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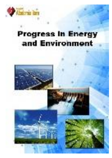

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Original Article

Bowtie analysis for risk assessment of confined space at sewerage construction project

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Abstract

This paper aims to investigate the issues related to safety in confined space at the sewerage treatment plant construction project in the Hulu Langat district and to provide a solution by proposing a substantial approach to mitigating risk during confined space entry due to an ineffective risk assessment and poor compliance by project management. The methods used were site visit observation and survey, followed by an analysis 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 as 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 analyzed 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 proposed Bowtie Risk Assessment graphical framework provides a sewerage treatment plant construction project with a holistic technique for preventing confined space accidents. It also provides a safe work system, manages hazards and risks effectively, promotes good leadership practices, improves company reputation, and significantly reduces accident costs. The framework is also helpful as a reference model for other industry players.

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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 of 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 the 19th century. Kletz et al. [1] 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 common practice for all related sectors involved in this area. Examples of confined space are storage tanks, boilers, silos, pits, sewers, tunnels, shipboard space entered through a small maintenance hole, cargo tanks, cellular double bottom deck, duct keels, ballasts, and oil tanks. Activities conducted in confined space include cleaning, inspection, maintenance, abrasive blasting and surface coating, repair, welding, modification, and adjustments to mechanical equipment, rescue, and construction. The category of hazard in confined space is depicted in Table 1.

Table 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 to acceptable condition before entry. This process is called a risk assessment. Risk assessment evaluates the risks to safety and health arising from hazards at work [2,3]. The risk assessment process consists of risk identification, risk analysis, and risk evaluation [4]. Failing to plan an adequate risk assessment approach would result in catastrophic confined space incidents. In Malaysian industries, some incidents have identified an exhausting list of contributing factors to confined space accidents, as shown in Fig. 1.

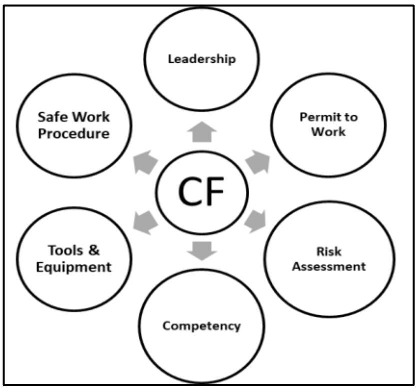

Fig. 1 Contributing factors towards confined space accident.

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 assigned by higher management, such as project managers, engineers, and supervisors. Leading by example shows that or visible leadership approach needs to be applied by all organizations to ensure compliance with the established company Safety and Health Policy statement. Permit to Work (PTW) also contributes to non-compliance issues with a lack of knowledge on PTW implementation, and such failure to identify the type of confined space, number of an occupant, types of work, tools and equipment to be used, types of Personal Protective Equipment, potential hazards and rescue method. Regarding risk assessment, most employers or contractors carrying out confined space works either do not have a suitable risk assessment method or blindly proceed with an entry. This kind of practice would cause unexpected circumstances during entry, such as oxygen deficiencies, inhalation of toxic gasses, and contact with machinery, and might lead to an explosion [5]. Another incident contributor during confined space entry is the competency of personnel, and the correct selection, integrity, and usage of tools and equipment while performing jobs must also be considered [6].

In Malaysia, safe working conditions in confined space were established in 1998 and started with Guidelines for Safe Working in Confined Space. The development followed the Code of Practice (COP) for Safe Working in Confined Space in 2001. Due to rapid industrial development and technological advancement, DOSH realized the COP needed to review two years later. 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 the industry. Also, the amendment of OSHA 1994, including section 38, which stated using the approved Code of Practice in the proceeding, would lead to ICOP 2010 as a legal compliance document. However, since a new ICOP 2010 started enforcing, confined space accident seems to increase and does not show any potential to decrease. Fig. 2 shows the Department of Occupational Safety and Health statistics on confined space fatality accidents from 2010 until 2020.

