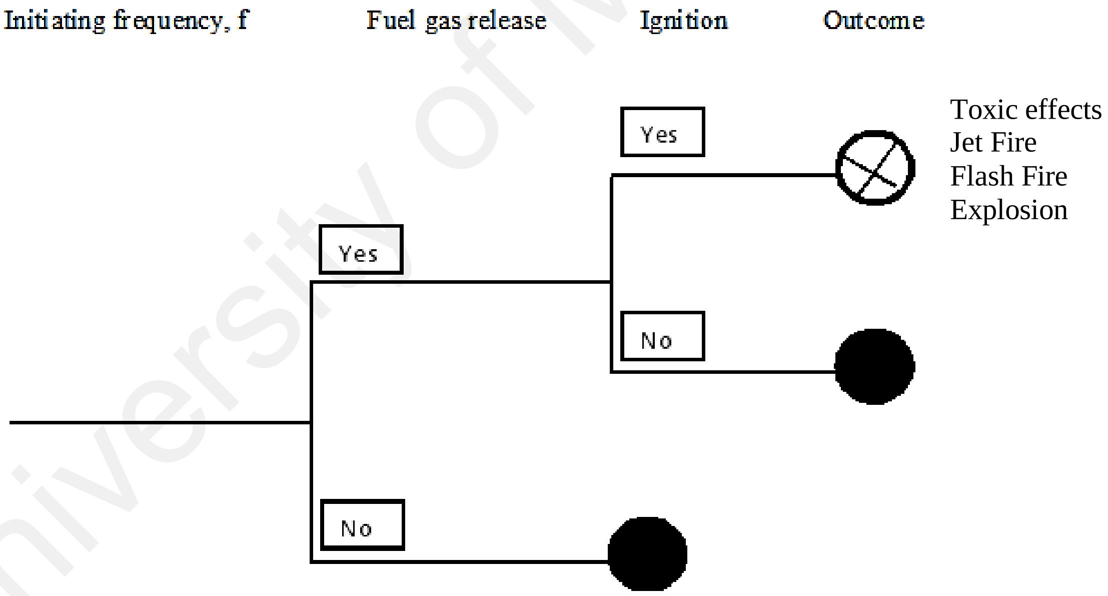

Figure 4.2: Event tree for scenario 2

According to Ngan (1997), failure frequency for fuel dispensers is 1.48 x 10^{-7} per year. The following data were used for the calculation:

- Ignition probability = 0.30 (Table 3.3, Large)

- Ignition Probability Distribution, Immediate = 0.5, Delayed = 0.5 (Table 3.4, Medium)
- Probability of explosion = 0.12 (Table 3.5, 1-50 kg/s)

Therefore,

i) the overall frequency of toxic effect and flash fire per year (when the ignition is delayed)

$= 1.48 \times 10^{-7} \times 12 \times 0.5 = \mathbf{8.88 \times 10^{-7}}$

ii) frequency for fireball (in case of immediate ignition)

$= 1.48 \times 10^{-7} \times 12 \times 0.5 = \mathbf{8.88 \times 10^{-7}}$

iii) For explosion, the probability of explosion given ignition

$= 1.48 \times 10^{-7} \times 12 \times 0.3 = \mathbf{2.13 \times 10^{-7}}$

c) Scenario 3- Underground fuel storage explosion due to overpressure which was caused by the presence of thermal trapped fuel liquid in the fuel delivery system (Evans, 2007). The event tree for this scenario is shown in Figure 4.3.

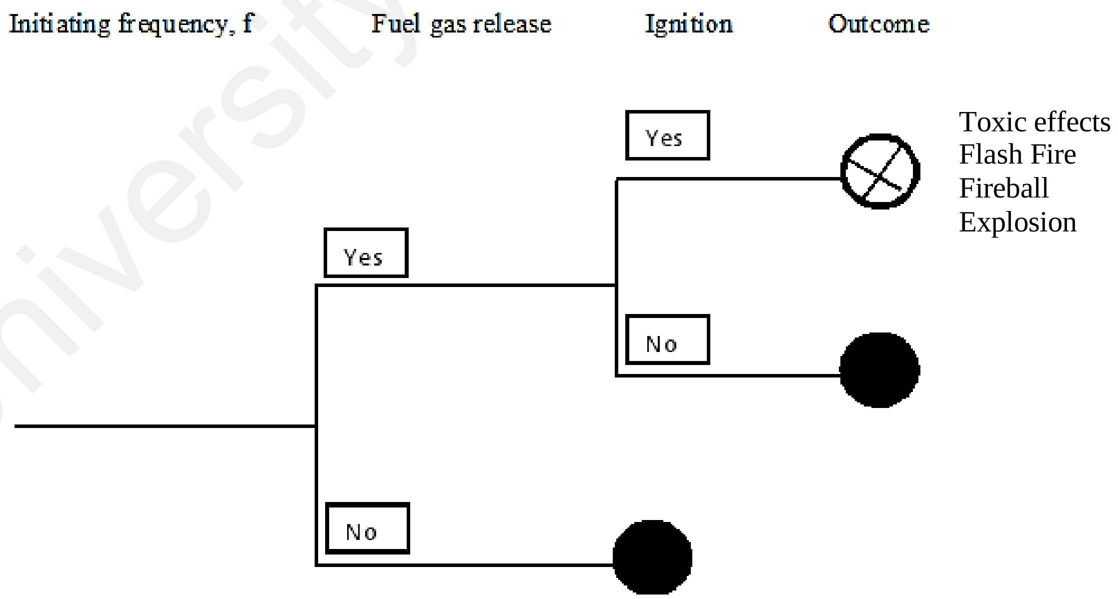

Figure 4.3: Event tree for scenario 3

The failure frequency of underground storage tank is 5.38 x 10^{-7} per year (Barringer & Kotlyar, 1996). The following data were used for the calculation:

- Ignition Probability Distribution, Immediate = 0.6, Delayed = 0.4 (Table 3.4, Large)
- Probability of explosion = 0.3 (Table 3.5, >50 kg/s)

Therefore,

i) the overall frequency of toxic effect and flash fire per year (when the ignition is delayed)

= 5.38 x 10^{-7} x 12 x 0.4 = **2.58 x 10^{-6}**

ii) frequency for fireball (in case of immediate ignition)

= 5.38 x 10^{-7} x 12 x 0.6 = **3.87 x 10^{-6}**

iii) For explosion, the probability of explosion given ignition

= 5.38 x 10^{-7} x 12 x 0.3 = **1.94 x 10^{-6}**

4.5 Consequence and effect analysis result

Consequence analysis is done using ALOHA software which estimates radiation due to different fire developed and pressure blast area due to explosion. This includes the release rates, flames characterization and thermal radiation ranges, estimation of dispersion distances and overpressure from vapour cloud explosion. The consequence and effect analysis were specified each threat according to zone.

The most prominent zone in the summation of the individual risk per annum (IRPA) is the red zone as it serves as the distance for the level of concern (LOC) (Xu *et al.*, 2012). Other zones such as orange and yellow are used as a reference in the likelihood of injury when exposed to the specified distance.

4.5.1 Input data for consequence analysis

For modelling, ALOHA require data input before each scenario can be modelled. Table 4.6 showed the main input that are required for the calculation of consequence and effect analysis for all scenarios.

Table 4.6: ALOHA input and output data

Site location (Input)	
Location	Shah Alam, Selangor
Building air exchanges per hours	0.46 (unsheltered double storied)
Chemical data (Output)	
Chemical name	Benzene
AEGL-1	52 ppm
AEGL-2	800 ppm
AEGL-3	4000 ppm
LEL	12000 ppm
UEL	80000 ppm
Ambient boiling point	79.9 ^{0}C
Vapour pressure at ambient temperature	0.15 atm
Ambient saturation concentration	150, 578 ppm or 15.1%
Atmospheric data (Input – assumption or average)	
Wind	3.4 metres/second from Northwest at 3 metres
Ground roughness	Open country
Cloud cover	10 tenths
Air temperature	29 ^{0}C
Stability class	D (Neutral)
Inversion height	Nil
Relative humidity	69 %

4.5.2 Consequence and effects result from ALOHA modelling

For scenario 1:

The source of strength data for leakage during offloading of petroleum product based on ALOHA modelling calculation are listed in Table 4.7. The possible event includes toxic gas release, flash fire and explosion. The release duration was assumed in every second for one-hour duration, and calculated released amount released was 4,692 kilograms. The input used for this direct source model is appended in Table 4.7.

Table 4.7: Consequence and effect calculation outcome for fuel release from leakage during offloading of product from road tanker

Source of strength for direct source	
Source height	0 (ground)
Source temperature	Equal to ambient
Release duration	60 minutes
Release rate	78.2 kilograms/min
Total amount release	4,692 kilograms

Since leakage has resulted in release of fuel, it contributed to toxic effect consequences that could result in fatality incident, provided no ignition existed. The affected area based on ALOHA calculation is mentioned in Table 4.8 and illustrated in Figure 4.4 and Figure 4.5. The LOC distance is within 46 metres radius from point of release.

Table 4.8: Level of concern (LOC) for toxic gas release (Leakage during offloading of product from road tanker

Toxic threat zone:	
Model run	Heavy gas
Red	46 metres (4000 ppm = AEGL-3 [60 minutes])
Orange	127 metres (800 ppm = AEGL-2 [60 minutes])
Yellow	665 metres (52 ppm = AEGL-1 [60 minutes])

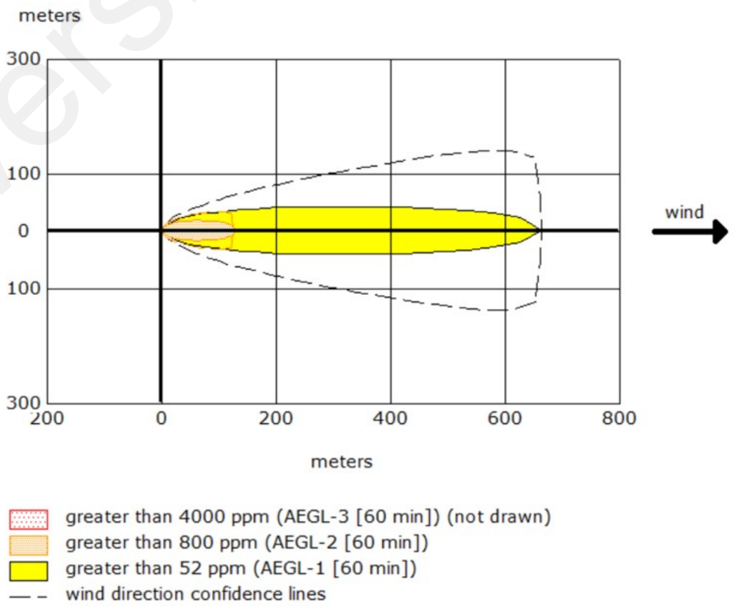

Figure 4.4: Graph of LOC on toxic gas release (leakage during offloading of product from road tanker)

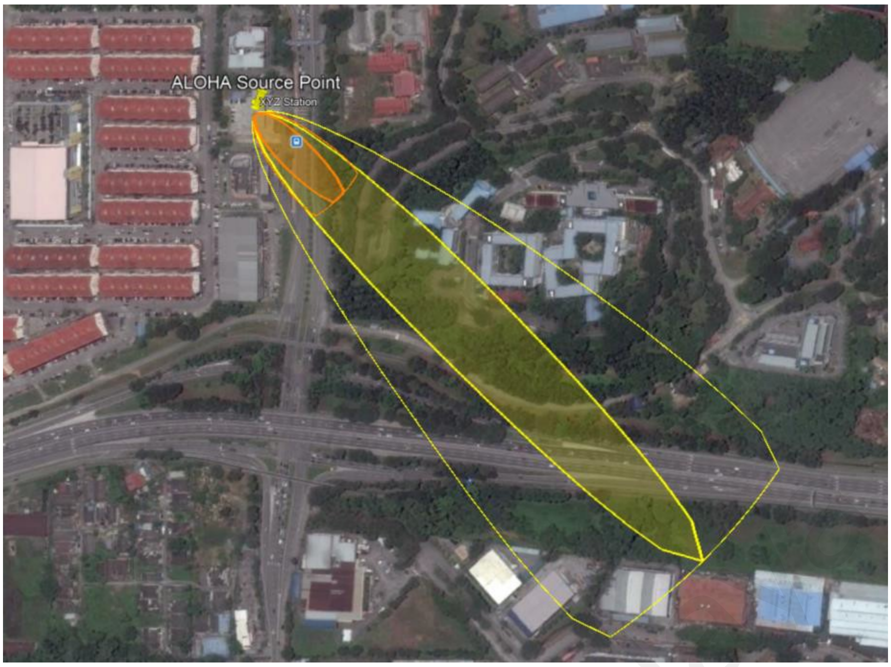

Figure 4.5: Individual risk contour for toxic threat zone (leakage during offloading of product from road tanker)

Delay ignition resulted in the release of vapour which had the potential of flash fire occurrence. The LOC distance for flammable area was 23 metres radius from the source of release as shown in Table 4.9 and illustrated in Figure 4.6 and Figure 4.7.

