# CONFINED SPACE BOWTIE RISK ASSESSMENT FRAMEWORK FOR SEWERAGE TREATMENT PLANT IN CONSTRUCTION PROJECT

ZAMREE BIN AMIN

UNIVERSITI TEKNOLOGI MALAYSIA

# CONFINED SPACE BOWTIE RISK ASSESSMENT FRAMEWORK FOR SEWERAGE TREATMENT PLANT IN CONSTRUCTION PROJECT

ZAMREE BIN AMIN

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Universiti Teknologi Malaysia

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**DEDICATION**

*To my beloved parents, wife, and kids*

*Thank you for your support and encouragement*

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The success of this Engineering Doctorate dissertation is through dedicated support received from all friends and colleagues. I have been through several challenges preparing this dissertation, especially while collecting information about risk assessment, selecting relevant documents, and gathering several literature pieces.

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Lastly, all my family members, for their moral support, especially my wife, keep encouraging me to achieve my ambition.

# ABSTRACT

The Langat Sewerage Treatment Plant (STP) project, which covers a 60.9 sq km catchment area starting from Cheras Batu 11 to Kajang, is a state-of-the-art and modern facility. The STP will be equipped with green technology initiatives and public facilities which can accommodate sewerage inflow around 207,000 $m^3$ per day or 920,000 population equivalent (PE). The purpose of this research is to investigate the issues related to safe working in confined spaces at sewerage treatment plant construction project in Hulu Langat district and to provide a solution by proposing a substantial approach in mitigating risk during confined space entry due to an ineffective risk assessment and poor compliance by project management. Since 2010, the Department of Occupational Safety and Health Malaysia has recorded numerous fatal confined space accidents, in which the main contributing factors are attributed to leadership, permit to work, risk assessment, competency, tool and equipment, as well as safe work procedure. Several Malaysia and international safety requirements have been reviewed to contribute to confined space improvement opportunities, such as legislations, standards, guidelines, and industrial codes of practice. This research proposed for the Bowtie Risk Assessment graphical framework of confined space to be implemented at the sewerage treatment plant construction project in the Hulu Langat district. The methods used were through site visit observation and survey, followed by an analysis process of the selected risk assessment method. The site visit to the sewerage treatment plant project investigated the compliance of confined space risk assessment documents to established requirements such OSHA 1994, FMA 1967, ICOP 2010, HIRARC Guidelines 2008, Quebec Regulation 2015, ISO 31010, HSE UK, and BCGA UK. The selected risk assessment method was analysed with Bowtie Risk Assessment by referring to the preventive approach concept or barrier analysis. Next, additional information relevant to risk assessment from journals was included. Evaluation of Bowtie Risk Assessment was conducted through a focus group discussion (FGD), which plays an essential role in developing the Bowtie risk assessment graphical framework. The rationale for applying Bowtie Risk Assessment was based on its reliable technique, comprehensiveness, and graphical presentation. Finalization of the inputs provided by FGD was carried out with Bowtie specialists to ensure the quality of the developed framework. The outcomes from the Bowtie Risk Assessment provided a total output that generated 11 Threats with 39 Preventive Barriers and 10 Consequences with 29 Mitigation Barriers. The proposed Bowtie Risk Assessment graphical framework provides a sewerage treatment plant construction project with a holistic technique in preventing confined space accidents. It also provides a safe work system, manages hazards and risks effectively, promotes a good leadership practice, improves company reputation, and significantly reduces accident costs. The framework is also useful as a reference model to other industry players.

# ABSTRAK

Projek loji rawatan pembetungan (STP) Langat yang meliputi kawasan tadahan seluas 60.9 km persegi bermula dari Cheras Batu 11 hingga Kajang merupakan kemudahan canggih dan moden. STP akan dilengkapi dengan inisiatif teknologi hijau dan kemudahan awam yang dapat menampung aliran masuk pembetungan sebanyak 207,000 $m^3$ sehari atau 920,000 setara penduduk (PE). Tujuan kajian ini dilaksanakan adalah untuk menyiasat isu-isu berkaitan keselamatan bekerja di dalam ruang terkurung di projek pembinaan loji kumbahan berpusat yang terletak di daerah Hulu Langat dan seterusnya menyarankan kaedah terbaik untuk menangani risiko semasa kemasukan ruang terkurung. Sejak 2010, Jabatan Keselamatan dan Kesihatan Pekerjaan Malaysia telah mencatatkan banyak kemalangan di ruang terkurung di mana faktor penyumbang utama dikaitkan dengan kepimpinan, permit pekerjaan, penaksiran risiko, kecekapan, alat dan peralatan dan prosedur kerja yang selamat. Beberapa keperluan keselamatan Malaysia dan antarabangsa telah dikaji untuk menyumbang kepada peluang penambahbaikan ruang terkurung seperti, perundangan, piawaian, garispanduan dan kod amalan industri. Kajian ini telah mengusulkan kerangka grafik penaksiran risiko Bowtie ruang terkurung untuk dilaksanakan di projek pembinaan loji rawatan pembentungan di daerah Hulu Langat. Kaedah yang digunakan adalah pemerhatian dan tinjauan kunjungan lokasi, diikuti dengan proses analisis untuk penaksiran risiko yang dipilih. Lawatan tapak ke projek loji rawatan pembentungan memeriksa pematuhan dokumen penaksiran risiko ruang terkurung terhadap keperluan yang ditetapkan seperti OSHA 1994, FMA 1967, ICOP 2010, Garispanduan HIRARC 2008, Peraturan Quebec 2015, ISO 31010, HSE UK dan BCGA UK. Kaedah penaksiran risiko yang dipilih dianalisis dengan menggunakan penaksiran risiko Bowtie iaitu merujuk kepada konsep pendekatan pencegahan atau analisis halangan. Kemudian, maklumat tambahan yang berkaitan dengan penaksiran risiko dari jurnal telah dimasukkan. Penilaian terhadap penaksiran risiko Bowtie telah dilakukan melalui perbincangan kumpulan fokus (FGD), yang memainkan peranan penting dalam membangunkan kerangka grafik penaksiran risiko Bowtie. Rasional untuk menerapkan penaksiran risiko Bowtie adalah berdasarkan teknik, kelengkapan dan persembahan grafik yang boleh dipercayai. Penyelesaian input yang diberikan oleh FGD dilakukan dengan pakar Bowtie untuk memastikan kualiti kerangka yang dibangunkan. Hasil dari penaksiran risiko Bowtie memberikan hasil yang komprehensif di mana ia menghasilkan 11 Ancaman dan 39 Penghalang Pencegahan dan 10 Akibat dan 29 Penghalang Mitigasi. Kerangka grafik penaksiran risiko Bowtie yang dicadangkan menyediakan projek loji rawatan pembentungan dengan teknik yang holistik untuk mencegah kemalangan ruang terkurung. Ia juga menyediakan sistem kerja yang selamat, mengurus bahaya dan risiko dengan berkesan, mempromosikan amalan kepimpinan yang baik, meningkatkan reputasi syarikat dan mengurangkan kos kemalangan dengan ketara. Kerangka kerja ini juga berguna sebagai model rujukan kepada pemain industri yang lain.

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| | | |
|---|---|---|
| ASHRAE | - | American Society of Heating, Refrigerating, and Air-Conditioning Engineers |
| AS 2865 | - | Australian Standard 2865 |
| BCGA | - | British Compressed Gas Association |
| CSBRA | - | Confined Space Bowtie Risk Assessment |
| DOSH | - | Department of Occupational Safety and Health |
| FMA 1967 | - | Factory and Machineries Act, 1967 |
| HIRARC | - | Hazard Identification, Risk Assessment & Risk Control |
| HIRADC | - | Hazard Identification, Risk Assessment & Determining Control |
| HSE UK | - | Health and Safety Executive United Kingdom |
| ISO | - | International Standard Organization |
| ICOP | - | Industrial Code of Practice |
| MoD UK | - | Ministry of Defense United Kingdom |
| OSHMS | - | Occupational Safety and Health Management system |
| OSHA 1994 | - | Occupational Safety and Health Act, 1994 |
| PPE | - | Personal Protective Equipment |
| POPEA | - | Policy, Organizing, Planning, Evaluate, Action |
| PTW | - | Permit to Work |
| Quebec | - | Quebec Regulation Respecting Occupational Safety and Health |
| SOP | - | Safe Operating Procedure |

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# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

Malaysia is one of the countries that focus on industrial sectors such as manufacturing, construction, oil & gas, agriculture, and services due to the Malaysian government's diversification strategy in modernizing its industry after the tin market collapse 1980s. The implication from the industrial development initiatives, there were substantial numbers of equipment and recent technology and increased the type of activities or works to be carried out. From that instance, it would create a different working environment that leads to multiple hazards. One type of working environment in an industry that commonly threatens the life of workers is confined space. This working environment is carried out in most industries in Malaysia, such as the oil & gas, construction, manufacturing, and services industry.