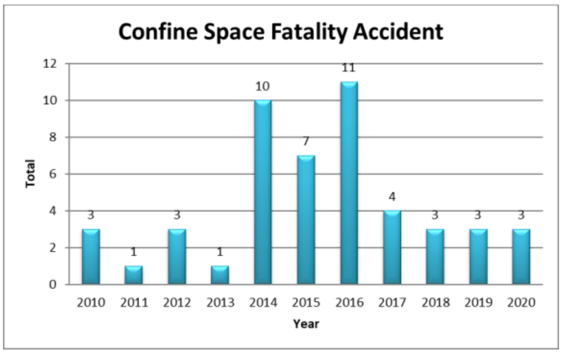

Fig. 2 Confined space accident statistics [14].

From the statistics, confined space-related accidents, especially those involving a fatality, show its incident trend from 2010 until 2020. The most severe fatality accident was recorded in 2016 when 11 deaths were reported. Even started in 2017, it showed a reduction in fatality cases, the incident still keeps occurring, and it could 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 to launch their OSH Master Plan 2020 from 2016 until 2020. Using the theme 'OSH Transformation – Preventive Culture,' the OSH MP 2020 direction 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. Government Leadership and Mainstreaming Industrial Hygiene are two key strategies contributing much to reducing confined space accidents.

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. The first is about the requirements to identify allhazards prior to entering a confined space by familiarizing the threats according to job types and confined space category [7]. Hazards like Biological, physical, chemical, and health are the most common category contributing to the risky work environment. Another recommendation was to improvise the Permit to Work (PTW) system for confined space, which contributes much to incidents nowadays [8]. The study revealed that the existing PTW required a proper review and proposed a comprehensive type of PTW.

Furthermore, a correct method for conducting a risk assessment is essential. A five-step risk assessment was helpful to be referred since the recommendations were based on the real confined space incident scenario [5]. It also observed less and no specific approach in ensuring the confined space works are carried out safely throughout the operation period. A study was conducted on the importance of intervention strategy for confined space. They proposed that all personnel need to know about confined space safety [5]. Involvement from other parties with the required skills and competencies would improve the quality and safety during confined space entry. Safety Leadership issues faced by the industry were one of the contributing factors. 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 is essential in ensuring compliance with established safety rules and regulations [9]. A proper method and requirement of atmospheric testing were studied since most of the incident was observed related to failure to perform atmospheric testing by a competent gas tester [10]. It is also related to the correct ventilation method in confined spaces where the different types of confined space, such as size and shape, require detailed assessment in applying a ventilation system to expel toxic gases and induce fresh air into a confined space [11]. Another challenge faced in confined space is during an emergency requiring a systematic rescue approach [12]. A recommendation was made where the proposed concept comprises Reconnaissance, Eliminate hazards, Access to the casualty, Life-saving first aid, and Extrication, which is considered an essential element in rescuing prevent other lives in dangerous conditions [13].

2 Methodology

Many methods have been conducted, including processes and steps to be accomplished, such as Risk Assessment Tools Compliance, Risk Assessment Tools Method, Confined Space Safety Management, Risk Assessment Tools Analysis, and Focus Group Discussion.

2.1 Confined space risk assessment tools compliance

According to the Fish Bone approach, the assessment of confined space analysis compliance will be was introduced by Kaoru Ishikawa in 1968. The site visit was carried out at a sewerage treatment plant construction project to assess the level of implementation and compliance towards Confined Space Risk Assessment Tools and its requirements, especially the Industrial Code of Practice [14], Guidelines for Hazard Identification, Risk Assessment, and Risk Control, 2008 [9], Occupational Safety and Health Act, 1994 [15] and Factories and Machinery Act, 1967 [16]. A selected sewerage treatment plant construction project is assessed on the entire occupational health and safety management system, where it will be reviewed and assessed according to the scope of works related to confined space activitiessuch as trenching, underground tunnels, tankage, and pits. The rationale for selecting the method is structured into five main categories that most contribute to workplace accidents: people, machine or equipment, job method, material, and work environment. to analyze confined space compliance. Another category will be included, which is management or leadership.