Table 4.9: Level of concern (LOC) on flammable area for flash fire (leakage during offloading of product from road tanker)

Threat zone:	
Model run	Heavy gas
Red	23 metres (12000 ppm = LEL)
Orange	33 metres (7200 ppm = 60% LEL = Flame pockets)
Yellow	99 metres (1200 ppm = 10% LEL

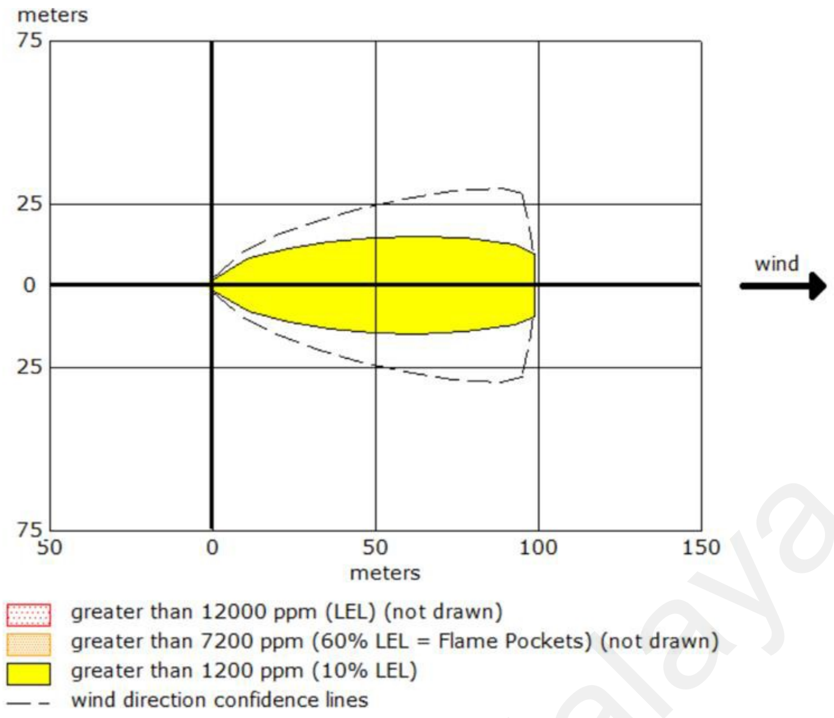

Figure 4.6: Graph of LOC on flammable area for flash fire (leakage during offloading of product from road tanker)

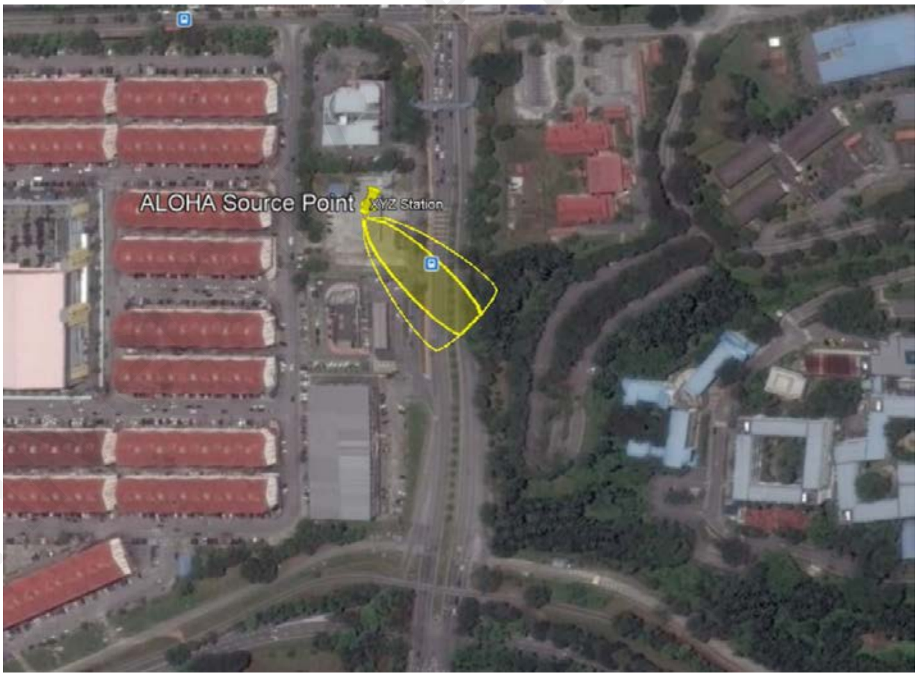

Figure 4.7: Individual risk contour on flammable area for flash fire (leakage during offloading of product from road tanker)

The third event modelled by ALOHA is overpressure occurrence due to impact from vapour cloud explosion as shown in Table 4.10. There is no potential blasting resulted from explosion in this scenario as the LOC was never exceeded.

Table 4.10: Level of concern (LOC) for overpressure from vapour cloud explosion (leakage during offloading of product from road tanker)

Threat model:	
Source height	0 metres
Type of ignition	Ignition by spark or flame
Level of congestion	Uncongested
Threat zone:	
Model run	Heavy gas
Red	LOC was never exceeded (8.0 psi = destruction of buildings)
Orange	LOC was never exceeded (3.5 psi = serious injury likely)
Yellow	LOC was never exceeded (1.0 psi = shatters glass)

The consequence and effect modelling by ALOHA for scenario 1 had shown that toxic released, and flash fire had the most significant risk where affected area is within 21 metres radius.

For scenario 2:

Potential events due to the fuel release in the fuel dispenser were toxic release, flash fire and explosion. The model used for this scenario was direct source assuming the dispenser failure was due to failure of safeguarding equipment for dispenser or external event which could result in release of petroleum product. The source of strength was stated in Table 4.11 with the amount of gas release is estimated at 7.24 kilograms/second with total amount released of 434 kilograms.

Table 4.11: Consequence and effect calculation outcome for fuel release from fuel dispenser failure

Source of strength for direct source	
Source height	0 (ground)
Source temperature	Equal to ambient
Release duration	60 minutes
Release rate	7.24 kilograms/minutes
Total amount release	434 kilograms

Based on ALOHA modelling, LOC distance for toxic gas release and flash fire was estimated to be less than 11 metres where the affected area was the surrounding area of the facility as listed in Table 4.12 and Table 4.13 and whereby the graph and diagram are illustrated in Figure 4.8 and Figure 4.9. Since LOC distance was 10 metres, the red zone was not drawn because effects of near-field patchiness make dispersion predictions less reliable for short distances.

Table 4.12: Level of concern (LOC) for toxic gas release (Fuel dispenser failure)

Threat zone:	
Model run	Heavy Gas
Red	15 metres (4000 ppm = AEGL-3 [60 minutes])
Orange	42 metres (800 ppm = AEGL-2 [60 minutes])
Yellow	192 metres (52 ppm = AEGL-1 [60 minutes])

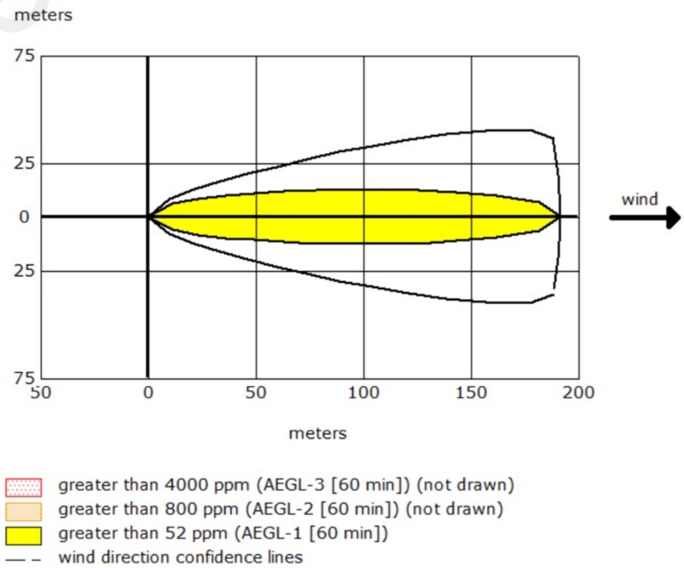

Figure 4.8: Graph of LOC on toxic gas release (Fuel dispenser failure)

Figure 4.9: Individual risk contour for toxic area (fuel dispenser failure)

Table 4.13: Level of concern (LOC) on flammable area for flash fire (dispenser failure)

Threat zone:	
Model run	Heavy Gas
Red	11 metres (12000 ppm =LEL)
Orange	11 metres (7200 ppm = 60% LEL = Flame pockets)
Yellow	32 metres (1200 ppm = 10% LEL)

There is no occurrence of overpressure incident as no part of the cloud is above lower explosive limits (LEL) at any time. This was demonstrated in Table 4.14.

Table 4.14: Level of concern (LOC) for overpressure from vapour cloud explosion (fuel dispenser failure)

Threat model:	
Type of ignition	Ignited by spark or flame
Level of congestion	Uncongested
Threat zone:	
Model run	Heavy Gas
Red	No part of the cloud is above LEL at any time
Orange	No part of the cloud is above LEL at any time
Yellow	No part of the cloud is above LEL at any time

For scenario 3:

The last scenario was considered as the worst-case scenario event that could happen. This was due to large fuel inventory in the tank in this scenario. Table 4.15 showed the source of strength due to the loss of fuel vapour containment. Amount of gas release is estimated at 218 kilograms/minutes and continuous release happened within one hour.

Table 4.15: Consequence and effect calculation outcome for fuel release from underground fuel storage tank due to overpressure

Source of strength for leak from hole in horizontal cylindrical tank	
Tank diameter	2.54 metres
Tank length	5.33 metres
Tank volume	27,000 litres
State of chemical	Tank contains liquid
Internal temperature	36^0C
Chemical mass in tank	23,100 kilograms (90% full by volume)
Circular opening diameter	0.6 metres
Height of tank opening	0.25 metres from tank bottom
Ground type	Default
Ground temperature	Equal to ambient
Maximum puddle diameter	Unknown
Release duration	36 minutes
Maximum average sustained release rate	624 kilograms/min
Total amount released	19,838 kilograms

For delayed ignition, the LOC distance for toxic effect and flash fire was 107 metres and 42 metres radius respectively as shown in Table 4.16, Table 4.17, Figure 4.10 until Figure 4.13.