By history, working in confined space had been carried out as early as in the $19^{th}$ century. Kletz et al. (2007) revealed this evidence about the confined space jobs carried out in the industry by a Chimney Sweeper in the 1800s. Refer to the Industrial Code of Practice for a Safe Working in a Confined Space, 2010, a confined space is defined as "an enclosed or partially enclosed space that is at atmospheric pressure during occupancy and is not intended or designed as a place of work and is liable at any time to have an atmosphere which contains potentially harmful levels of contaminants, have an oxygen deficiency or excess, cause engulfment and have restricted means for entry and exit." This definition is used as common practice for all related sectors involved in this area.

Examples of confined spaces are storage tanks, boilers, silos, pits, sewers, tunnels, shipboard spaces entered through a small maintenance hole, cargo tanks, cellular double bottom deck, duct keels, ballasts, and oil tanks. Figure 1.1 shows examples of the type of confined space commonly originated in industry.

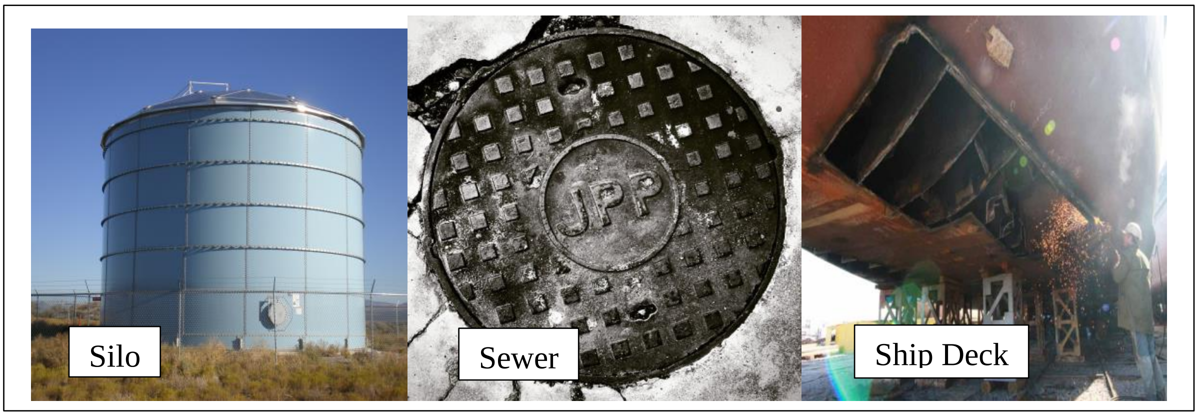


Figure 1.1 Types of confined space

As shown in Figure 1.1, the silo is commonly observed in the industry such as cement plants, chemical process plants, and sewerage treatment plants. The entry of this type of confined space is needed when there is a requirement for maintenance such as cleaning or inspection. Due to its internal shapes and configuration, it would limit the access, and egress includes conducting tasks and rescue. Sewer manhole is the most common observed which it is constructed at several locations of underground sewer piping as a check point if there are any issues related to sewer flows. The access and egress of the manhole are limited due to the small size of the manhole, and the entry is through vertical access. There were several cases related to an incident in the sewer manhole, which most of the cases were due to ignorance of established requirements by authority. The ship deck is the works carried out at the ship dock where it involves repair works underneath or inside the ship, such as the keel and hull area. Most of the task involves machinery and hot works. The internal configuration of the ship deck is part of the challenges during carried-out works, and appropriate assessment is required before entry.

Furthermore, activities conducted in confined spaces include cleaning, inspection, maintenance, abrasive blasting and surface coating, repair, including welding, modification, and adjustments to mechanical equipment, rescue, and construction. Figure 1.2 shows an example of activities to be carried out in a confined space depending on the type of industry and its purposes.


Figure 1.2 Activities in confined space

As depicted in Figure 1.2, cleaning and repairing are the most activities carried out by industries. Those activities are much related to the maintenance regime where the entire process of the plant would not operate smoothly if there is any faulty to the system. On top of that, maintenance needs to ensure all equipment is in optimum condition due to certain types of equipment required Certificate of Fitness renewal by authority where in Malaysia, the approving authority is the Department of Occupational Safety and Health (DOSH). In the construction sector, working inside deep and steep trench and construction of tankage is observed. A proper plan is vital to prevent casualties, such as the collapse of soil structure or exposure to toxic gases generated from the construction process or tasks. Rescuing activities only conducted once there is an emergency occurred to the entrant. Well-trained rescue personnel is required to prevent additional personnel injuries. Records from the previous confined space accident by DOSH revealed several cases related to untrained rescue personnel rescuing. Due to multiple activities in confined space, the generation of hazards arising out from such activities are significant, and this is the main issue to overcome by industry to ensure the safety of their employees. Hazard means any source or situation for harm in terms of human injury or ill health, property damage, damage to the environment, or a combination of these (Guidelines for Hazard Identification, Risk Assessment and Risk Control, 2008). As listed in Table 1.1, examples of hazards present in confined space are physical, health, biological, and chemical.

Table 1.1 Hazards in confined space

| CATEGORY OF HAZARD | EXAMPLES |
|---|---|
| Physical | Machinery, claustrophobia, slip & fall, manual handling, heat, electrical, fire, lack & enrichment of oxygen |
| Health | Radiation, noise, fumes, toxic gasses |
| Biological | Viruses, fungus, insect bites, reptiles |
| Chemical | Cleaning agent, test medium such as lubricant or spray paint, existing residue such as sludge |

Hazard being identified while working in confined space needs special attention by industries to eliminate or reduce it to acceptable condition before entry. This process is called a risk assessment. Risk assessment is the process of evaluating the risks of safety and health arising from hazards at work (Guidelines for Hazard Identification, Risk Assessment and Risk Control, 2008). The risk assessment process consists of risk identification, risk analysis, and risk evaluation (ISO 31010: Risk Management-Risk Assessment Techniques, 2009). Failing in planning towards an adequate risk assessment approach would result in catastrophic confined space incidents.

## 1.2 Background of the Study

This section describes risk assessment implementation in industries such as standards, legislation, and guidelines. It might include the type of techniques or methods applied to the assessment of risk at the workplace. Furthermore, factors that influence the compliance towards safe working in confined space is explained.

While working in a confined space, the most common issues are the effectiveness of the risk assessment method and industry compliance. The risk assessment approach's application varies depending on the type of industry and the scope of work. The provision of risk assessment is established for all industries, and selecting the appropriate method is required. For example, ISO 31010:2009 (Risk Management-Risk Assessment Techniques) has thirty-one types of risk assessment techniques outlined and used for various work applications. Besides that, those types of risk assessment techniques could be divided into three categories: qualitative, quantitative, and hybrid techniques, where the examples of techniques are shown in Figure 1.3 (P.K. Marhavilas et al., 2011).

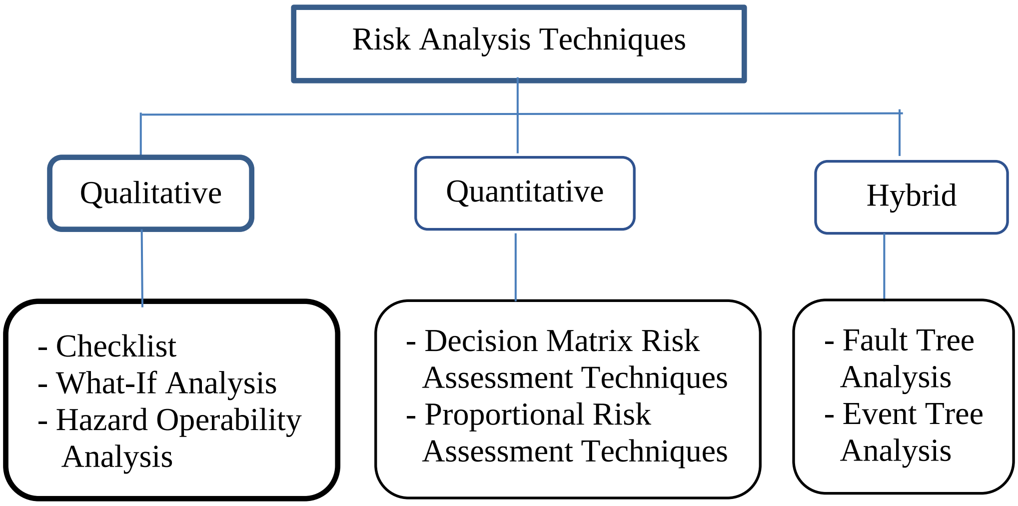


Figure 1.3 Risk assessment techniques category

Figure 1.3 shown examples of categorization on Risk Analysis techniques. For the qualitative technique, three types of risk analysis are Checklist, What-if-analysis, and HAZOP. A checklist to do inspection or audit, and it is a straightforward analysis. What-if-analysis uses a formula to know the outcomes based on the input value, such as assessing workplace hazards. HAZOP or Hazard and Operability analysis is the technique for identifying hazards at the work process, such as the process plant. The Quantitative technique, Decision Matrix Risk Assessment (DMRA), and Proportional Risk Assessment Technique (PRAT) are used. DMRA is a risk assessment technique that combines the consequence or severity and likelihood range. The risk rating used a ten-by-ten risk matrix table, and the risk action plan table will determine the required action. PRAT is a technique that combines a likelihood factor, severity of harm factor, and frequency factor. The risk rating obtains from the multiplication value where is determined according to the risk action table. An example of a hybrid risk analysis technique is Even Tree analysis (ETA) and Fault Tree Analysis (FTA). Event Tree analysis is a risk analysis technique to mitigate the risk that is achieved by the Top Event. The process of risk mitigation depends on the mitigation barrier's effectiveness. The Fault Tree Analysis is a failure analysis technique to analyze an undesired state of a system using Boolean logic, which combines the event's lower levels.