2.2 Risk assessment tools method

Various risk assessment tools are being implemented in the industry where applications' objective differs, whether it is precisely for confined space entry or other job analysis. The Risk Assessment Tools being selected are derived from the reviewed literature and references from Guidelines. The summary of the Risk Assessment Tools is depicted in Table 2.

2.3 Confined space safety management

The results obtained from the site visit at the Sewerage Treatment Plant project will assess the issues and challenges of confined space works. The common confined space issues are listed, and the real challenges will be described. The inputs then will be useful for analyzing and developing a comprehensive Confined Space Risk Assessment approach. The issues while working in a confined space are Depth, Physical Condition, Work Environment, Presence of Toxic Gases, Noise, Duration, and Numbers of Entrant. The project's confined space reports are Confined Space Safe Operating Procedure, Hazard Identification, Risk Assessment & Determining Control (HIRADC), Safe Operating Procedure, Confined Space Permit to Work, and HIRADC from confined space. All the confined space Reports will be assessed on their compliance against local and international requirements such as Standards, Legislation, and Guidelines.

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2.4 Risk assessment tools analysis

Ten types of Risk Assessment tools will be further analyzed qualitatively. The analysis is conducted using two approaches: the first is against Industrial Practices & Application (IP), and the second is the Barrier Analysis approach (BA). An IP analysis method is measured through five parameters: the purpose of the application, specific functions, the scope of application, availability in Standards, Legislation or guidelines, and relevance to the STP project. Table 3 shows the analysis format to be used.

Table 2 Summary of risk assessment tools.

Item	Author	Journal/document title	Type of risk analysis tool
1	D. Burlet-Vienney et al. [17]	Risk Analysis for Confined Space Entries: Critical Analysis of four tools applied to three risks scenario	a.Checklist b.Risk Scale c.Risk Calculation d.Questionnaire & Risk Matrix (*similar to RA tool in Item 3*)
2	A. Moatari- Kazerouni et al. [18]	A propose occupational health and safety risk estimation tool for manufacturing system	Risk Estimation
3	D. Burlet-Vienney et al. [5]	Design and Application of a 5 step Risk Assessment Tool for Confined Space Entries	Ishikawa 5 Step Risk Assessment
4	K. Reinhold et al. [19]	Practical Tool and Procedure for Workplace Risk Assessment: Evidence from SMEs in Estonia	Flexible Risk Assessment
5	O.N. Aneziris et al. [20] I, Voicu [21] Jonas Aust & Dirk Pons [22] Dong et al. [23]	• Occupational Risk Quantification owing to Falling Object, tunneling, Building construction • Risk Management with Bowtie diagram • Bowtie Risk Analysis in the Aerospace industry • Bowtie Risk Analysis for accident investigation	Bowtie Risk Analysis

Table 3 Risk analysis method 1.

Item	Journal/document title & author	Type of risk assessment	Industrial practices application
1	Risk Analysis for Confined Space entries: Critical Analysis of four tools applied to three risks scenario - D. Burlet-Vienney et al. [17]	Checklist	i. Purpose of application ii. Specific functions iii. Scope of application iv. Availability in Standards, Legislation & Guidelines v. Relevance to STP project

The BA analysis method uses a Bowtie Risk management concept elements [12]. The Ten key elements are Solid Technique, Comprehensive - graphical approach, Promote an Understanding, Reciprocal Relationship, Clear Communication, Underlying More Complex Scenarios, Demonstrate the Level of Control, Audit Friendly, Increase workers' awareness, and Operational safety oriented. Refer to Table 3; the results from the analysis will be used as additional input for BA analysis and during the development of comprehensive confined space risk assessment tools. It will then be measured against three advantages of Bow-tie Risk management: Exclusive, Practical, and Easy-to-Understand (ETU). Table 4 shows the analysis format to be used.