Table 4.16: Level of concern (LOC) for toxic gas effects (Underground fuel storage tank overpressure)

Threat zone:	
Model run	Heavy gas
Red	107 metres (4000 ppm = AEGL-3)
Orange	320 metres (800 ppm = AEGL-2)
Yellow	1.9 kilometres (52 ppm = AEGL-1)

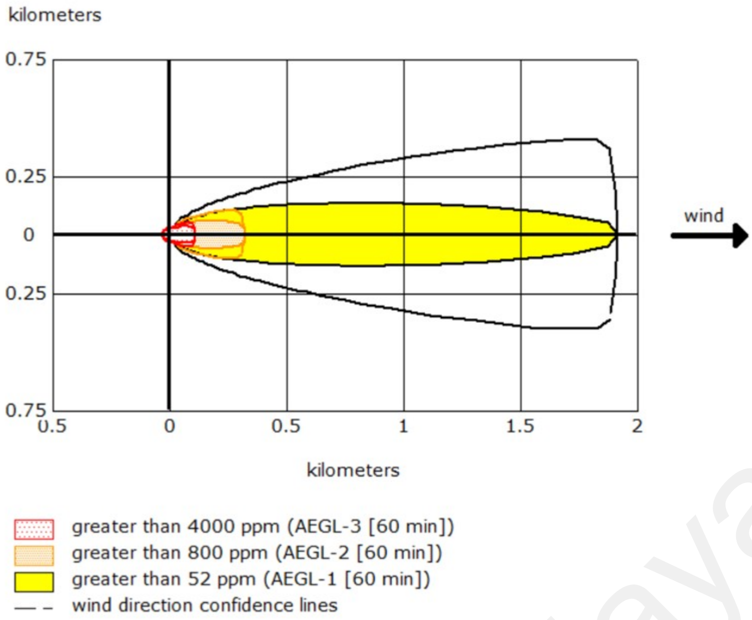

Figure 4.10: Graph of LOC on toxic gas effects (Underground fuel storage tank due to overpressure)

Figure 4.11: Individual risk contour for toxic threat (Underground fuel storage tank due to overpressure)

Table 4.17: Level of concern (LOC) on flammable area for flash fire (Underground fuel storage tank due to overpressure)

Threat zone:	
Model run	Heavy gas
Red	42 metres (12000 ppm = LEL)
Orange	68 metres (7200 ppm = 60% LEL = Flame pockets)
Yellow	244 metres (1200 ppm = 10% LEL)

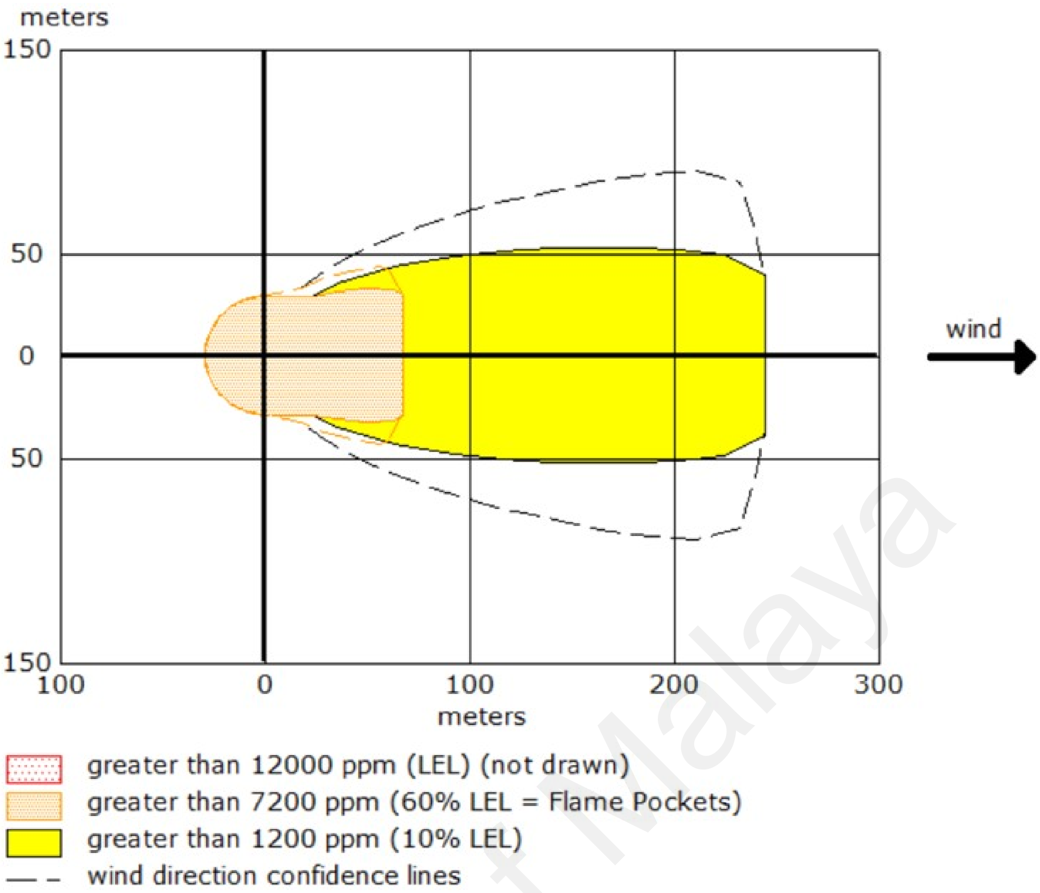

Figure 4.12: Graph of LOC on flammable area for vapour cloud (Underground fuel storage tank due to overpressure)

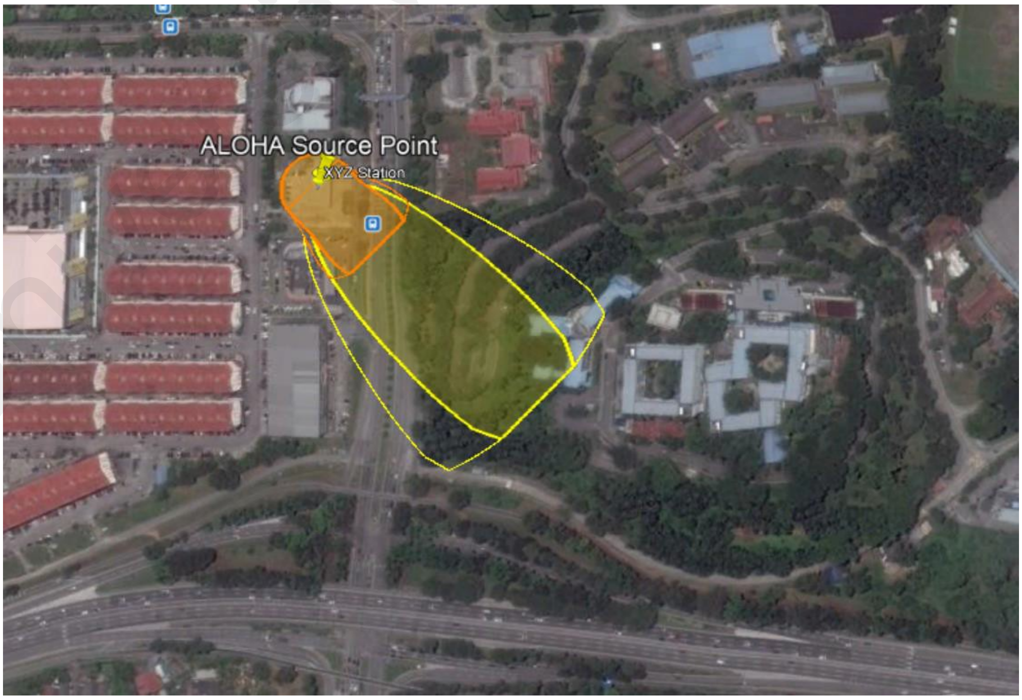

Figure 4.13: Individual risk contour on flammable area for vapour cloud (Underground fuel storage tank due to overpressure)

There was no potential blast force impact due to explosion in this scenario as the LOC was never exceeded as shown in Table 4.18.

Table 4.18: Level of concern (LOC) for overpressure from vapour cloud explosion (Underground fuel storage tank overpressure)

Threat model:	
Type of ignition	Ignited by spark or flame
Level of congestion	Uncongested
Threat zone:	
Model run	Heavy gas
Red	LOC was never exceeded (8.0 psi = destruction of buildings)
Orange	LOC was never exceeded (3.5 psi = serious injury likely)
Yellow	LOC was never exceeded (1.0 psi = shatters glass)

If the petrol inside the tank is burning, it may form a pool fire event which can happen within 112 meters from the release source provided the ignition existed. This was shown in Table 4.19 while the graph LOC and individual risk contour were shown in Figure 4.14 and Figure 4.15.

Table 4.19: Level of concern (LOC) for thermal radiation from pool fire (Underground fuel storage tank overpressure)

Threat zone: (Thermal radiation from pool fire)	
Chemical mass in tank	21,000 kilograms
Puddle diameter	53 metres
Burn duration	3 minutes
Maximum flame length	62 metres
Red	112 metres [10.0 kW/(sq m) = potential lethal within 60 seconds]
Orange	158 metres [5.0 kW/(sq m) = 2^{nd} degree burns within 60 seconds]
Yellow	245 metres [2.0 kW/(sq m) = pain within 60 seconds]

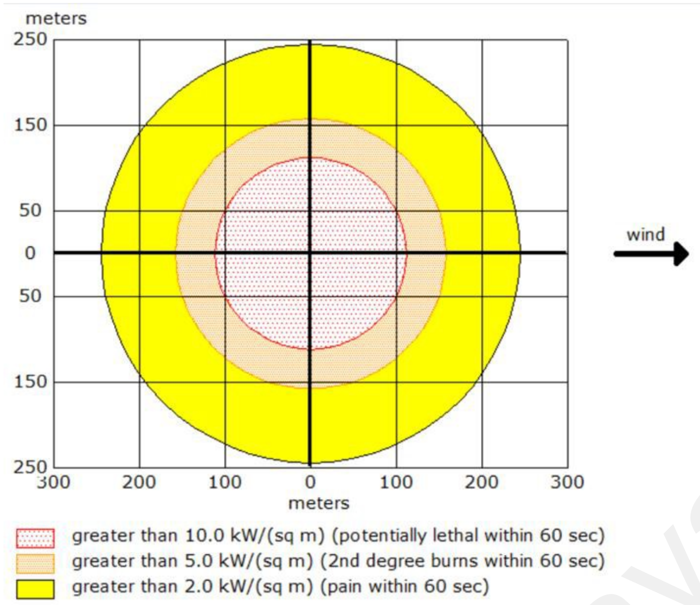

Figure 4.14 Graph of LOC on thermal radiation threat zone from pool fire (Underground fuel storage tank due to overpressure)

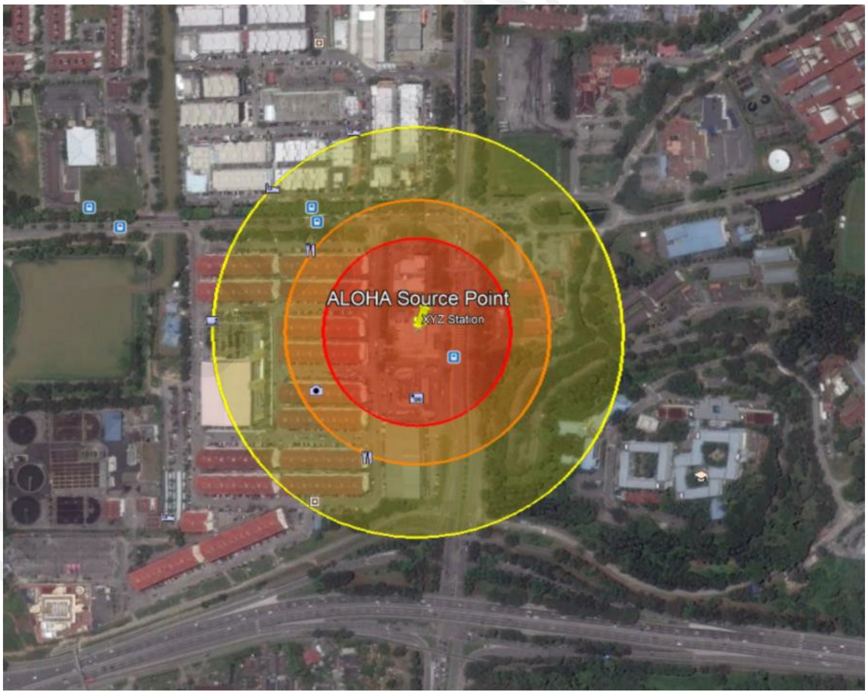

Figure 4.15: Individual risk contour on thermal radiation threat zone from pool fire (Underground fuel storage tank due to overpressure)

Last but not least, the possible event is BLEVE which occur within 224 metres from the source of release provided that immediate ignition existed. This was shown in Table

4.20 whereby the graph of LOC and individual risk contour were depicted in Figure 4.16 and Figure 4.17.