Nationwide, government bodies and other accredited health and safety organizations have developed standard practices and industry guidelines, the fundamental risk management used to develop a specific risk assessment method. For that instance, guidance from ISO 31000:2009, Risk Management-Principles and Guidelines, and ISO 31010:2009, Risk Management-Risk Assessment Techniques, observe a valuable platform for developing such a method. Generally, ISO 31000 has clearly defined the principles in managing risk, the framework on which it occurs, and the risk management process to understand the risk management standard requirements. As for ISO 31010, the detailed requirements are specifically about risk assessment, including risk identification, risk analysis, and risk evaluation. Figure 1.4 shows the Risk Management Standard relationship (Block 1,2 & 3) and the Risk Assessment Process (Block 3).

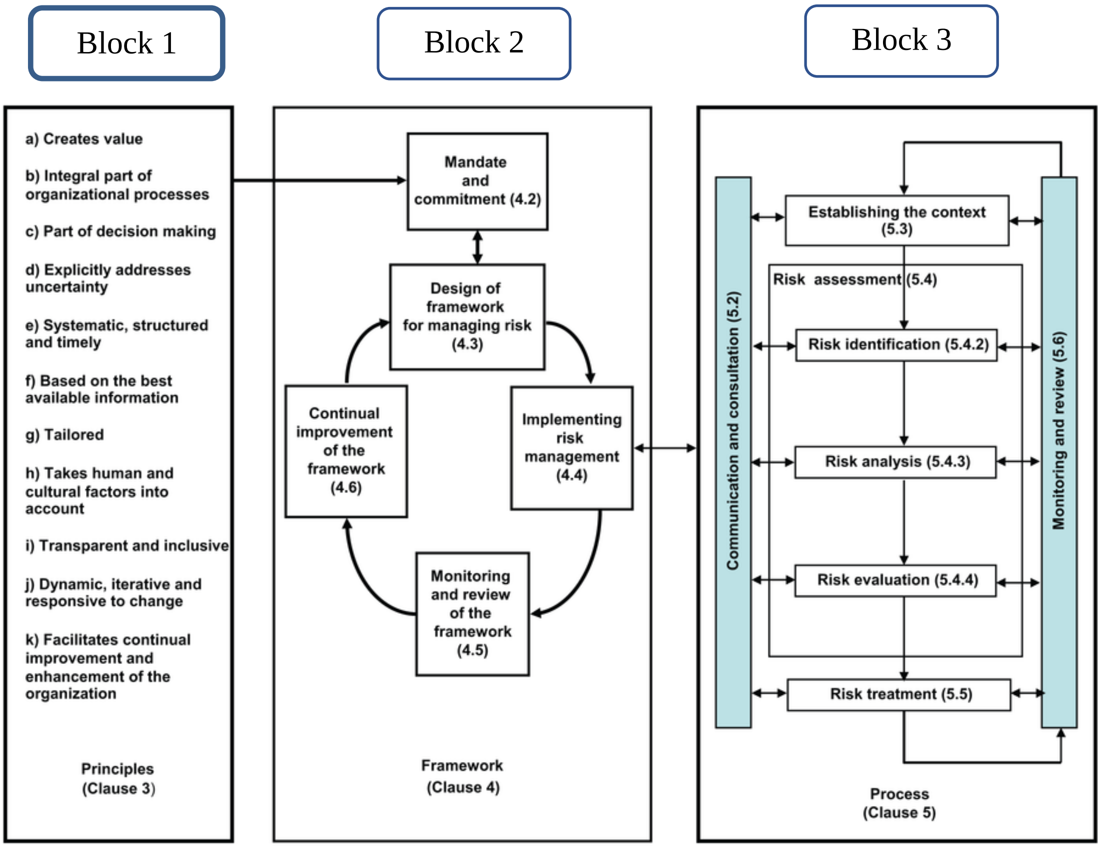


Figure 1.4 Relationship between risk management principles, framework, and process

The principles of Risk Management standards need to be understood by the organization before implementation. The Risk Management principles, which are divided into eleven key elements, are shown in Block 1. Each element plays its important functions where any weakness observed would lead to an ineffective Risk Management framework. Block 2 describes the Risk Management framework as guidelines towards the entire Risk Management Standard, where each process is explained in detail in the clauses. The risk assessment process provided in Block 3 used a necessary step in assessing risk in the workplace where the details of the requirements need to be identified according to the type of jobs and scope. Several documents were developed to fulfill the workplace's risk assessment requirements, especially for confined space activities. Mainly, the establishment of the documents such as Guidelines and Standards was referring to the fundamentals of risk management in ISO 31000 such as American Society for Heating, Refrigerating and Air-conditioning Engineers, 2009 (ASHRAE US 2009), British Compressed Gas Association, 2015 (BCGA UK 2015), A brief Guide for Working Safely, 2013 (HSE

UK 2013), Industrial Code of Practice for Safe Working in Confined Space, 2010 (ICOP 2010), Occupational Safety & Health Management System, 2011 (OSHMS 2011), Hazard Identification, Risk Assessment & Risk Control, 2008 (HIRARC 2008), AS 2865: 2009, Safe Working in a Confined Space (AS 2865 2009), ISO 12100: 2010, Safety of Machinery-General Principles for Design-Risk Assessment and Risk Reduction (ISO 12100 2010) and ISO 14120: 2002, Safety of Machinery-Guards-General Requirements for the Design and Construction of Fixed and Movable Guards (ISO 14120 2002).

The list of documents related to risk assessment entries shows that every country has its Standards Guidelines. The development of the risk assessment concept to be implemented varies in job scope, whether related to confined space works or otherwise. Examples of areas of risk assessment are building maintenance, manufacturing, military, and safety of machinery. In building maintenance, the American Society of Heating, Refrigerating and Air-conditioning Engineers (ASHRAE US 2009) provides risk assessment guidelines on evaluating the buildings' performance about occupational safety and health matter ASHRAE US 2009 is specifically towards Heating Ventilation Air-conditioning (HVAC) maintenance. It could also extend to the risks might contribute while performing other areas of the buildings such as cable ducting, pump room, and basement, which are classified as confined spaces, is what is happening in industries where ignorance towards those work areas might expose to biological, physical, and oxygen deficiency (Ana Stojkovic, 2013).

In the manufacturing industry, which is provided by British Compressed Gas Industry (BCGA UK 2015), has clearly stated the overall confined space risk assessment in drinks dispense activities, is a decent example of specific, confined space risk assessment toward identified activities due to the reasons where specific activities have their specific risks that need mitigating. The military industry provided by the Ministry of Defense (MoD UK 2014) provides a solution on the confined space activities related to their contractors by establishing a specific risk assessment methodology, especially the civil and mechanical & electrical works that might involve confined space entry to protect all their contractors in health and safety matters.

Countries like the United Kingdom, Australia, and Malaysia have established their risk assessment guidelines and standards. The established risk assessment documents provide general guidelines to all industries in identifying risk in confined space. Guidelines by Health and Safety Executive 2013 (HSE UK 2013) stated brief description about confined space safe working requirements, including its common hazards whereas Malaysian Industrial Code of Practice for Safe Working in Confined Space (ICOP 2010) and Australian Standard for Safe Working in Confined Space (AS 2865) specify the detail requirements on prior entering, while working, after working in confined space as well as the method of rescuing in confined space. Figure 1.5 shows the essential stages of safe working in a confined space.