Table 4 Risk analysis method 2.

Risk assessment tools				
No	**Key elements**	**Exclusive**	**Practical**	**Etu**
1	Solid technique	YES/NO	YES/NO	YES/NO
2	Comprehensive-graphical approach	YES/NO	YES/NO	YES/NO
3	Promote an understanding	YES/NO	YES/NO	YES/NO
4	Reciprocal relationship	YES/NO	YES/NO	YES/NO
5	Clear communication	YES/NO	YES/NO	YES/NO
6	Underlying a more complex scenario	YES/NO	YES/NO	YES/NO
7	Demonstrate the level of controls	YES/NO	YES/NO	YES/NO
8	Audit friendly	YES/NO	YES/NO	YES/NO
9	Increase workers' awareness	YES/NO	YES/NO	YES/NO
10	Operational safety-oriented	YES/NO	YES/NO	YES/NO

2.4 Focus group discussion

The establishment of a Focus Group Discussion (FGD) evaluates, develops, and validates the research process outputs and data and finalizes Risk Assessment tools' results for confined space. The selection criteria of the FGD members are carried through advice by an appointed Bowtie specialist. Table 5 shows the guidance in selecting the FGD members.

The 'YES' answer would provide a significant indication of BA compliance. Once completed, the analysis will be evaluated by an appointed Bowtie specialist accredited by CGE Risk Management, Netherlands, and the inputs will be gathered and finalized on the suitable approach in selecting a confined space risk assessment tool.

Table 5 FGD selection guidance.

Selection criteria			
Department/division	**Designation**	**Involvement in confined space**	**Target numbers of personnel**
Construction	Site Manager, OSH officer, Engineer, Supervisor	Confined space Competent personnel, OSH personnel, personnel hold any task in processing confined space Permit to Work	Four groups consisting of five to six personnel (each division nominates five or six personnel)
Maintenance			
Inspection/QC			
Operation			

The brainstorming session, namely as 'World Café Session,' will be used to obtain inputs from every FGD member, and it needs to be presented to the Bowtie specialist to finalize the Risk Assessment tools analysis for confined space.

3 Results

3.1 Confined space work challenges

The site visit and observation conducted at Sewerage Treatment Plant (STP) project have resulted in several categories of confined space work challenges, which directly reflected the types of Risk assessment tools applied and it's compliance. Factors need to be considered before confined space entry, such as the purpose of entry, duration, access and egress, numbers of the entrant, physical configuration, and the most vital parts are the potential hazards that might arise during occupancy. Table 6 depicts the list of challenges while working in a confined space at the STP project.

3.2 Confined Space Safety Management

Four types of confined space reports derived from the project OSH division have been investigated to verify its adherence to Standards, Legislation, Industrial Code of Practice, and Guidelines. The project safety and health management system investigation results will be used for additional inputs to develop a confined space risk assessment. Table 7 depicts the compliance of project confined space reports to Malaysia Legislation, Guidelines, and Industrial Code of Practice.

Table 6 STP confined space works challenges.