Table 4.20: Level of concern (LOC) for thermal radiation from BLEVE (Underground fuel storage tank overpressure)

Threat zone: (Thermal radiation from fireball)	
Internal temperature at failure	100^0C
Percentage of tank mass in fireball	30.7 %
Fireball diameter	108 metres
Fireball burn duration	8 seconds
Pool fire diameter	67 metres
Fireball burn duration	40 seconds
Flame length	83 metres
Red	224 metres [10.0 kW/(sq m) = potential lethal within 60 seconds]
Orange	318 metres [5.0 kW/(sq m) = 2nd degree burns within 60 seconds]
Yellow	496 metres [2.0 kW/(sq m) = pain within 60 seconds]

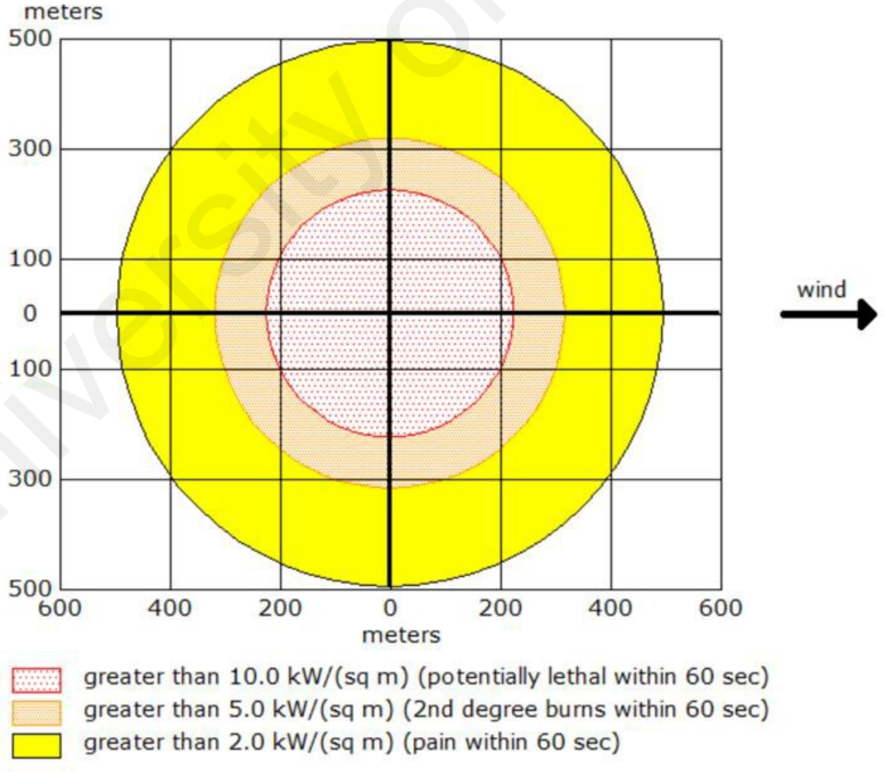

Figure 4.16: Graph of LOC on thermal radiation from BLEVE (Underground fuel storage tank overpressure)

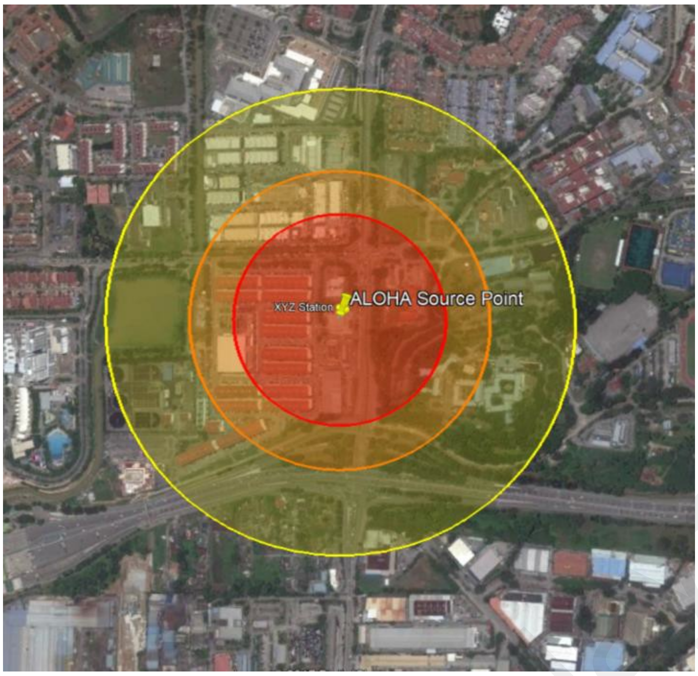

Figure 4.17: Individual risk contour on thermal radiation from BLEVE (Underground fuel storage tank overpressure)

Among the entire events occurred in this scenario, the most significant risk was toxic gas release and flash fire even though the impact might be minimal due to the vapour dispersion in the air. The nearest distance of the event consequence was within 11 metres from the loss of containment source.

4.6 Risk evaluation on consequence and effect analysis

Consequence and effect analysis had been conducted using ALOHA software for 3 different scenario which is selected based on significant risk from qualitative risk assessment findings. Each identified scenario had led to several events such as toxic release, flash fire, jet fire, pool fire and explosion. Table 4.21 summarized the outcome from ALOHA software and the estimation of the event consequences and effects. Three zones were modelled by ALOHA software which were red, orange and yellow.

Table 4.21: Summary of consequence and effect analysis

Accidental scenario	Release rate and duration	Mass released	Event		Consequence distance (m)			Event frequency
					Red	Orange	Yellow	
Scenario 1:	The initial release is estimated at 78.2 kg/min	4,692 kg in one hour	Toxic effect	Distance to LOC	46	127	665	7.18×10^{-4}
			Flash fire	Distance to LOC	23	33	99	7.18×10^{-4}
			Explosion	R – 8 psi O – 3.5 psi Y – 1.0 psi	Nil	Nil	Nil	5.38×10^{-4}
Scenario 2:	The initial release is estimated at 7.24 kg/min	434 kg in one hour	Toxic effect	Distance to LOC	15	42	192	8.88×10^{-7}
			Flash fire	Distance to LOC	11	11	32	8.88×10^{-7}
			Explosion	R – 8 psi O – 3.5 psi Y – 1.0 psi	Nil	Nil	Nil	2.13×10^{-7}
Scenario 3:	The initial release is estimated at 624 kg/min	19,838 kg in 36 minutes	Toxic effect	Distance to LOC	107	320	1900	2.58×10^{-6}
			Flash fire	Distance to LOC	42	68	244	2.58×10^{-6}
			Explosion	R – 8 psi O – 3.5 psi Y – 1.0 psi	Nil	Nil	Nil	1.94×10^{-6}
			Pool fire	R – 10 kW/m^2	112	158	245	3.87×10^{-6}

				O – 5.0 kW/m^2 Y – 2.0 kW/m^2				
			BLEVE	R – 10 kW/m^2 O – 5.0 kW/m^2 Y – 2.0 kW/m^2	224	318	496	1.94×10^{-6}

4.7 Risk summation and evaluation

Risk summation can be divided into individual risk and societal risk. The detailed explanation was discussed in Section 4.7.1 and 4.7.2.

4.7.1 Comparison of individual risk with risk acceptance criteria

Table 4.22 shown the overall risk result for individual risk per annum (IRPA) based on the established scenario and most possible events such as flash fire, explosion, toxic effect and jet fire. Since there are three zones for each ALOHA modelling, the LOC distance in the red zone was the only zone that was taken into consideration for the calculation of the overall IRPA with regards to risk associated to fuel systems at petrol station. Individual risk frequency for explosion of each scenario would not be included in the risk summation as the impact is minimal. For the final risk summation, BLEVE is not taken into consideration as this consider very highly unlikely due to the facts that the tank are mounded and stored under the ground.

The nearest LOC distance for fatality was modelled at 112 metres which was due to the pool fire event (10 kW/m^2) radius and the potential affected distance due to flash fire was less than 11 metres radius from the source of containment loss.

Table 4.22: Risk summation from all scenarios

Scenario	Event	Individual risk per annum frequency
Leakage during offloading of petroleum product from road tanker due to hose or fitting failure	Toxic Effect / Flash fire	7.18 x 10^{-4}
Leakage at dispenser area due to failure in safeguarding systems	Toxic Effect / Flash fire	8.88 x 10^{-7}
Underground fuel storage tank explosion due to overpressure	Toxic Effect/ Flash fire	2.58 x 10^{-6}
	Pool Fire	3.87 x 10^{-6}
Total		7.25 x 10^{-4}

The total individual risk per annum (IRPA) for this petrol station was 7.25 x 10^{-4}. This figure had exceeded a risk acceptance criterion that was set by DOE which is 1 x 10^{-6} per year. The combine individual risk contour for each event is shown in Figure 4.18.

As such, the frequency of fatal incident to occur per year for individual with regard to fuel containment loss or events such as toxic release, flash fire, jet fire, fireball and explosion was not within acceptable level. The potential affected areas based on Figure 4.18 were the other petrol station next to, commercial area, higher learning institution and nearby residential area.