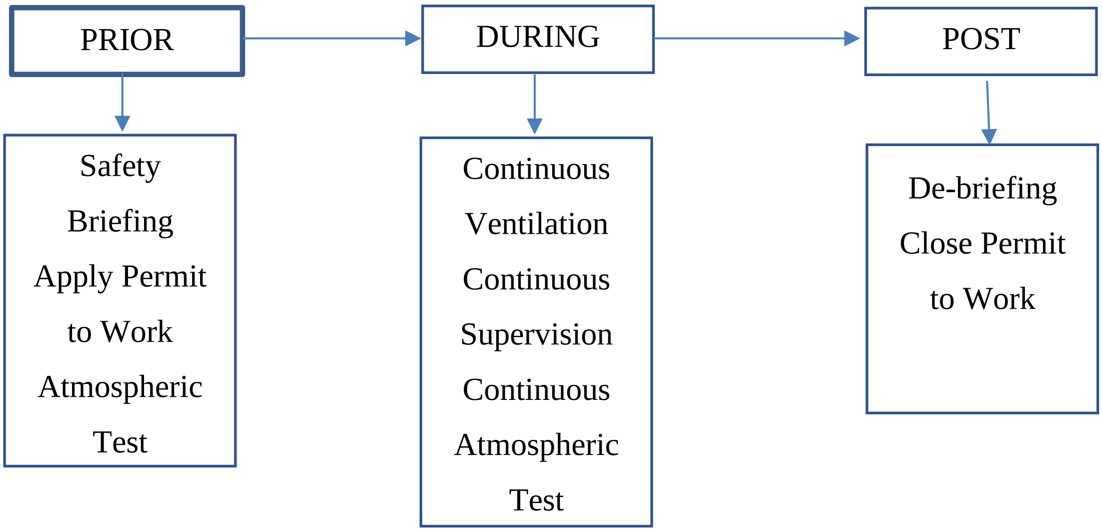


Figure 1.5 Basic stage of confined space entry

Guidelines on risk assessment, Malaysian Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC 2008), and Malaysian Guidelines on Occupational Safety and Health Management System (OSHMS 2011), developed to implement in industries. The application of these guidelines is dedicated to any industries where the extended application of the risk assessment approach is to be initiated by the respective organization through their types of work scope. An example of HIRARC 2008 described the detailed risk assessment process, which starts from

Classifying Work Activities, Consultation, Identify Hazard, Risk Assessment, Prepare Risk Control Action Plan, Implementation, and Review when required. It is a comprehensive risk assessment guideline in which every step of processes is explained, including employee and employee involvement, which falls under the Consultation stage.

Moreover, OSHMS 2011 provides industry guidelines on developing the Occupational Safety and Health Management System (OSHMS) at the workplace. It uses a Policy, Organising, Planning & Implementation, Evaluation, and Action for improvement (POPEA) concept through continual improvement strategy adopted from International Labour Organization 2001 (ILO-OSH 2001). The requirements for conducting a risk assessment are under the planning & implementation stage, and the methodology on risk assessment refers to HIRARC 2008. Figure 1.6 shows the conceptual sub-elements of OSHMS 2011.

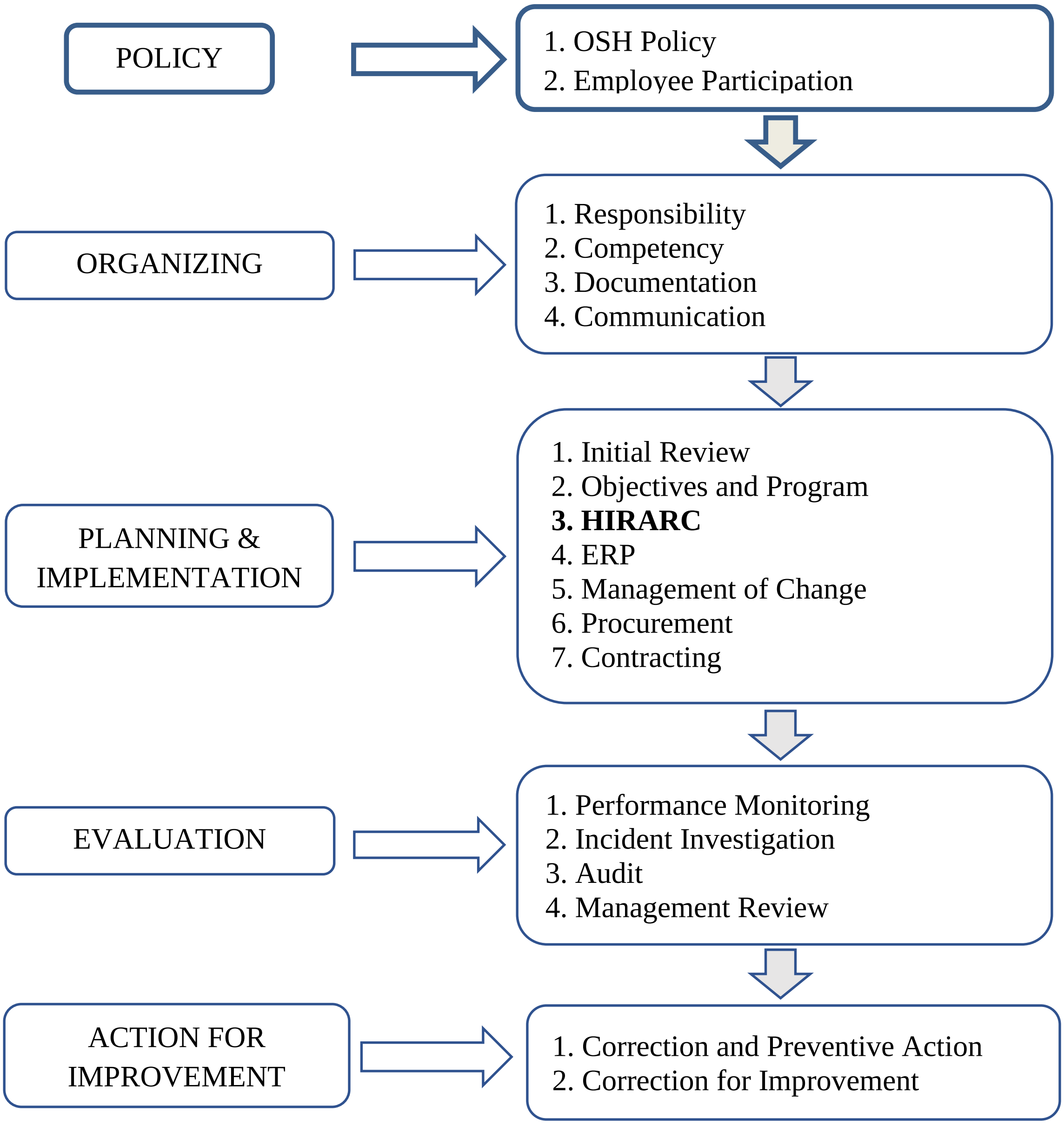


Figure 1.6 Conceptual Sub-element in OSHMS 2011

Most of the industry incidents are related to mechanical hazards from the tools and equipment being used, such as ejection, draw-in, or caught in between hazards (A.C. Caputo et al., 2013). Moreover, incidents in confined space might also contribute by tools and equipment used while carrying out jobs in confined space. The hazards generated by tools and equipment are substantial, and an appropriate risk assessment needs to be carried out (Yuvin Chinniah, 2015). Internationally, some Standards guide machinery safety, namely ISO 12100:2010, Safety of Machinery-General Principles for Design-Risk Assessment and Risk Reduction (ISO 12100), and ISO 14120:2002, Safety of Machinery-Guards-General Requirements for the Design and Construction of Fixed and Movable Guards (ISO 14120). Even the intention of these Guidelines is different; its purpose is to reduce risk while performing works, especially during confined space entry in ensuring the safeguarding of machinery, several guards states in ISO 14120, such as adjustable guards, inter-locking guards, and distance guards, including risk assessment.

Furthermore, the safe design of machinery or work area is vital to prevent any unexpected incident. The risk assessment strategy and reduction is shown in ISO 12100 allow designers to ensure that the machine's design is safe. The observed paramount importance for safety. In most industries where machine operation is part of their primary routine functions, the root cause of incidents after human factors is unsafe machinery, especially during operation or maintenance (Etherton, 2007).

The government also gazetted the legislation in order to enforce occupational safety and health rules at the workplace. Commonly all the legislation established is stated in general regarding occupational safety and health (OSH) requirements. Examples of OSH legislation in Canada is Quebec Regulation Respecting Occupational Safety and Health, 2015 (Quebec 2015), whereas, in Malaysia, they have Occupational Safety and Health Act, 1994 (OSHA 1994) and Factories and Machinery Act, 1967 (FMA 1967). Generally, those legal requirements have their objectives, and mostly they aim to ensure the safety, health, and welfare of all workers, manage risks at the workplace, and promote health and safety compliance at the workplace. Even though they have common objectives, the specific content in legislation plays a significant role in promoting risk management at the workplace, specifically for confined space works. In conjunction with that, Quebec 2015 has twelve key elements contributing to risk assessment, whereas OSHA 1994 has four and FMA 1967 has three. The critical risk assessment elements of Quebec 2015, OSHA 1994, and FMA 1967 are shown in Figure 1.7