No	Type of challenges	Description
1	Depth	Most of the workplace under-construction stage has more than 2 meters, whether above ground or underground. The deeper the workplace, the level of risk would increase and lead to difficulties accessing and egressing the entrant. In most cases, rescuing is the most challenging issue during emergencies. Fig. 4.1 below shows an example of the deep workplace during the Pumping Station of the sewerage treatment plant.
2	Physical Condition	**Access & egress** - Workers are required to climb down or climb up to the desired work area. Limitation of access or egress due to the work area's actual condition would expose them to risky situations such as falls from height. **Physical Attachment** - Various works must be carried out during the construction stage. Installation of brackets, piping, and pumps is an example of physical attachment in a confined space. Workers involved in these activities need to be alert to the presence of such objects to prevent injuries. **Uneven Surface** - The under-construction confined space's uneven surface is likely at the base and wall. This is due to the process of fabricating the pit, which required shoring to strengthen the structure. **Obstruction** - The scaffold is widely used during the project site observation to perform works requiring a specific area extension. It includes works under confined space such as tankage and pit. Due to limited space, the erection of the scaffold is demanding and challenging. Due to the criticality of jobs, a competent erector and inspector must ensure the integrity of the scaffold structure and prevent a catastrophic event.
3	Work Environment	**Dark -** Commonly, confined space works would limit light levels to the work area, such as tankage, silo, and underground construction. Sufficient lighting is to be provided to prevent an incident from occurring. **Watery** - The construction site is exposed to extreme weather and threat. Places that easily contain and accumulate foreign materials, such as construction debris, construction waste, and water, were randomly observed
4	Presence of Toxic Gasses	**Local -** Hot work activities such as welding where the welder is directly exposed to welding fume or the person who uses chemical base materials are directly exposed to a chemical vapor through inhalation, ingestion, or skin contact while performing jobs **Systemic -** The entrant doing jobs in confined space is exposed to fumes or vapor from nearby or adjacent areas due to several factors such as wind direction, low air change rate or movement, poor isolation, and failure to adhere to established Safe Operating Procedure.
5	Noise	The generation of noise is commonly generated from grinding, using an air gun, and using hand or power tools such as hacking, drilling, and hammering. Rather than affecting workers' hearing, it also leads to ergonomic risk and poor communication during entry.

6	Duration	Duration of entry plays an important factor in reducing exposure and risk, specifically for high-risk activities such as hot works and tasks that need to use the high release of potential energy, such as high-pressure water jetting, rotating tools, and electrical works.
7	Numbers of Entrant	Too many entrants may lead to additional risk while carrying out work. The numbers of the entrant to be assessed, and consideration needs to be taken in terms of space size and jobs to be carried out. Since working in a confined space is limited access and egress, it might affect the rescue during emergencies and physical-related hazards such as sharp edges

Table 7 Confined space reports compliance – Malaysia.

No	Document title	Malaysia legislation	Code of practice / guidelines
1	a. Confined Space Safe Operating Procedure (SOP) b. HIRADC Safe Operating Procedure (SOP) c. Confined Space Permit to Work d. HIRADC for Confined Space works	Occupational Safety and Health Act, 1994: Section 4 (c): To promote an occupational environment for persons at work adapted to their physiological and psychological needs. Section 15 (1): It shall be the duty of every employer and every self-employed person to ensure, so far as is practicable, the safety, health, and welfare at work of his employees. Section 15 (2)(a): The provision and maintenance of plant and systems of work that are, so far as is practicable, safe and without risks to health Section 15 (2)(c): The provision of such information, instruction, training, and supervision as is necessary to ensure, so far as is practicable,	DOSH Industrial Code of Practice for Safe Working in Confined Space. 2010 (ICOP 2010)
2	a. Confined Space SOP b. Confined Space Permit to Work c. HIRADC Confined Space	The safety and health at work of his employees. Factories and Machinery (Safety, Health & Welfare), 1970; Regulation 13: Confined Space Regulation 25: Ventilation	

The STP project confined space reports compliance with international requirements such as Standards, Legislation, and Guidelines, which have been investigated and depicted in Table 8.

Table 8 Confined space reports compliance – International.

No	Document title	International standards & legislation	Code of practice / guidelines
1	Confined space Safe Operating Procedure (SOP)	Quebec Regulation 2015 (respecting occupational safety and health) Australian Standard: AS2865 2009 Safe Working in a Confined Space ISO 31010: Risk Management-Risk Management Techniques	HSE UK 2013 Confined Space: A brief guide to working safely British Compressed Gas Association (BCGA UK 2015) Ministry of Defense UK (MOD UK 2014): Safe Working in Confined Space
2	Confined Space Permit to Work		
3	HIRADC Confined Space		
4	HIRADC Safe Operating Procedure		

3.3 Risk assessment tools analysis

A review of the risk analysis method has been done, and a list of identified risk assessment approaches applied by industries has been studied. The review process covered a broad scope of the area, not limited to journals but extended to documents such as Legislation, Standards, and Guidelines. Table 9 depicts the outcomes of the analysis.