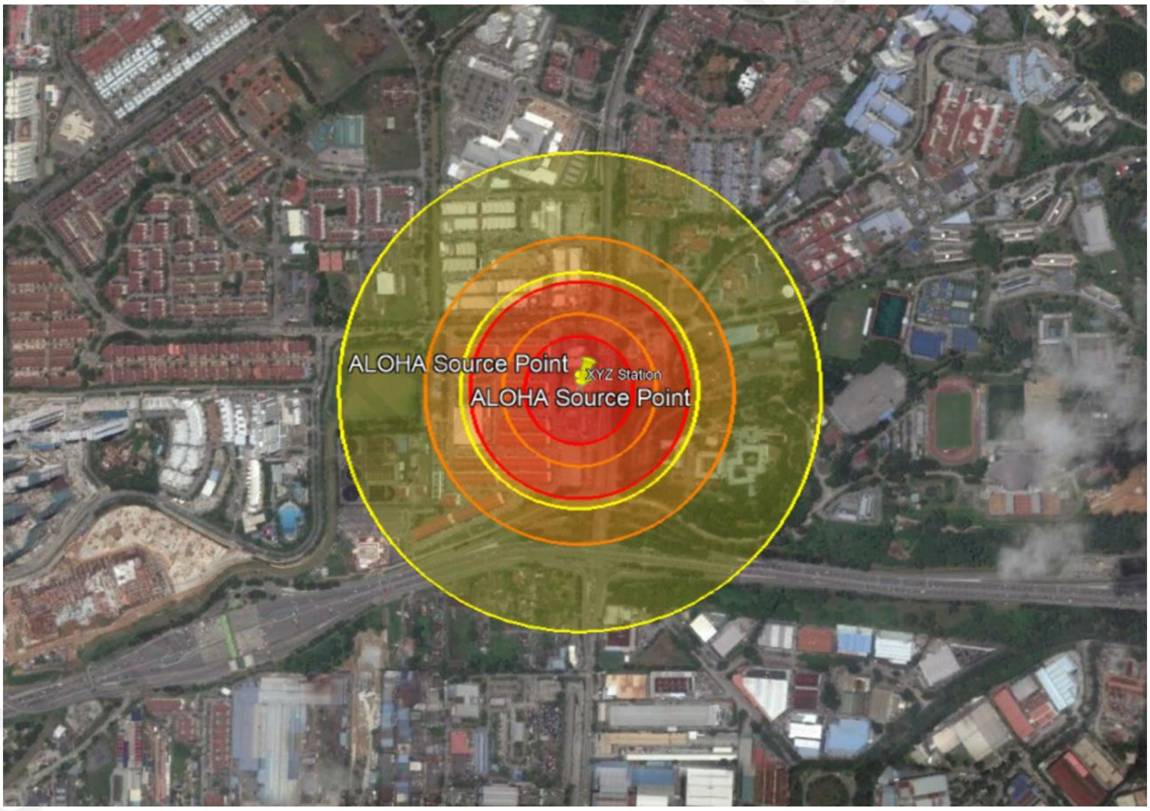

Figure 4.18: Individual risk contour for petrol station

4.7.2 Societal risk

As stated by CCPS (2009), simplified analogy as outlined in the study is used for the calculation of the societal risk. From this, each scenario and its overall risk frequency would contribute to the formation of F-N curve. In this study, observation of the population in the petrol station facility and the surrounding areas was conducted as part of the formation of F-N curve.

It was noted that the potential where people would be affected within the event consequences are inside the facility itself which consist of employees and public who came to refuel their vehicles. However, since the location of this facility is at the high-density area with many points of interest nearby which attract the public, the number of people would increase during the peak time especially during the weekend.

For scenario 1, the affected population would be the workers inside the facilities and the public who came to refuel their vehicles as shown in Table 4.26. The event in scenario 1 can give severe impact to those near this area such as flash fire. In normal operation, three people were involved during unloading of fuel from the road tanker to the underground fuel storage tank. The road tanker driver, his assistant or co-driver and the worker of the petrol station who will observe and witness the tanker operation during the offloading activities including taking the random sample of the product.

In scenario 2, the customer and passenger or petrol station workers who refuel customer's vehicles will be affected should the incident happen. Though the effect is very minimal if it is toxic release, there are still possibility of flammable area or flash area within 11 metres from the release point that might bring severe injury if the barrier failure escalates to this event.

On the other hand, scenario 3 will bring the worst-case scenario due the fact the inventory of the flammable material stored on site. From this information, the total number of affected population for each scenario expected is shown in Table 4.23.

Table 4.23: Total number of affected population for each scenario

Scenario	Event	Consequence distance (m) for red zone	Estimated population
Scenario 1	Toxic effects	46	15
	Flash fire	23	
Scenario 2	Toxic effects	15	15
	Flash fire	11	
Scenario 3	Toxic effects	107	600
	Flash fire	42	
	Pool Fire	112	

4.8 Risk characterization

The risk can be characterized by model validation as well as accuracy and uncertainty. They were further discussed in Section 4.6.1 and 4.6.2.

4.8.1 Validation of model

The accident prone failures were portrayed by the calculated consequences models in ALOHA. Although the model of accident sequence cannot be accurately demonstrated, the effort to approximation of reality was done from the selection of scenarios and event that have been used to identify their effects. On the other hand, it is understandable that it is quite impossible to predict other factors and contributors which lead to an incident precisely. Likewise, most consequence models are at best correlations derived from experimental evidence. Even if the models are "validated" through field experiments for some specific situations, it is difficult to validate them for all possibilities, and the question of model appropriateness will always exist.

For example, in this study, there were quite number of uncertainties when dealing with sequence of event based on established scenarios such as fire or explosion in the retail shop may give impact to the surrounding area. For example, the model run in scenario 3 was only for single underground tank whereby in actual there are 4 underground tanks altogether at site. does not taking into account. However, this was not taken into account either due to the ALOHA limitation.

4.8.2 Accuracy and uncertainty

Various factors contributed to the accuracy of absolute risk results. The factors are the analysis of risk for all significant contributors, the realism of the mathematical models used to predict failure characteristics and accident phenomena, and the statistical uncertainty associated with the various input data as well as the types of hazards being analysed. In the event that risk contributors were calibrated, uncertainty could be reduced to several percent. The calibrations occurred with the help of the ample historical data such as risk of safeguarding failures resulting in equipment damage.

In contrast, numerous studies stated that the uncertainties could be greater than one to two orders of magnitudes. This was due to the rarity of major contributors for catastrophic events (CCPS, 2003). As a practical matter, the best estimation and judgement led to the best decision on data inputs. In this study, uncertainties in failure frequencies of hose, valves and tanks will also play important roles in determining the frequency of the incident as well.

Since ALOHA is an open software to be used for the consequence and effect analysis. However, there are some in ALOHA software such as its inability to include explosions, or chemical reactions, particulates, chemical mixture, terrain, hazardous fragments and also downwind toxic effect of the by-products. Other than that, it also makes an assumption that the atmospheric gases such as oxygen and water vapour will not react with the dispersing chemical cloud even though chemicals react with dry or humid air, water, and other chemicals or even with themselves (EPA, 2007).

Furthermore, ALOHA is designed to model the release of pure chemicals and some chemical solutions. The behaviour of a solution or mixtures can be difficult to forecast as the prediction of chemical properties for solutions or mixtures could be very challenging. In ALOHA, the predictions are based on the chemical properties where the incorrect value of property will lead to invalid release rate of model and estimation of dispersion (EPA, 2007).

Last but not least, the results of ALOHA can also be unreliable in determining the spread of toxic gas release during certain weather conditions such as very low wind speeds, very stable atmospheric conditions, wind shifts and terrain steering effects, concentration patchiness, particularly near the release source.

4.9 Evaluation of questionnaire to selected government agencies

Survey was conducted to three selected government agencies which are involved in giving technical input or approving the Development Plan for petrol station development. Questionnaire were distributed to relevant personnel of Local Authorities, Department of Environment (DOE) and Department of Occupational Safety and Health (DOSH). The objective of this survey is to get the current practices and opinion from the respondents on the petrol station development.

Further analysis on the responses were done using SPSS software version 25 to assist in determining statistical value such as mean and standard deviations from the raw data collected. During the data collection, there were no unanswered question as the survey were conducted online and respondent is required to select answer for each question due to mandatory in the survey setup. The statistical analyses of each response from the three selected government agencies were further discussed as below.

4.9.1 Survey to Local Authorities

Eight questions were asked to Local Authorities with regards to the proposed development of petrol station as listed in Table 4.24. The survey was conducted for the staff who are directly involved in the One Stop Centre (OSC) at their respective OSC. The questionnaire were distributed to few Local Authorities in Klang Valley which were OSC in the state of Selangor and Kuala Lumpur. The summary of response from the respondents are summarised in Table 4.25. The variables were rated from the most positive to least positive scale which was 4 to 1 for strongly agree and strongly disagree respectively.

Table 4.24 List of questions to Local Authorities

QUESTIONS	
Q1	Proposed petrol station development which is submitted to Local Council will be referred to other Technical Agencies such as BOMBA, DOSH, DOE, JKR etc for comments and inputs.
Q2	Proposed petrol station locations will be assessed either it is in accordance with Gazetted Local Plan.
Q3	Not all submitted development plan are referred to other technical agencies as petrol station is not categories as critical activity.
Q4	Operational and safety aspect of petrol station is not under Local Authorities jurisdiction. Other technical agencies are looking at that aspect.
Q5	Petrol station also pose hazards to the consumer and nearby residence such as fire, explosion, oil and gas leakage etc.
Q6	Incidents happened in petrol stations such as fire, explosion, gas leakage etc.
Q7	Safety measures including holistic risk assessment and engineering control shall be integrate with development planning such as setback or buffer zone for the development of petrol station.
Q8	Holistic planning includes safety, environmental, town planning and etc which involve relevant technical agencies shall be done in future for petrol station development.

Table 4.25: Summary of responses from Local Authorities staff

	% Strongly disagree	% Disagree	% Agree	% Strongly Agree
Q1	0	0	20	80
Q2	0	0	50	50
Q3	0	30	70	0
Q4	0	30	70	0
Q5	0	0	0	100
Q6	0	0	0	100
Q7	0	0	0	100
Q8	0	0	20	80

As can be seen in Table 4.25, 80% staff strongly agreed that the proposed development of petrol station which were submitted to OSC will be directed to other technical agencies for input and comments from each respective department (Q1). Remaining 20% were also agreed on this statement. This was usually supported by the average (mean). However, in this study, mean was not significant as it did not give an optimal interpretation as this type of likert questionnaire is more beneficial to be analysed using median and interquartile ranges (IQR) as shown in Table 4.26. Median was equalled to 3 and the interquartile range (IQR) equalled to 1. Higher level of agreement among Local Authorities Staff might be due to the fact that each this is standard practices by OSC from different municipalities to request input from relevant technical agencies when assessing the Development Plan submission including petrol station.

For the Q2 which was on the assessment according to gazetted Local Plan, 100% respondents were agreed to the statement. This was further supported as stated in Table 4.26 where the median equalled to 4 and the interquartile range (IQR) equalled to 1. This shows that all OSC are implementing the requirement in following the gazetted local plan which all development must comply to the zoning for industrial, residential and commercial activities including the petrol station. In each Local Plan by Jabatan

Perancang Bandar dan Desa Semenanjung Malaysia, location of future petrol station has been identified.

However, it is not consistent practices by every staff of Local Authorities to request input from other technical agencies with regards to the petrol station development. Based on responses for Q3, 70% agree with this statement as compared to only 30% disagree. This showed that the flow process on evaluating Development Submission for petrol station were not consistently followed. Table 4.26 demonstrated that the median and interquartile range (IQR) supported the rating where the median was 3 and interquartile was 1.

As for the safety aspect of the petrol station (Q4), 30% disagree and 70% agree that the operational and safety aspect is not under jurisdiction of Local Authorities and are under purview of other agencies like Department of Occupational Safety and Health (DOSH) and BOMBA. Further investigation was done by establishing median and IQR to support the statement where the median equalled to 3 and IQR equalled to 1.

100% respondents were strongly agreed that the petrol station also pose hazards to the consumer and nearby resident (Q5). The same score were received for Q6 and Q7 which respondents were asked on their agreement that possibility of incident involving petrol station incident (Q6) and the need to have holistic risk assessment and engineering control on top of development control for petrol station (Q7). The highest level of agreement might be contributed by the awareness of respondent on the hazards and knowledge from previous incidents which were reported by mass media.

For the final question asked to the Local Authorities staff, 20% and 80% agreed and strongly agreed to the statement that holistic planning is required in future to incorporate all requirements for petrol station development. This indicated that they want an improvement for the benefit of all stakeholders including government agencies, project proponent and last but not least for the safety and well-being of the community at large.

Further investigation of responses from Local Authorities staff showed that α = .902 as shown in Table 4.26. According to Gliem and Gliem (2003), the closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale. From here, it can be concluded that the Cronbach's alpha reliability coefficient was good and most of questions correlated with each other as shown in Table 4.27.