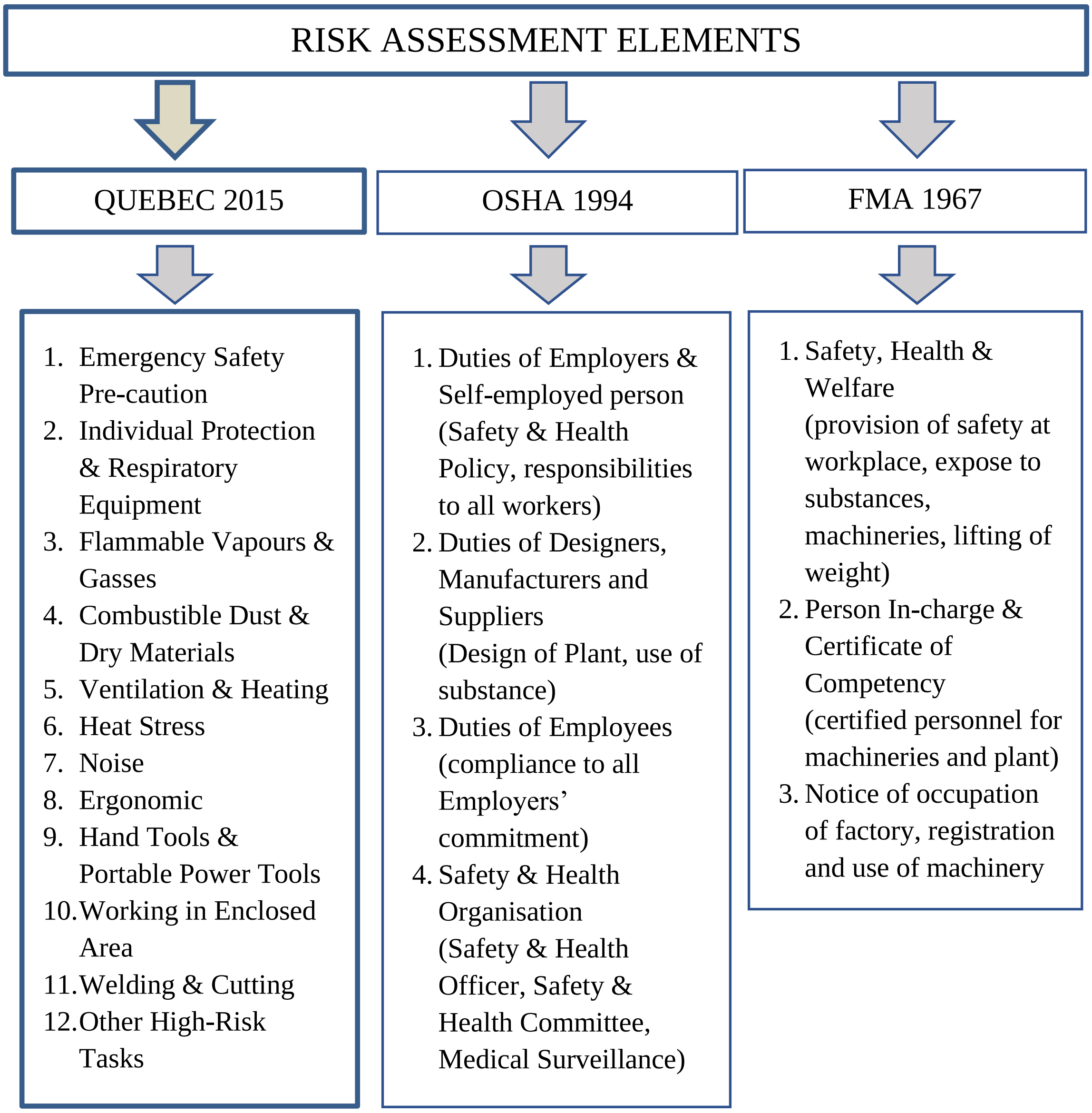


Figure 1.7 Risk assessment elements for Quebec, OSHA 1994 & FMA 1967

The guidance provides established risk assessment documents such as Standards, Guidelines, and legislation implemented at the workplace before confined space entry. However, the incident related to confined space keep occur. The Authority such as the Department of Occupational Safety and Health (DOSH) or Non-Government Organization (NGO) such as the Malaysian Society of Occupational Safety and Health (MSOSH) are managing to enforce safety rules and regulations as well as contributing their expertise in investigating the accident to know the primary causes of the incident. All parties need to mitigate several non-compliance or root causes of the incident, namely, Authority, Employer, and Employee. Figure 1.8 listed the common contribution factors (CF) of incidents specifically for Malaysia's confined space works.

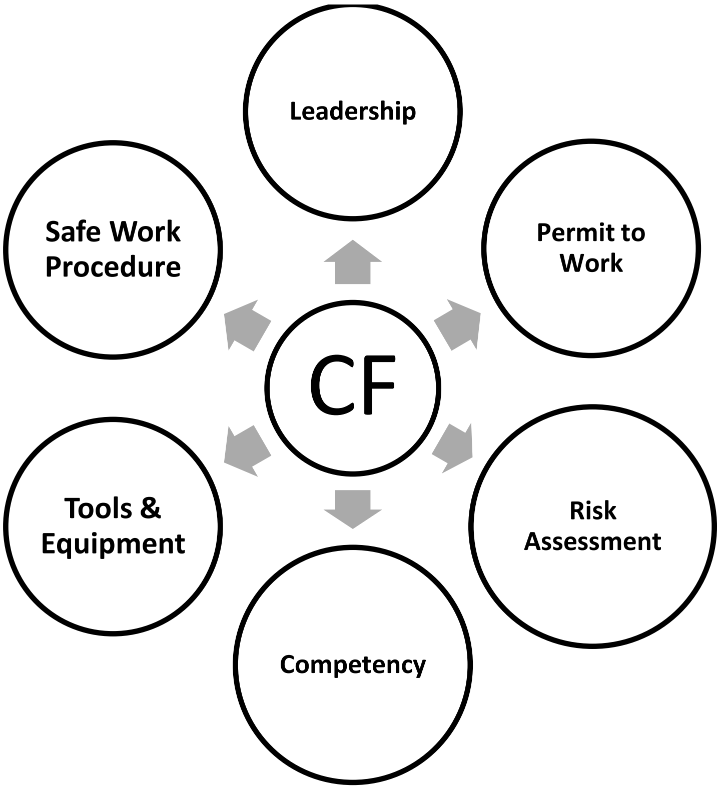


Figure 1.8 Contribution factors of confined space incident

Leadership in an organization plays a principal factor in complete safety and health performance. Despite top management commitment, leadership roles are held by designated personnel assign by higher management, such as project managers, engineers, and supervisors. Lead by example shows or visible leadership approach needs to be applied by all organizations to ensure compliance with the established company Safety and Health Policy statement. Examples of programs involved are leading all the incident investigation processes, Coaching or Mentoring, OSH Audit, and scheduled OSH Inspection. Those programs could indirectly increase OSH awareness of the leaders in hazard and risk identification, reducing the number of accidents (A. Perlman et al., 2014).

Furthermore, Permit to Work (PTW) also contributes to non-compliance issues with a lack of knowledge on PTW implementation. Examples of the function of PTW are to identify the type of confined space, numbers of an occupant, types of work, tools and equipment to be used, types of Personal Protective Equipment, hazards might arise and rescue method. In Malaysia, the National Institute of Occupational Safety and Health (NIOSH) is one of the approved training providers by the Ministry of Human

Resource Malaysia has offered Confined space training to all relevant workers. It could directly promote a safe working environment for all situations (Wilkinson et al., 2012).

Regarding the risk assessment approach, most employers or contractors carrying out confined space works either do not have a suitable risk assessment method or do not conduct it at all. This kind of practice would cause unexpected circumstances during the entry period, such as oxygen deficiencies, inhalation of toxic gasses, contact with machinery, and might lead to the explosion (D. Burlett Vienney et al., 2015). The hazards from failing to conducting risk assessment could also contribute to failure in planning for rescuing in case of emergencies such as chemical spillage, the release of toxic gasses, unconsciousness of workers, and insufficient rescue devices (Allen C. Duke, 2012).

Another incident contributor during confined space entry is the competency of personnel. According to ICOP 2010, any workers to enter a confined space must undergo Authorized Entrant and Standby Person (AESP) training by NIOSH. Apart from that, atmosphere test and supervision procedures, namely, Authorized Gas Tester (AGT) and Entry Supervisor (ES), also required trained competent personnel. Contractors' common non-compliance and these issues immediate control measures where the Client or Contract Owner's role is vital. Once those issues resolve, hazards during confined space entry could be to an acceptable risk level.

Moreover, the correct selection, integrity, and usage of tools and equipment while performing jobs must also be considered (A.C. Caputo et al., 2013). Not every incident involving tools and equipment, but its contribution to the incident required attention to avoid any recurrence and lead to catastrophic incidents (Yuvin Chinniah, 2015). The absence of a Confined Space Entry procedure is Malaysia's most common findings of confined space accidents. The critical issues on this non-compliance reflected all requirements that need to be adhered to before entering a confined space, such as PTW, competency, and risk assessment. Once the confined space procedure is developed, the contractors would be aware of the basic requirements for confined space works, and the knowledge towards the nature of works, hazards, selection of Personal Protective Equipment, and rescue are intact (Wilkinson, 2012).