Table 9 Risk analysis.

Item	Journal/document title & author	Type of risk analysis	Industrial practices application
1	Risk Analysis for Confined Space Entries: Critical Analysis of four tools applied to three risks scenario - D. Burlet-Vienney et al. [17]	Checklist	i. Audit and inspection ii. Non-specific risk analysis iii. Widely applied by industries iv. Available in Standards and Guidelines v. Current STP project practices: - pre-entry confined space checklist
2	Risk Analysis for Confined Space Entries: Critical Analysis of four tools applied to three risks scenario - D. Burlet-Vienney et al. [17]	Risk Scale	i. Risk Assessment process ii. Non-specific risk analysis iii. Widely applied by industries iv. Available in Standards and Guidelines v. Current STP project practices: - part of the risk analysis process for confined space entry
3	Risk Analysis for Confined Space Entries: Critical Analysis of four tools applied to three risks scenario - D. Burlet-Vienney et al. [17]	Risk Calculation	i. Risk Assessment process ii. Non-specific risk analysis iii. Widely applied by industries iv. Available in Standards and Guidelines v. Current STP project practices: - Part of the risk analysis process for confined space
4	A proposed occupational health and safety risk estimation tool for manufacturing system - A. Moatari- Kazerouni et al. [18]	Risk Estimation	i. Risk Assessment process ii. Non-specific risk analysis iii. Widely applied by industries iv. Available in Standards and Guidelines v. Current STP project practices: Part of the risk analysis process for confined space
5	3.1 Design and Application of a 5 step Risk Assessment Tool for Confined Space Entries - D. Burlet-Vienney et al. [5] 3.2 Risk Analysis for Confined Space Entries: Critical Analysis of four tools applied to three risks scenario - D. Burlet-Vienney et al. [17]	Ishikawa 5-Step Risk Assessment (Questionnaires & Risk Matrix)	i. Risk assessment process ii. Specific risk analysis iii. Purposely to identify the root cause of confined space accident iv. Available in Standards and Guidelines v. Current STP project practices: - HIRADC SOP of project
6	Practical Tool and Procedure for Workplace Risk Assessment: Evidence from SMEs in Estonia - K. Reinhold et al. [19]	Flexible Risk Assessment	i. Risk Assessment process ii. Specific risk analysis iii. To assess risk in the SME industry iv. Available in Standards v. Current STP project practices: - HIRADC SOP of project
7	Occupational Risk Quantification owing to Falling Object - O.N. Aneziris et al. [20] Quantification of Occupational Risk owing to contact with moving parts of machines - O.N. Aneziris et al. [27] Risk Management with Bowtie diagrams	Bowtie Risk Assessment	i. Risk Assessment process & Barrier analysis ii. Non-specific risk analysis iii. Applied at specific industries (Oil & gas, petro-chemical) iv. Available in Standards v. Current STP project practices:

	- Voicu et al. [21] Bowtie methodology for risk analysis of visual borescope inspection during aircraft engine maintenance - Jonas Aust & Dirk Pons [22] Lessons learned from analyzing an explosion at the Shanghai SECCO petrochemical plant - Dong et al. [23]		- HIRADC SOP of project
8	On the Development of a new Hybrid Risk Assessment Process using Occupational Accidents Data - P.K. Marhavillas et al. [28]	Proportional Risk Assessment (PRAT)	i. Risk Assessment process ii. Specific risk analysis iii. Proposed risk assessment for the utility industry (electrical) iv. Available in Standards v. Current STP project practices: - HIRADC SOP of project
9	Construction Job Safety Analysis (CJSA) - O. Rozenfeld et al. [29]	Three-step CJSA	i. Risk Assessment process ii. Non-specific risk analysis iii. Widely applied in the industry iv. Available in Standards v. Current STP project practices: - part of risk assessment process before confined space entry
10	Developing a Risk Assessment Model for Construction Safety - I.W.H. Fung [30]	Risk Assessment Model	i. Risk Assessment process ii. Specific risk analysis iii. Proposed Risk Assessment model for the construction industry iv. Available in Standards v. Current STP project practices: - HIRADC SOP of project