In conclusion, all the questions for the Local Authorities staff had received positive responses which indicated that they process in evaluating the Development Plan for petrol station are duly in place though there are some inconsistencies in getting the technical inputs from government agencies before the approval is issued by OSC.

Table 4.26: Summary of statistical analysis on the responses received from Local Authorities Staff

	Median	**Interquartile range**	**Cronbach's alpha (α)**
Q1	3.00	1.00	.902
Q2	4.00	1.00	
Q3	3.00	1.00	
Q4	3.00	1.00	
Q5	4.00	0.00	
Q6	4.00	0.00	
Q7	4.00	0.00	
Q8	4.00	0.00	

Table 4.27: Inter-correlation among the questionnaire distribute to Local Authorities Staff

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8
Q1	1	.327*	.429	.429	.	.	.	.327
Q2	.327	1	.764*	.764*	.	.	.	1.000**
Q3	.429	.764*	1	1.000**	.	.	.	.764*

Q4	.429	.764*	1.000**	1	.	.	.	.764*
Q5	.	.	.	.	.	.	.	.
Q6	.	.	.	.	.	.	.	.
Q7	.	.	.	.	.	.	.	.
Q8	.327	1.000**	.764*	.764*	.	.	.	1

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

4.9.2 Survey to Department of Occupational Safety and Health (DOSH)

The survey to the DOSH staff from few different state in Malaysia were also made which comprises of 10 questions as listed in Table 4.28. A summary of responses from the staff was shown in Table 4.29. The variables were also rated from the most positive to least positive scale which was 4 to 1 for strongly agree and strongly disagree respectively.

Table 4.28: List of questions to DOSH staff

Questions	
Q1	Petrol Station does not fall under the Petroleum (Safety Measures) Act, 1984.
Q2	Some proposed petrol station is referred by Local Council via One Stop Centre (OSC) to get comments and inputs from DOSH.
Q3	Inputs from DOSH on proposed petrol station development will be based on statutory requirement under DOSH and also zoning as per Gazetted Local Plan by Town and Country Planning Department (JPBD).
Q4	Inputs from DOSH on proposed petrol station development will be based on related technical safety proposed by the project proponent.
Q5	Other aspect with regards to petrol station development and operation are not taken into consideration when giving input to Local Authorities.
Q6	Operational and safety aspect of petrol station is under purview of DOSH but also being monitored by other department like Fire and Rescue.
Q7	Petrol station also pose hazards to the consumer and nearby residence such as fire, explosion, oil and gas leakage etc.
Q8	Incidents happened in petrol stations such as fire, explosion, gas leakage etc.
Q9	Safety measures including holistic risk assessment and engineering control shall be integrate with development planning such as setback or buffer zone for the development of petrol station.
Q10	Holistic planning includes safety, environmental, town planning and etc which involve relevant technical agencies shall be done in future for petrol station development.

Table 4.29: Summary of responses from DOSH staff

	% Strongly disagree	% Disagree	% Agree	% Strongly Agree
Q1	50	20	30	0
Q2	0	0	100	0
Q3	33	0	67	0
Q4	33	0	67	0
Q5	33	67	0	0
Q6	0	0	67	33
Q7	0	0	33	67
Q8	0	0	33	67
Q9	0	0	0	100
Q10	0	0	0	100

The response seemed to be divided among the staff with regards to Q1. 50% and 20% strongly disagreed and agreed respectively that the Petrol Station development does not fall under the Petroleum (Safety Measures) Act, 1984. Whereby remaining 30% agreed on this statement. These differences might be due to different interpretation on act administered by DOSH. Though all DOSH in each state are under Federal Government, implementation by each state department might differ from one state to the other.

100% agreed that some proposed petrol stations development are being referred by OSC for their technical input (Q2). However, for Q3, divided opinions were received among DOSH staff that their inputs to OSC will be based on statutory requirement enforce by them and gazetted Local Plan. As listed in Table 4.29, 33% strongly disagreed while majority of 67% staff agreed on the Q3. This might be due to other factor or internal guidelines that may be referred by DOSH staff in giving inputs to OSC. Similarly, on Q4, the same results were received whereby 33% disagree and 67% agreed that inputs will also be based on the related technical safety of the proposed petrol station. This was further supported by median and IQR in Table 4.30.

On the other hand, 100% of respondents were strongly disagreed and agreed that other aspect of petrol station development are not taken into consideration when giving input to OSC (Q5). This might be some of other internal directive which they also referred when evaluating the proposal. For Q6, 67% and 33% respondents agreed and strongly agreed that that operational and safety aspect of petrol station is under purview of DOSH but also being monitored by other department like BOMBA.

Last but not least, for the Q7 to Q10, 100% respondents were agreed and strongly agreed on the statement asked. This shows that all of them are fully aware on the associated risk from the operational of petrol station which warrants an improvement in future. This is supported by median and interquartile range (IQR) for each question as shown in Table 4.30.

Further investigation of this study showed that α = .945. According to Gliem and Gliem (2003), the closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale. From here, it can be concluded that the Cronbach's alpha reliability coefficient was very good where majority of the questions are correlated to each other as shown in Table 4.31.

In conclusion, all the questions in this section had reached positive responses which indicated that the DOSH staff are currently involved in giving inputs to OSC for Development Planning of petrol station. However, there are some responses which divided opinion among them which lots of other variables that may influence the responses. This can only be identified if further elaboration and query are done for each of their responses.

Table 4.30: Summary of statistical analysis on responses received from DOSH Staff

	Median	Interquartile range	Cronbach's alpha (α)
Q1	1.50	2.00	.945
Q2	3.00	.00	
Q3	3.00	2.00	
Q4	3.00	2.00	
Q5	2.00	1.00	
Q6	3.00	1.00	
Q7	4.00	1.00	
Q8	4.00	1.00	
Q9	4.00	.00	
Q10	4.00	.00	

Table 4.31: Inter-correlation among the questionnaire distribute to DOSH Staff

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Q1	1	.	.678**	.678**	.678**	.870**	.678**	.327	.	.
Q2	.	.	.	.	.	.	.	.	.	.
Q3	.678**	.	1	1.000**	1.000**	.515**	1.000**	1.000**	.	.
Q4	.678**	.	1.000**	1	1.000**	.515**	1.000**	1.000**	.	.
Q5	.678**	.	1.000**	1.000**	1	.515**	1.000**	1.000**	.	.
Q6	.870**	.	.515**	.515**	.515**	1	.515**	.515**	.	.
Q7	.678**	.	1.000**	1.000**	1.000**	.515**	1	1.000**	.	.
Q8	.678**	.	1.000**	1.000**	1.000**	.515**	1.000**	1	.	.
Q9	.	.	.	.	.	.	.	.	.	.
Q10	.	.	.	.	.	.	.	.	.	.

** Correlation is significant at the 0.01 level (2-tailed)

4.9.3 Survey to Department of Environment (DOE)

The survey was also conducted to Department of Environment (DOE) staff which also comprises from different states. 10 questions were also asked as listed in Table 4.32 which variables were also rated from the most positive to the least positive scale which was 4 to 1 for strongly agree and strongly disagree, respectively. Table 4.33 shows the summary of responses from the DOE staff.

Table 4.32: List of questions to DOE

Questions	
Q1	Petrol Station is not listed in the Prescribed Activity under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 2015.
Q2	Some proposed petrol station is referred by Local Council to get comments and inputs from DOE
Q3	Inputs from DOE on proposed petrol station development will be based on statutory requirement govern by DOE and zoning as per Gazetted Local Plan by Town and Country Planning Department (JPBD).
Q4	Inputs from DOE are normally related to environmental aspect i.e the oil and grease trap.
Q5	Operational and safety aspect of petrol station are not taken into consideration when giving input to Local Authorities.
Q6	Operational and safety aspect of petrol station is not under DOE jurisdiction. Other technical agencies are looking at that aspect.
Q7	Petrol station also pose hazards to the consumer and nearby residence such as fire, explosion, oil and gas leakage etc.
Q8	Incidents happened in petrol stations such as fire, explosion, gas leakage etc.
Q9	Safety measures including holistic risk assessment and engineering control shall be integrate with development planning such as setback or buffer zone for the development of petrol station.
Q10	Holistic planning includes safety, environmental, town planning and etc which involve relevant technical agencies shall be done in future for petrol station development.

Table 4.33: Summary of responses from DOE staff

	% Strongly disagree	% Disagree	% Agree	% Strongly Agree
Q1	0	0	60	40
Q2	20	20	60	0
Q3	0	0	100	0
Q4	0	0	80	20
Q5	0	20	60	20
Q6	0	0	100	0
Q7	0	20	60	20
Q8	0	0	80	20
Q9	0	0	60	40
Q10	0	0	80	20

For Q1, 60% and 40% respondents are agreed and strongly agreed respectively that petrol station is not govern under the EIA Order 2015. This is supported by median and interquartile range (IQR) as shown in Table 4.34. However, divided opinion were received for Q2 which observed both strongly disagree and disagree score 20% each on the statement that some proposed development of petrol station are being referred to them for inputs whereby another 60% agreed to that statement. This might be due to the fact that inconsistent practices by different OSC with regards to the inputs request to DOE. Assumption made was only some of the Development Plan for Petrol station is being referred to other technical agencies. As for the Q3, 100% respondents agreed that their inputs to OSC will be based on related act and regulations administered by DOE and also the gazetted Local Plan for each area in the respective state. Similarly, for Q4 which 100% agreed that their inputs will also be based on other environmental requirement for the benefit of pollution prevention during the operational stage.

Divided opinion were also received on the related safety and operational aspect when giving inputs to OSC (Q5) which 20% were disagreed whereby 60% and 20% agreed and strongly agreed on that statement. This might be due to DOE officer who are also giving inputs on the related safety and operational aspect though that elements are not directly under their purview. However, 100% respondents were agreed that the safety aspect of petrol station is not under DOE jurisdiction as mentioned in Q6.

On the contrary, for Q7 where 20% disagreed that petrol station may pose hazards to the consumer and surrounding resident though 80% are agreed and strongly agreed on that statement. The reason why this 20% disagreement might be due to the lack of knowledge on safety aspect since this is not the core business of DOE.

Last but not least for Q8, Q9 and Q10, 100% agreement were received from the respondents which they also aware on the incidences that happened at petrol station and agreed that necessary measures and improvement are needed in future. Table 4.34 shows that the median and IQR that supported this response.

Further investigation of this study showed that α = .934. According to Gliem and Gliem (2003), the closer Cronbach's alpha coefficient is to 1.0 the greater the internal consistency of the items in the scale. From here, it can be concluded that the Cronbach's alpha reliability coefficient was excellent where most questions correlated with each other as shown in Table 4.35.

In conclusion, all the questions in this section had reached positive responses which indicated that the DOE staff are currently involved in giving inputs to OSC for Development Planning of petrol station. However, there are some responses which divided opinion among them which lots of other variables that may influence the responses. This can only be identified if further elaboration and query are done for each of their responses.