Regarding the cost of an incident, the losses faced by organizations who are reluctant to invest in safety prevention costs will found the losses are more than they expected (M.Bayram et al., 2016), relevant to the Iceberg Theory. The theory stated that the accident's indirect cost is much higher than the accident's direct cost, as shown in Figure 1.9.

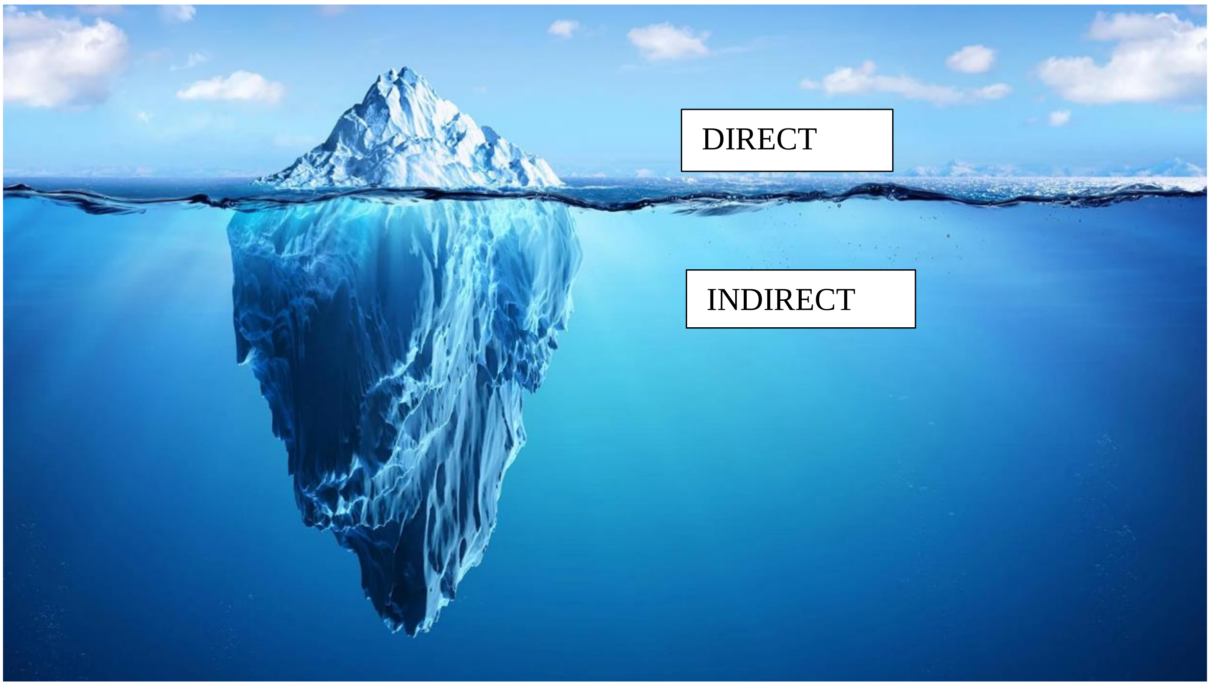


Figure 1.9 Iceberg theory

According to Figure 1.9, the direct cost of an accident located at the tip of an iceberg is insurance, medical claims, workers' compensation, and repair costs. In contrast, the Indirect Cost of the accident in the submerged iceberg area is productivity loss, skill workers due to re-train cost, investigation cost, reputation, and loss of trust and litigation loss. Prove that the Indirect Cost is much higher than Direct Cost, which most organizations do not realize and fail.

## 1.3 Problem Statement

In Malaysia, safe working conditions in confined space established in 1998 started with Guidelines for Safe Working in Confined Space. It was followed by developing the Code of Practice (COP) for Safe Working in Confined Space in 2001. DOSH realized the COP needs to review two years later due to rapid industrial development and technological advancement. After a completed review in 2008, the new Industrial Code of Practice for Safe Working in Confined Space was gazetted in 2010, presently being used by industry. Also, the amendment of OSHA 1994, including section 38, where it stated using the approved Code of Practice in the proceeding, would lead ICOP 2010 as a legal compliance document. However, since a new ICOP 2010 started enforcing, the confined space accident seems to increase, and it does not show any potential to decrease. Figure 1.10 shows the Department of Occupational Safety and Health statistics on confined space fatality accidents from 2010 until 2020.

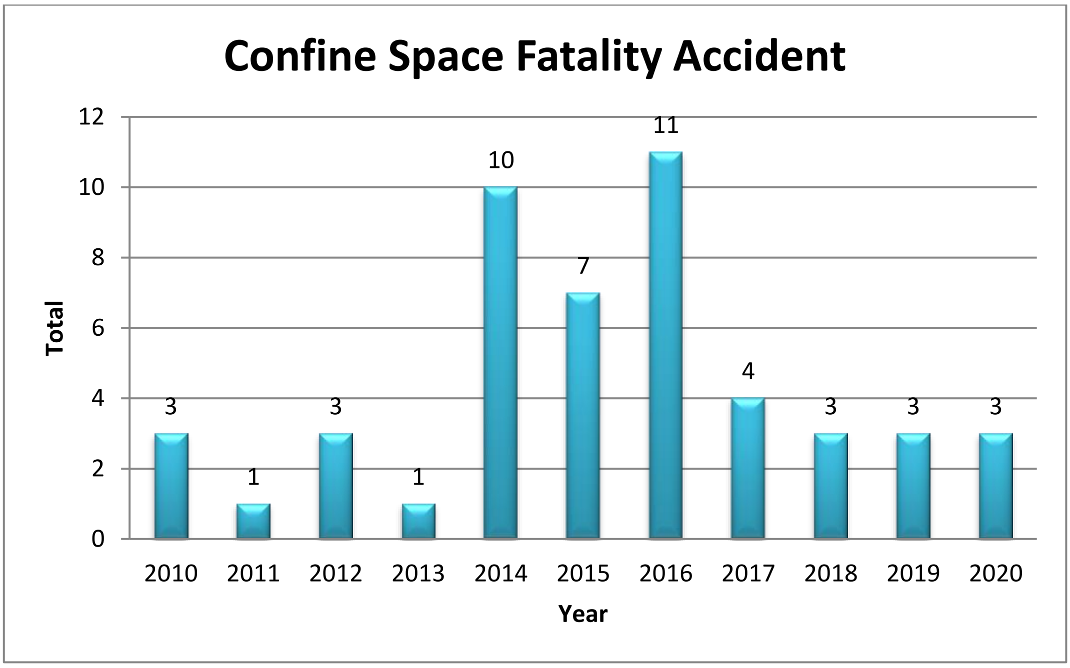


Figure 1.10 Confined fatality accident statistics

From the above statistics, confined space-related accidents, especially involving a fatality, show its incident trend from 2010 until 2020. The most severe fatality accident was recorded in 2016, where 11 deaths were reported. Even started in 2017, it showed a reduction in fatality cases, the incident still keeps occurring, and it could be spike again if there is a lack of continuous enforcement and no drastic changes to the existing risk management approach. Additionally, the decreasing trend also led to an initiative from DOSH by launching their OSH Master Plan 2020 from 2016 until

2020. Using the theme 'OSH Transformation – Preventive Culture,' the OSH MP 2020 direction was embarked on five key strategies: Government Leadership, Strengthening OSH Management in the Workplace, OSH Sharing, and Network, Mainstreaming of Industrial Hygiene, and International OSH Strategic Alliance. Two key strategies that contribute much to reducing confined space accidents are Government Leadership and Mainstreaming Industrial Hygiene. Based on non-compliance towards confined space requirements published by DOSH, six contribution factors led to an accident: leadership, PTW, risk assessment method, competency, tools & equipment, and safe work procedure. From the contribution factor list, there is no specific approach or method in conducting confined space risk analysis wherein ICOP 2010 provides generic guidelines on safe working in confined space rather than holistic approach such as the configuration of confined space, described the component of risk, risk estimation, a summary of estimation and risk reduction (D. Burlett- Vienney et al., 2015). On the other hand, additional references are still required to determine the likelihood, severity, and risk matrix in conducting the risk assessment as in HIRARC 2008.

Furthermore, several incidences are not being reported or published to preserve the company image, which is observed as not a healthy practice in industry or specifically in Malaysia, one of the developed countries worldwide. As an example, the confined space fatality occurred in February 2016. The incident started when a group of workers carries out maintenance works in Cement Silo when suddenly the shale caking inside the feed bin dislodged and buried him alive. Figure 1.11 shows the incident pictures during rescuing procedures carried out by BOMBA Malaysia.


Figure 1.11 Rescuing incident by BOMBA Malaysia

The above incident shows that total commitment from the employer or client is required, and it is crucial to share the root causes of the incident to the public to create awareness and lessons learned that could be part of the motivating factor towards preventing a future incident. In this accident, the top three root causes of the incident were failing to review Safe Work Procedure, the emergency response team's inactive, and the rescue equipment not being available.