The additional analysis of each Risk assessment tool revealed that Bowtie risk Assessment had met all the requirements in developing a holistic Confined Space Risk Assessment framework, as depicted in Table 10. The critical consideration in the justification for confined space risk analysis is the exclusivity, practicality, and easy-to-understand (ETU) concept, specifically towards the prevention approach or so-called a Barrier Analysis, which mainly failed to apply in the risk assessment process. Furthermore, additional elements such as reliable technique, comprehensive through graphical approach, promote an understanding, reciprocal relationship, clear communication, underlying more complex scenario, clearly demonstrate the level of control, audit friendly, increase workers awareness and operational safety-oriented are measured [21].

Table 10 Risk Analysis-Bowtie.

Bowtie risk assessment				
No	**Key elements**	**Exclusive**	**Practical**	**Etu**
1	Solid technique	YES	YES	YES
2	Comprehensive-graphical approach	YES	YES	YES
3	Promote an understanding	YES	YES	YES
4	Reciprocal relationship	YES	YES	YES
5	Clear communication	YES	YES	YES
6	Underlying more complex scenario	YES	YES	YES
7	Demonstrate the level of controls	YES	YES	YES

8	Audit friendly	YES	YES	YES
9	Increase workers' awareness	YES	YES	YES
10	Operational safety-oriented	YES	YES	YES

3.4 Focus group discussion

Evaluation criteria towards Bowtie Risk Assessment compared to conventional risk assessment method has been discussed where the outcomes from the discussion are according to the following:
3.4.1 Solid technique - The technique applied is derived from several risk analysis tools such as Even Tree Analysis, Fault Tree Analysis, Barrier Analysis, Root cause Analysis, and Cause Consequence Analysis. Hence this technique could prevent an accident and manage risk effectively (ISO 31010, Annex A & Annex B).
3.4.2 Comprehensiveness - The Bowtie diagram showed a comprehensive approach in its analysis, providing a reciprocal relationship that contributes to a more comfortable understanding of the scenario presented by all employee levels. For example, the Threat is linked to the Barriers that prevent an accident from occurring and risky operations or hazards which create the accident. As for Consequences, the barriers linked to them are presented in the risk reduction or elimination measures.
3,4,3 Graphical approach - The graphical information presented by Bowtie would provide clear communication to all parties involved in any high-risk operation. Also, the barriers provide 'to do' words rather than an instruction for procedures, which is more prescriptive.

A task force was formed through the implementation of Focus Group Discussion (FGD), which aims to discuss further the results of the Confined Space Bowtie Risk Assessment and its key elements. A Certified Bowtie Specialist leads the Confined Space Bowtie Risk Assessment discussion process accredited by CGE Risk Management Netherland.

4 Conclusions

Malaysia's confined space accident trends showed that it needs to look seriously. Even though there were legal requirements, such as the Industrial Code of Practice, the compliance level is still disappointing. Initiatives by an authority such as DOSH by embarking on an OSH-MP2025 are considered proactive measures towards an accident reduction strategy. An efficient approach to enhancing a Confined space Risk Assessment is observed as one of the strategies for reducing confined space accidents. The risk analysis results have come out with a new approach to assessing risk using Bowtie. The significant contribution toward implementing a Confined Space Bowtie Risk Assessment is the reduction of confined space accidents, leadership enhancement, culture development, improved safe work system, and prioritized personnel competency. Future works are suggested to extend the area of Bowtie Risk Assessment and advance the risk assessment using Bowtie, such as adding Escalation Factor and Bowtie Chaining.

Declaration of Conflict of Interest

The authors declared that there is no conflict of interest with any other party on the publication of the current work.

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