Table 4.34: Summary of statistical analysis on responses received from DOE Staff

	Median	**Interquartile range**	**Cronbach's alpha (α)**
Q1	3.00	1.00	.934
Q2	3.00	.00	
Q3	3.00	.00	
Q4	3.00	1.00	
Q5	3.00	.00	
Q6	3.00	.00	
Q7	3.00	.00	
Q8	3.00	.00	
Q9	3.00	1.00	
Q10	3.00	.00	

Table 4.35: Inter-correlation among the questionnaire distribute to DOE Staff

	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Q1	1	.406**	.	.612**	.645**	.	.645**	.612**	1.000**	.612**
Q2	.406**	1	.	.248	.786**	.	.786**	.248	.406**	.248
Q3	.	.	.	.	.	.	.	.	.	.
Q4	.612**	.248	.	1	.791**	.	.791**	1.000**	.612**	1.000**
Q5	.645**	.786**	.	.791**	1	.	1.000**	.791**	.645**	.791**
Q6	.	.	.	.	.	.	.	.	.	.
Q7	.645**	.786**	.	.791**	1.000**	.	1	.791**	.645**	.791**
Q8	.612**	.248	.	1.000**	.791**	.	.791**	1	.612**	1.000**
Q9	1.000**	.406**	.	.612**	.645**	.	.645**	.612**	1	.612**
Q10	.612**	.248	.	1.000**	.791**	.	.791**	1.000**	.612**	1

** Correlation is significant at the 0.01 level (2-tailed)

4.9.4 Summary of survey

In summary, the results of data analysis from the survey conducted at three selected government agencies involved shows positive implementation among the government agencies in evaluating and approving the Development Planning for petrol station projects. The final 4 questions asked to each department were the same which all of them agreed that improvement action shall be done on the current process. Holistic planning which combines all aspects is deemed necessary so the impact of the associated risk from the operational of petrol station can be identified and minimised during the planning stages.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

It can be concluded that the safety aspect of the selected petrol station is relatively good with some deficiencies in certain categories which poor or fair were scored. This condition could potentially contribute to fire and hazards risk on top of the statutory requirement. The hazards could in fire or explosion if it is not being addressed accordingly to improve the condition. Thus, it is important to ensure periodic surveillance such as walkabout to monitor the safety level and other precautionary measures are always in place to prevent the occurrence of unexpected incidents especially fire and explosions.

The qualitative risk assessment managed to identify the possible source and consequences from each specific activity. The hazard control which being in place or provided were also identified together with the recovery options and method should the incident happened. This exercise really helps in identifying hazards to ensure all aspects and impacts are covered in this study. Determination of possible events for the purpose of conducting the quantitative risk assessment (QRA) were lot easier since the whole process and hazards have been identified.

From the QRA study, among the major hazards associated to the operational of petrol station are toxic gas release, fire, vapour cloud explosion and catastrophic explosion from equipment. From these hazards, three scenarios have been established and analysed. From that assessment, the overall individual risk per annum (IRPA) for the selected petrol station was 7.25×10^{-4}. This was based on frequency, consequence and effect analysis that were done on the established scenarios and events.

Consequence and effect analysis which been modelled by ALOHA software found that the flash fire and explosion were beyond petrol station. The thermal radiation effect (10 kW/m^2) from the pool fire and flash fire which were 112 metres and 42 metres radius respectively can also be a contributor to the fatal incident. Therefore, it can be concluded that the risks from the selected petrol station were not within the risk acceptance criteria whereby the limit set was 1 x 10^{-6} per year. Since the IRPA for the selected petrol station were not within the acceptance criteria, active control measures by all parties especially the Company XYZ which own the petrol station and the dealer who operates so that any potential of containment loss can be reduced as low as reasonably practicable (ALARP).

From the survey to the selected government agencies, it was noted that there are some processes in place in getting inputs from the technical agencies by One Stop Centre (OSC) of the Local Authorities before the Development Planning of petrol station project is approved. It was also noted that there were inconsistencies among the officer in the selected government agencies when giving inputs on the petrol station project. However, all respondents agreed that improvement is needed to have better holistic planning which covers all aspects not only on the development planning requirement but also integrate health, safety and environmental point of view.

5.2 Recommendation for improvement

Human factor is always being the main factor in major industrial incident. Thus, according to Sonnemans and Körvers (2006), the capability of an organization in preventing accidents is indicated by the intervention of management to response immediately to business operation associating risks. He also stated that the precursors for vast majority of industrial accidents are the repeated disruptions. Thus, the management should take action in controlling these disruptions from escalating into an accident.

Among actions that can be suggested to prevent major accident as follows;

a) Preventive and corrective maintenance program for all equipment associated with fuel delivery systems and other supporting equipment are needed to be done rigorously according to schedule.
b) Comprehensive emergency response plan (ERP) which covers all potential incident scenarios associated to fuel's loss of containment such as fire and explosion so that the impact of accident can be reduced.
c) The specification of hazardous area classification in which any potential ignition source can be adequately controlled.
d) The establishment of additional mitigation measure such as foam sprinklers for fire-fighting.

5.3 Recommendation for future studies

It is encouraged that future studies of the same process shall be done by integrating other process hazard analysis such as Hazard and Operability Study (HAZOP) and Layer of Protection Analysis (LOPA) as this will improve scenario identification for the study. Safety Integrity Level (SIL) study on the equipment especially on the Safety Critical Equipment (SCE) will also help to give more knowledge in assessing the overall effectiveness of the safety barrier in place.

Other than that, health risk assessment should be done to specify the toxic criterion which will be assumed that individual exposed to the certain concentration of exposure will be in danger. Thus, the concentration obtained from the calculation will be compared with the Emergency Response Planning Guidelines (ERPG) for air contaminant as published by American Industrial Hygiene Association (AIHA) or other relevant standards or guidelines.

Further study on related aspect of approval process and regulatory requirements from all government agencies will be crucial as this can be used to further suggest the improvement actions that can be done such as integration of holistic planning in the Development Planning for petrol station.

More importantly, the consequences and effect analysis for future studies shall use more accurate and reliable software such as PHAST, Shepherd and PLATO. Thus, the quantified risks can cover all events from possible scenario and other variables which makes the overall QRA study more comprehensive.

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Appendix A

Hazard Assessment Checklist

The following checklist is used to identify and evaluate hazards at the petrol station.

	Yes	No
Site perimeter		
Are safety signs/warnings posted where appropriate?		
Are all worksites clean and orderly?		
Are work surfaces kept dry or appropriate means taken to assure the surfaces are slip-resistant?		
Are all corridors and passageways free from obstruction, trips, slips & fall hazards?		
Are all work areas properly illuminated?		

Electricity at work		
Has all portable electrical equipment been tested in the last 12 months?		
Are all outdoor connection using the appropriate type of socket?		
Are there any visible signs of damage to the appliance, outer cables and plugs?		
Are all electrical sockets and switches in good repair?		
Are all employees required to report as soon as practicable any obvious hazard to life or property observed in connection with electrical equipment or lines?		
Are all cord, cable and raceway connections intact and secure?		
In wet or damp locations, are electrical tools and equipment appropriate for the use or location or otherwise protected?		
Are extension cords prohibited from being run through doors/windows?		

Hazardous chemical exposure, management and communications		
Are workers aware of the hazards involved with the various chemicals they may be exposed to in their work environment?		
Is there a list of hazardous substances used in the workplace?		
Is there a Material Safety Data Sheet readily available for each hazardous substance used?		
Are workers knowledgeable of potential workplace chemical hazards?		
Is employee exposure to chemicals in the workplace kept within acceptable levels?		
Are workers required to use personal protective clothing and equipment when handling chemicals?		
Are standard operating procedures established and being followed when cleaning up chemical spills?		
Are respirators intended for emergency use adequate for the various uses for which they may be used?		
Are all workers aware of when and how to use respirators?		
Are the respirators NIOSH approved for this particular application?		
Is general dilution or local exhaust ventilation systems used to control dusts, vapours, gases, fumes, smoke, solvents or mists which may be generated in the workplace?		
Are employees prohibited from eating in areas where hazardous chemicals are present?		
Are all workers trained on the appropriate ways of using personal protective equipment?		
Is there an employee training program for hazardous substances?		

Tanker filling operation		
Does the tanker vehicle position itself appropriately on site within the property boundaries?		
Is there any barricade around connection points and warning signage put in place?		
Is there any safety measures or control i.e fire extinguisher provided?		
Are any dispensers within the exclusion area shut down for the duration of the transfer process?		
Are the products properly filled into the tank without spills?		

Fuel dispensing area		
Are the fuelling hoses designed to handle the specific type of fuel?		
Where fuelling or transfer of fuel is done through a gravity flow system, are the nozzles of the self-closing type?		
Are hosepipes and nozzles free of damage?		
Is it prohibited to conduct fuelling operations while the engine is running?		
Are fuelling operations done in such a manner that likelihood of spillage will be minimal?		
When spillage occurs during fuelling operations, is the spilled fuel cleaned up completely, evaporated, or other measures taken to control vapours before restarting the engine?		
Are smoking, open lights, open flames, sparking or arcing equipment prohibited near fueling or fuel transfer operations?		
Are fuel tank caps replaced and secured before starting the engine?		
Are ‘A Stop Engine. No Smoking’ sign and other safety signs posted at each flammable liquid dispenser?		
Is a fire extinguisher available in case of emergency?		
Are emergency stop buttons provided at each dispenser?		
Are fuel tanks properly labeled NO SMOKING?		
Are aboveground tanks protected from spills?		

Operator console and retail area		
Is the emergency stop switch in the console area clearly labelled?		
Are all the dispensing units clearly visible by direct vision or cameras?		
Is there an up-to-date emergency telephone/contact list adjacent to the control console?		
Is a copy of the site emergency plan easily accessible to the console operator?		
Are all hazardous chemicals and combustible liquids in packages stored and handled so they cannot contaminate food, food packaging and personal use products?		
Is the first aid kit appropriately stocked and readily accessible?		
Is the work area well ventilated?		
Are the cooling units in good condition and effective in the work area?		
Are fridges and food storage areas kept clean and hygienic?		
Are food items stored in fridge in date?		
Are all food items properly arranged in the shelves provided?		
Are stacked material interlaced to prevent sliding or tipping?		
Does the food shelves’ arrangement obstruct the pathway in the area?		
Are shelves secured and constructed to withstand the maximum designated storage weight		
Are shelves secured to prevent tipping or falling?		

Does the task require prolonged rising of the arms?		
Do the neck and shoulders have to be stooped to view the task?		
Are there sufficient rest breaks, in addition to the regular rest breaks, to relieve stress from repetitive-motion tasks?		
Are work surfaces kept dry or appropriate means taken to assure the surfaces are slip-resistant?		
Are all corridors and passageways free from obstruction, trips, slips & fall hazards?		

Fire safety		
Is there a fire prevention plan?		
Are employees aware of the fire hazards of the material and processes to which they are exposed?		
Are all exit routes kept clear and free from obstruction?		
Are emergency instructions clearly displayed		
Are all relevant fire emergency direction signs kept clear and unobstructed?		
Is the fire alarm system tested annually?		
Are sprinkler heads protected by metal guards, when exposed to physical damage?		
Are automatic sprinkler system water control valves, air and water pressures checked weekly/periodically as required?		
Are portable fire extinguishers provided in adequate number and type?		
Are fire extinguishers mounted in readily accessible locations?		

Exit		
Are all exits marked with an exit sign and illuminated by a reliable light source?		
Are the directions to exits, when not immediately apparent, marked with visible signs?		
Are there sufficient exits to permit prompt escape in case of emergency?		
Are special precautions taken to protect employees during construction and repair operations?		
Are doors that are required to serve as exits designed and constructed so that the way of exit travel is obvious and direct?		

General Management		
Is potable water provided for drinking and washing?		
Are water outlets not suitable for drinking clearly identified?		
Are all toilets and washing facilities clean, sanitary and well ventilated?		
Are adequate toilets and washing facilities provided?		
Are the Scheduled and Non-Scheduled Waste Management appropriately identified?		
Are wastes handling instructions properly displayed and communicated?		
Are suitable containers provided for the collection of waste?		
Is rubbish stored appropriately and removed regularly?		

HSE Communication and Record keeping		
Is dedicated communication board provided to disseminate information with regards to HSE matters?		
Are site operating and maintenance procedures available?		
Are staffs training logs and record available?		
Are register of safety meeting and minutes available?		