A study conducted by a previous researcher specifically aimed at confined space works is gathered to relate to the issues faced during confined space entry. Ana Stojkovic (2013) about the requirements to identify all hazards prior to entering confined space by familiarizing the threats according to job types and confined space category. Hazards like Biological, physical, chemical, and health are the most common category contributing to the risky work environment. A recommendation by D. Burlett-Vienney et al. (2014) is related to improvising the Permit to Work (PTW) system for confined space, contributing much to incidents nowadays. In their study, the existing PTW required a proper review and proposed a comprehensive type of PTW. The PTW is the most important document stating all the hazards and risks, including control measures required.

Furthermore, a correct method in conducting a risk assessment is essential. A five-step risk assessment proposed by D. Burlett-Vienney et al. (2015) was helpful in be referred since the recommendations were based on the real confined space incident scenario. It also observed less, and no specific approach in ensuring the confined space works are carried out safely throughout the operation period. D. Burlett-Vienney et al. (2015) conducted a study on the importance of intervention strategy for confined space. They proposed that all personnel need to know about confined space safety. Involvement from other parties who have the required skills and competencies would improve the quality and safety during confined space entry. Safety Leadership issues faced by industry were studied by E.A. Kapp (2012). They have conducted a qualitative measurement on a group of workers with a different safety climate, resulting in employee safety performance. The study proved that leadership plays an important role in ensuring compliance with established safety rules and regulations. A proper method and requirement of atmospheric testing were studied by Pereira (2012) since most of the incident that occurred was observed related to failure to perform atmospheric testing by a competent gas tester. It is much related to the correct ventilation method in confined space recommended by Flyn (2012). The different types of confined space, such as size and shape, required detailed assessment in applying a ventilation system to expel toxic gases and induce fresh air into a confined space. Another challenge faced in confined space is during an emergency where it required a systematic approach in rescuing. A recommendation by J. Selman et al. (2019) where the concept proposed comprises Reconnaissance, Eliminate hazards, Access to the casualty, Life-saving first aid, and Extrication is considered an important element in rescuing prevent other lives in a dangerous condition.

Several confined space incidents had occurred and were investigated by an authority such as DOSH, where its Contributing Factor (CF) is observed similar. Figure 1.12 shows examples of confined space accident occurred in Malaysia.

| | |
|---|---|
|  | Scenario 1: Died during maintenance inside the barge<br>What happens: Carbon Monoxide poisoning<br>CF: No PTW, No Safe Work Procedure, lack Competency, incorrect job method<br>Repetitiveness: Yes<br>*Several incidents occurred inside ship deck |
|  | Scenario 2: Died during tank cleaning<br>What happens: Ammonia poisoning<br>CF: Unreview Safe Work Procedure, incorrect job method<br>Repetitiveness: No<br>*No similar incident |
|  | Scenario 3: Died due to suffocation during pipe laying<br>What happens: Soil collapse<br>CF: No PTW, No Safe Work Procedure, lack Competency, incorrect job method<br>Repetitiveness: Yes<br>*A similar incident occurred several times every year |

Figure 1.12 Examples of confined space accidents in Malaysia

The above incident clearly described no 'Learning from Incident' (LFI) observed in Malaysia towards combating confined space fatality cases. LFI means there is no follow-up on the action plan's effectiveness or preventive action from the root causes of accident investigation. Furthermore, almost all incidents that occurred are repeated several times and having the exact root cause. Due to the high fatality incident rate in confined space works, the risks of working in confined space are intolerable. Through referring to the existing approach in ICOP 2010 and HIRARC Guidelines 2008, the significant gaps observed are Leadership, Supervision, specific Job Planning, Permit to Work comprehensiveness, the absence of a method in identifying the physical condition of confined space, no specific process of risk estimation, no specific strategy for risk reduction and risk control. Figure 1.13 illustrates the overall view of the problem statement.

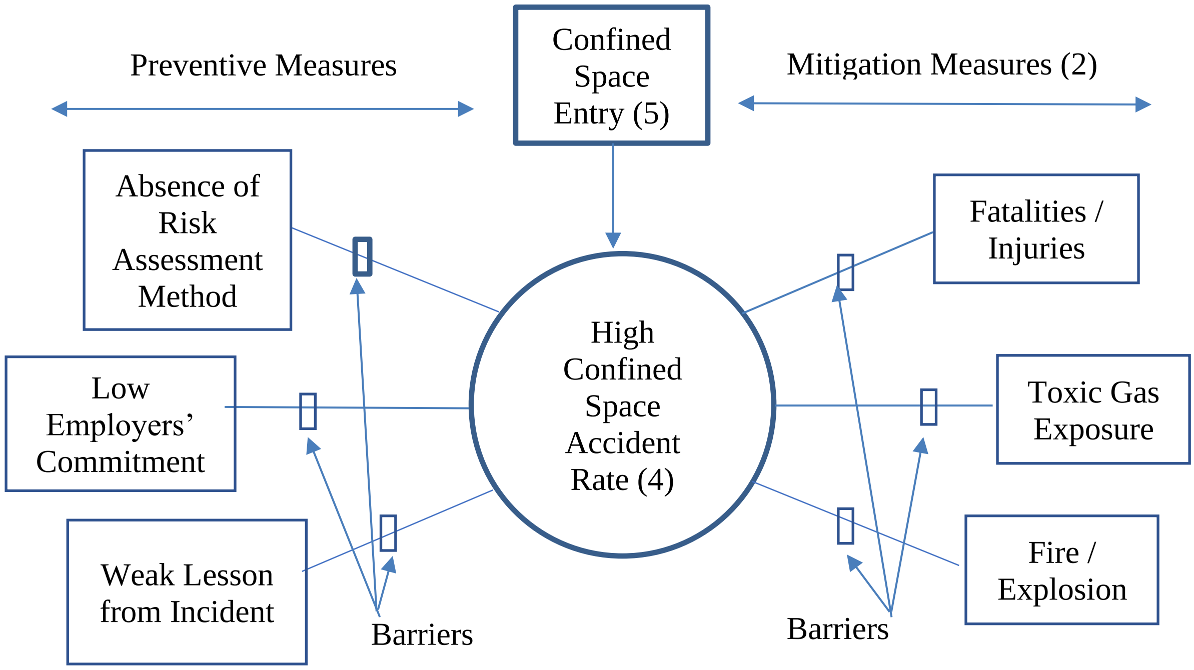


Figure 1.13 Overall view of the problem statement

The Bowtie concept is used to explain in a clearer picture of the confined space accident contribution factors. Bowtie diagram divide into two sides; threat or preventive measures (1) and consequence or mitigation measures (2). Also, there is a barrier (3) on each side. The center (4) is the top event, and the high-risk operation (5) creates an unsafe workplace condition once the hazard is released. For the Preventive Measures side, the barriers need to be well function and practical to prevent an accident from happening. The same goes for the Mitigation Measures side; the barriers need to function well and use to reduce to impact from the incident,

## 1.4 Research Objectives

The research aims to propose the Bowtie Risk Assessment graphical framework of confined space at the Hulu Langat district's sewerage treatment plant construction project. Therefore, the objectives of this research are:

i. **To identify** the issues of working in a hazardous environment and risk assessment of confined space at sewerage treatment plant construction project in Hulu Langat district.
ii. **To investigate** the compliance between confined space risk assessment reports with Legislation, Industrial Code of Practice, Guidelines, and Standard Operating Procedure implement by sewerage treatment plant construction project in Hulu Langat district.
iii. **To analyze** the risk analysis based on different risk methods with Bowtie Risk Assessment for working in confined space at sewerage treatment plant construction project in Hulu Langat district.
iv. **To evaluate** a Bowtie Risk Assessment through Focus Group Discussion in conducting a confined space risk analysis for sewerage treatment plant construction project in Hulu Langat District.
v. **To develop** the Bowtie Risk Assessment graphical framework for working in confined space at the sewerage treatment plant construction project in Hulu Langat District.
vi. **To validate** the Bowtie Risk Assessment graphical framework with Bowtie Risk Assessment Consultant.

## 1.5 Research Questions

The research questions from this research are:

i. What are the issues faced while working in a hazardous confined space environment?
ii. What is the level of compliance of the applied confined space risk assessment reports towards Legislation, standards, Industrial Code of Practice, and Guidelines?
iii. How to identify the most suitable risk assessment for working in a confined space?
iv. What is the method in obtaining the best approach in conducting a confined space risk assessment?

v. How to effectively analyze the substantial approach of confined space risk assessment?

vi. How to verify the effectiveness of the proposed Bowtie confined space risk assessment method?

## 1.6 Research Scope

The scope of the study is as follows:

i. Three Legislations from Quebec and Malaysia, Five Standards from Switzerland, Australia, New Zealand, and Seven Guidelines from the United Kingdom, United States of America, and Malaysia.

ii. Ten types of Risk Assessment tools technique.

iii. Sewerage treatment plant construction project in Hulu Langat District

iv. Confined space Risk assessment Report and confined space activities at STP project site.

v. Focus Group Discussion members from occupational safety and health experts and lead by the accredited consultant.

vi. Bowtie Risk Assessment method.

vii. Bowtie Risk assessment software – Bowtie XP version 9.2.11.

## 1.7 Significance of the Study

By conducting this study, it would contribute to the substantial compliance towards working safely in confined space as follow:

i. The risk assessment technique aided as a practical application for industry players to any confined space entry.

ii. The risk assessment technique could assist in conducting /risk identification and risk estimation process effectively.

iii. The risk assessment technique could enhance the existing safe system of work.

iv. The risk assessment technique would aid the organization in leveraging its existing leadership practices.

viii. The risk assessment technique serves as an incident prevention tool to reduce the accident's direct and indirect costs.

The comprehensive approach of risk assessment technique to be proposed could be a value-added approach to industry players, specifically in confined space entry, since they do not have a specific method in mitigating risks during occupancy. Moreover, it would be part of the crucial elements of risk identification and risk estimation.

Furthermore, it could enhance the existing safe work system practices during confined space entries whereby implementing the effective risk assessment technique could directly check the lack of any ineffective practices such as reviewing procedures. Besides, it could also increase the visible leadership awareness in the organization through a tri-party involvement approach. Therefore, this study's significant contribution is crucial in comprehensive risk identification, including analyzing all risk factors during confined space entry. With that, a risk mitigation strategy can be applied during entry by using specific assessment criteria. This is useful in determining the risk reduction measures, additional requirements from enforcement authority, the feasibility of internal and external rescuing methods, and impact from the human asset, environment, and reputation, reflected from the magnitude of risk exposure.

## 1.8 Summary

This chapter has described a comprehensive explanation of confined space and its requirements, including a detailed research direction. Definition of confined space is clearly described, and it is followed by types of confined space, industries involved in confined space works, activities carried out in confined space, as well as hazards in confined space. Examples of risk assessment techniques commonly implemented in the industry are shared, including the relationship of risk management principles, framework, and processes. A review of international and Malaysia risk assessment documents is conducted to obtain a holistic understanding of risk assessment requirements and its element, which could be useful for confined space risk assessment. A recent statistic on confined space fatality accidents from the Department of Occupational Safety and Health, Malaysia (DOSH) showed a trend of accidents that required further improvements in occupational safety and health compliance at the workplace by referring to contributing factors of confined space accidents revealed. A proposed method by a previous researcher on risk assessment and confined space safety is showing the importance of enhancing the standard of working specifically on the risk assessment approach. A site visit to the Sewerage Treatment Plant project is conducted to collect data and information related to confined space activities which might be used to identify the challenges, compliance to risk assessment requirements, and a qualitative measurement towards selected Risk Assessment technique from research documents. Additional analysis of the selected Risk Assessment technique is carried out by referring to the Barrier Analysis approach. The type of Risk Assessment to be developed is finalized through the evaluation from the appointed Risk Assessment specialist, where all the measurements conducted are taken into account. A Focus Group Discussion is formed to develop a comprehensive Risk Assessment technique for sewerage treatment plant construction projects and other scopes relevant to confined space works.

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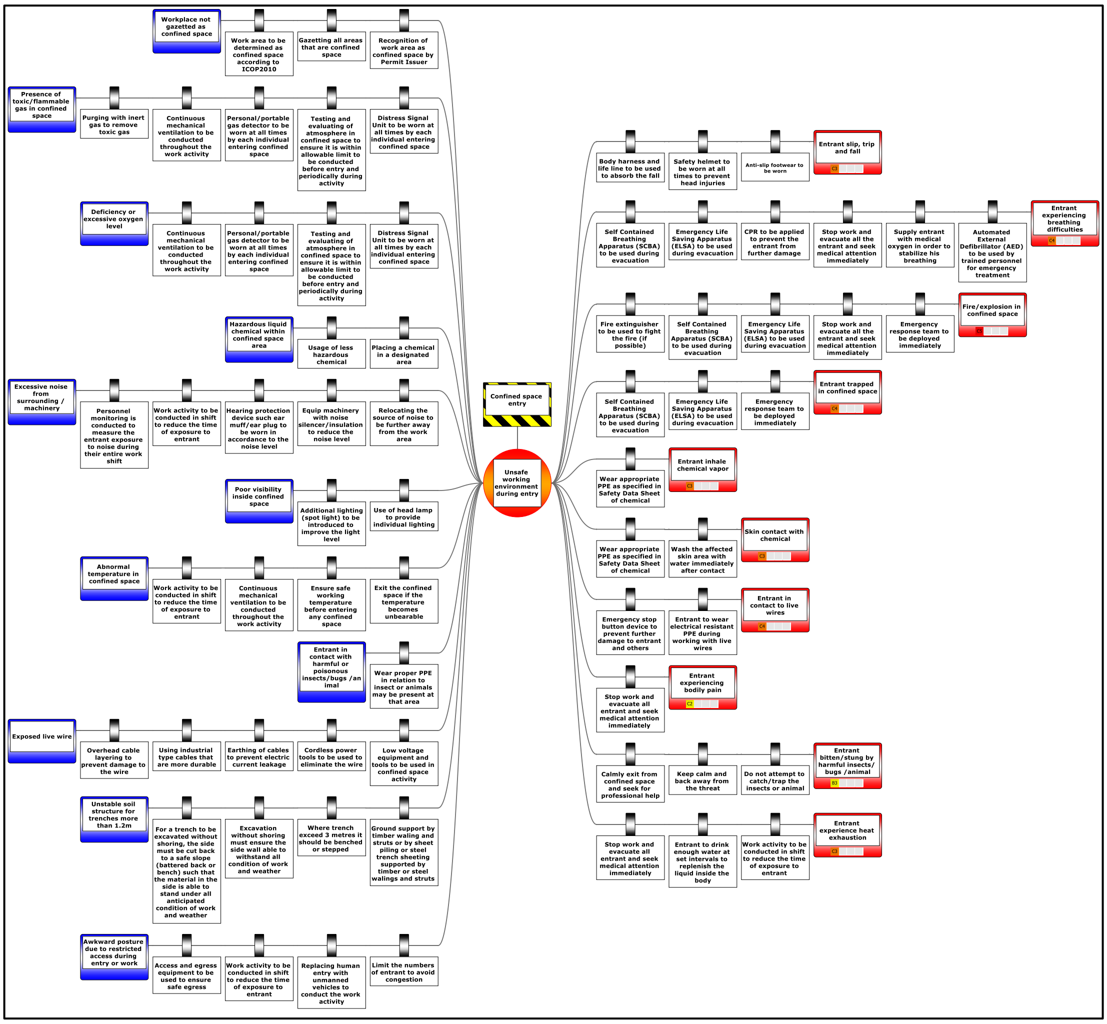
# Appendix A Confined Space Bowtie Risk Assessment Diagram



# LIST OF PUBLICATIONS


1. **Z. Amin**, R. Mohammad & S.A. Aziz, Hand Related Injury Accident Trend in Metal Fabrication Industry, Proceeding International Conference on Engineering Business Management, Universiti Teknologi Malaysia & Meiji University, September 2015.
2. **Z. Amin**, R. Mohammad & S.A. Aziz, Workers' Safety Awareness Level on Hand Related Injury Accident in Metal Fabrication Industry, Journal of Advanced Research in Applied Sciences and Engineering Technology ISSN (online): 2462-1943, Vol. 1, No. 1, Pages 1-12, 2015.
3. **Z. Amin,** R. Mohammad, N. Othman, A. Amrin, S. Chelliapan, S.A. Aziz & N. Maarop, A Review on Guidelines Related to the Risk Assessment of a Confined Space, International Journal of Mechanical Engineering and Technology (IJMET) Volume 8, Issue 11, November 2017, pp. 423-448.
4. **Z. Amin**, R. Mohammad, N. Othman, A. Amrin, S.A. Aziz & N. Maarop, Recent Review on Legislations Related to Risk Assessment for Confined Space, International Journal of Mechanical Engineering and Technology (IJMET) Volume 9, Issue 1, January 2018, pp. 934-949.
5. **Z. Amin**, R. Mohammad, N. Othman, A. Amrin, S.A. Aziz & N. Maarop, Recent Review on Standards Related to Risk Assessment for Confined Spaces, International Journal of Mechanical Engineering and Technology (IJMET) Volume 9, Issue 1, January 2018, pp. 950-969.
6. **Z. Amin,** R. Mohammad, Compatibility Analysis on the Risk Assessment Tools Proposed to Industry Code of Practice for Safe Working in Confined Space Malaysia, 2010 (ICOP 2010), Proceeding of 8$^{th}$ International Conference of Engineering Business Management, 3-4 August 2019, pp. 58-61.
7. **Z. Amin**, R. Mohammad, N. Othman, Review and Comparison of Confined Space Risk Assessment Tools Practiced by Industry Code of Practice for Safe Working in Confined Space of Malaysia, 2010 (ICOP 2010), Journal of Advanced Research in Business and Management Studies Volume 18, Issue 1, 2020, pp. 16-23.