Appendix B

Kaji Selidik Permohonan Pembangunan Stesen Minyak Yang Dikemukakan kepada Pihak Berkuasa Tempatan

Survey on Proposed Development of Petrol Station which is submitted to Local Authorities

Anda telah dijemput untuk berkongsi pendapat anda berhubung pembangunan stesen minyak yang dikemukakan kepada PBT. Sila jawab setiap soalan dengan teliti. Bagi setiap soalan, sila bulatkan jawapan yang terbaik untuk kenyataan tersebut, di mana 1 = Sangat tidak setuju, 2 = Tidak setuju, 3 = Setuju, dan 4 = Sangat setuju.

You are invited to share your opinions about proposed development of petrol station which submitted to Local Authorities. Please answer each question carefully. For each question, please circle the best response for the statement, where 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree.

	Sangat tidak setuju *Strongly Disagree*	Tidak setuju *Disagree*	Setuju *Agree*	Sangat setuju *Strongly Agree*
1. Permohonan pembangunan stesen minyak yang dikemukakan kepada PBT akan dirujuk kepada agensi teknikal seperti BOMBA, JKKP, JAS, JKR dan sebagainya untuk ulasan. *Proposed petrol station development which is submitted to Local Council will be referred to other Technical Agencies such as BOMBA, DOSH, DOE, JKR etc for comments and inputs.*	1	2	3	4
2. Lokasi stesen minyak yang dicadangkan akan disemak sama ada bersesuaian dengan Pelan Tempatan atau Rancangan Tempatan yang telah diwartakan. *Proposed petrol station locations will be assessed either it is in accordance with Gazetted Local Plan.*	1	2	3	4
3. Tidak semua permohonan Kebenaran Merancang bagi stesen minyak akan dirujuk kepada semua agensi teknikal kerana pembangunan stesen minyak bukanlah aktiviti yang dikira kritikal. *Not all submitted development plan is referred to other technical agencies as petrol station is not categories as critical activity.*	1	2	3	4
4. Aspek keselamatan stesen minyak bukanlah di bawah bidang kuasa PBT dan dipantau oleh agensi teknikal yang terbabit. *Safety aspect of petrol station is not under PBT jurisdiction. Other technical agencies are looking at that aspect.*	1	2	3	4
5. Stesen minyak juga mendatangkan risiko dan bahaya kepada pengguna dan penduduk setempat seperti	1	2	3	4

kebakaran, letupan, kebocoran minyak dan gas dan sebagainya. *Petrol station also have risk and hazards to the consumer and nearby residence such as fire, explosion, oil and gas leakage etc.*				
6. Antara kejadian kemalangan yang pernah berlaku di stesen minyak adalah seperti kebakaran, letupan, kebocoran gas dan sebagainya. *Incidents happened in petrol stations such as fire, explosion, gas leakage etc.*	1	2	3	4
7. Langkah keselamatan yang bersesuaian termasuklah penilaian risiko menyeluruh dan kawalan kejuruteraan perlulah diintegrasikan dengan kawalan perancangan yang lain seperti keperluan anjakan bangunan atau zon penampan dalam pembinaan stesen minyak. *Safety measures including holistic risk assessment and engineering control shall be integrate with development planning such as setback or buffer zone for the development of petrol station.*	1	2	3	4
8. Perancangan yang menyeluruh melibatkan semua aspek keselamatan, alam sekitar, perancangan dan sebagainya yang membabitkan agensi-agensi teknikal yang berkaitan adalah perlu dibuat pada masa hadapan berhubung pembangunan stesen minyak. *Holistic planning includes safety, environmental, town planning and etc which involve relevant technical agencies shall be done in future for petrol station development.*	1	2	3	4

Appendix C

Kaji Selidik Permohonan Pembangunan Stesen Minyak yang dirujuk kepada Jabatan Keselamatan dan Kesihatan Pekerjaan

Survey on Proposed Development of Petrol Station which is referred to Department of Occupational Safety and Health (DOSH)

Anda telah dijemput untuk berkongsi pendapat anda berhubung pembangunan stesen minyak yang dirujuk kepada pihak Jabatan. Sila jawab setiap soalan dengan teliti. Bagi setiap soalan, sila bulatkan jawapan yang terbaik untuk kenyataan tersebut, di mana 1 = Sangat tidak setuju, 2 = Tidak setuju, 3 = Setuju, dan 4 = Sangat setuju.

You are invited to share your opinions about proposed development of petrol station which refer to DOSH. Please answer each question carefully. For each question, please circle the best response for the statement, where 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree.

	Sangat tidak setuju *Strongly Disagree*	Tidak setuju *Disagree*	Setuju *Agree*	Sangat setuju *Strongly Agree*
1. Stesen minyak bukanlah salah satu aktiviti yang tertakluk di bawah Akta Petroleum (Langkah-Langkah Keselamatan) 1984. *Petrol Station does not fall under the Petroleum (Safety Measures) Act, 1984.*	1	2	3	4
2. Sesetengah pembangunan stesen minyak dirujuk oleh Pihak Berkuasa Tempatan (PBT) untuk ulasan pihak JKKP. *Some proposed petrol station is referred by Local Council to get comments and inputs from DOSH.*	1	2	3	4
3. Ulasan yang diberi oleh pihak DOSH berhubung pembangunan stesen minyak akan merujuk kepada peruntukan undang-undang di bawah JKKP selain *zoning* kawasan tersebut dengan merujuk Rancangan Tempatan yang telah diwartakan oleh pihak Jabatan Pembangunan Bandar dan Desa (JPBD) *Inputs from DOSH on proposed petrol station development will be based on statutory requiremets under DOSH and also zoning as per Gazetted Local Plan by Town and Country Planning Department (JPBD).*	1	2	3	4
4. Ulasan yang diberi berhubung pembangunan stesen minyak akan merujuk kepada aspek keselamatan teknikal yang dicadangkan oleh pemaju projek. *Inputs from DOSH on proposed petrol station development will be based on related technical safety proposed by the project proponent.*	1	2	3	4

5. Lain-lain aspek berhubung pembinaan dan operasi stesen minyak tidak akan dinilai oleh pegawai JKKP semasa memberikan ulasan kepada Pihak Berkuasa Tempatan (PBT). *Other aspect with regards to petrol station development and operation are not taken into consideration when giving input to Local Authorities.*	1	2	3	4
6. Aspek operasi dan keselamatan stesen minyak adalah di bawah bidang kuasa pihak JKKP tetapi turut dipantau oleh agensi teknikal yang lain seperti BOMBA *Operational and safety aspect of petrol station is under purview of DOSH but also being monitored by other department like Fire and Rescue.*	1	2	3	4
7. Stesen minyak juga mendatangkan risiko dan bahaya kepada pengguna dan penduduk setempat. *Petrol station also pose hazards to the consumer and nearby residence.*	1	2	3	4
8. Antara kejadian kemalangan yang pernah berlaku di stesen minyak adalah seperti kebakaran, letupan, kebocoran gas dan sebagainya. *Incidents happened in petrol stations such as fire, explosion, gas leakage etc.*	1	2	3	4
9. Langkah keselamatan yang bersesuaian termasuklah kawalan kejuruteraan atau kawalan perancangan seperti zon penampan adalah perlu dalam pembinaan stesen minyak. *Safety measures including engineering control and admin control such as buffer zone is required for the development of petrol station.*	1	2	3	4
10. Perancangan yang menyeluruh melibatkan semua aspek keselamatan, alam sekitar perancangan dan sebagainya adalah perlu dibuat pada masa hadapan berhubung pembangunan stesen minyak. *Holistic planning which includes safety, environmental, town planning and which involve relevant technical agencies shall be done in future for petrol station development.*	1	2	3	4

Appendix D

Kaji Selidik Permohonan Pembangunan Stesen Minyak yang dirujuk kepada Jabatan Alam Sekitar

Survey on Proposed Development of Petrol Station which is referred to Department of Environment (DOE)

Anda telah dijemput untuk berkongsi pendapat anda berhubung pembangunan stesen minyak yang dirujuk kepada pihak Jabatan. Sila jawab setiap soalan dengan teliti. Bagi setiap soalan, sila bulatkan jawapan yang terbaik untuk kenyataan tersebut, di mana 1 = Sangat tidak setuju, 2 = Tidak setuju, 3 = Setuju, dan 4 = Sangat setuju.

You are invited to share your opinions about proposed development of petrol station which refer to DOE. Please answer each question carefully. For each question, please circle the best response for the statement, where 1 = Strongly Disagree, 2 = Disagree, 3 = Agree, and 4 = Strongly Agree.

	Sangat tidak setuju *Strongly Disagree*	Tidak setuju *Disagree*	Setuju *Agree*	Sangat setuju *Strongly Agree*
1. Stesen minyak bukanlah salah satu Aktiviti Yang Ditetapkan di bawah Perintah Kualiti Alam Sekeliling (Aktiviti Yang Ditetapkan) (Penilaian Kesan Kepada Alam Sekeliling) 2015. *Petrol Station is not listed in the Prescribed Activity under the Environmental Quality (Prescribed Activities) (Environmental Impact Assessment) Order, 2015.*	1	2	3	4
2. Sesetengah pembangunan stesen minyak dirujuk oleh Pihak Berkuasa Tempatan (PBT) untuk ulasan pihak JAS. *Some proposed petrol station is referred by Local Council to get comments and inputs from DOE.*	1	2	3	4
3. Ulasan yang diberi oleh pihak JAS berhubung pembangunan stesen minyak akan merujuk kepada *zoning* kawasan tersebut dengan merujuk Rancangan Tempatan yang telah diwartakan oleh pihak Jabatan Pembangunan Bandar dan Desa (JPBD) *Inputs from DOE on proposed petrol station development will be based on zoning as per Gazetted Local Plan by Town and Country Planning Department (JPBD).*	1	2	3	4
4. Ulasan yang biasa diberikan oleh pihak Jabatan akan berkaitan dengan aspek pengurusan alam sekitar seperti keperluan perangkap minyak. *Inputs from DOE are normally related to environmental aspect i.e the oil and grease trap.*	1	2	3	4

5. Aspek operasi dan keselamatan stesen minyak tidak akan dinilai oleh pegawai JAS seperti penilaian kesan risiko semasa memberikan ulasan kepada Pihak Berkuasa Tempatan (PBT). *Operational and safety aspect of petrol station are not taken into consideration when giving input to Local Authorities.*	1	2	3	4
6. Aspek operasi dan keselamatan stesen minyak bukanlah di bawah bidang kuasa pihak JAS dan dipantau oleh agensi teknikal yang terbabit. *Operational and safety aspect of petrol station is not under DOE jurisdiction. Other technical agencies are looking at that aspect.*	1	2	3	4
7. Stesen minyak juga mendatangkan risiko dan bahaya kepada pengguna dan penduduk setempat. *Petrol station also pose hazards to the consumer and nearby residence.*	1	2	3	4
8. Antara kejadian kemalangan yang pernah berlaku di stesen minyak adalah seperti kebakaran, letupan, kebocoran gas dan sebagainya. *Incidents happened in petrol stations such as fire, explosion, gas leakage etc.*	1	2	3	4
9. Langkah keselamatan yang bersesuaian termasuklah kawalan kejuruteraan atau kawalan perancangan seperti zon penampan adalah perlu dalam pembinaan stesen minyak. *Safety measures including engineering control and admin control such as buffer zone is required for the development of petrol station.*	1	2	3	4
10. Perancangan yang menyeluruh melibatkan semua aspek keselamatan, alam sekitar, perancangan dan sebagainya yang membabitkan agensi-agensi teknikal yang berkaitan adalah perlu dibuat pada masa hadapan berhubung pembangunan stesen minyak. *Holistic planning includes safety, environmental, town planning and etc which involve relevant technical agencies shall be done in future for petrol station development.*	1	2	3	4