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Risk Assessment on Electrical Maintenance Activity at Menora Tunnel, Perak

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ABSTRACT

Risk assessment is an essential element for Occupational Safety and Health. Risk assessment allows an organization to assess and control the potential risks to a minimum so as not to impact or causes major accident to workers and organizations. Every maintenance activities in industries such as construction, manufacturing, agriculture or in other sector should ensure that risk assessment is carried out and all the inherent risks are well controlled. For example, electrical maintenance work in a highway tunnel is also necessary to ensure that the inherent risks are eliminated or controlled to a minimum during the work carried out. This study is to identify potential risks that could occur during electrical maintenance activities in highway tunnels. The objective of the study is to assess the risk faced by the staff during electrical maintenance activity and to recommend the action plans to manage the critical risk which can lead to fatalities during electrical maintenance activity. The risk will be identified and assess based on bowtie analysis method and the measurement of risk level will be referred to five levels of risk-matrix. The development of bowtie diagram will be using a fault tree together with an event tree and barriers to mapping the risk

1. Introduction

Highways are a vital lifeline and a current requirement for land transports to reach their destinations faster. Tunnels are used when highways are built across hilly or mountainous areas. In Malaysia, the longest highway maintenance concession with an overall length of 772 kilometers starts from Bukit Kayu Hitam in Kedah, Malaysia-Thai borders until Johor Bahru in the southern part of Peninsular Malaysia. Along the north south highway, there is a tunnel that connects the town of Ipoh and Kuala Kangsar on the route to the north known as the Menora Tunnel. Menora Tunnel is a highway tunnel located in the state of Perak and it is a tunnel of 800 meters in the North-South Highway near Jelapang, Ipoh. Menora tunnel was officially opened to the public in 1986. There are

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two tunnels side by side at each direction starting from KM261.8 to KM261.0 (for North Bound) and KM261.0 to KM261.8 (for South Bound).

Maintenance team is hired to maintain all these tunnel operations, especially in electrical maintenance. Highway that has been in operation also requires a risk assessment for all maintenance work so that it can be carried out safely by the maintenance team and safe for road users as well. Most fatalities in road tunnels appear to arise from ordinary traffic accidents. Norwegian data indicate that two-thirds of deaths in road tunnels are resulted from common traffic accidents and about one-third is from fire-related incidents and 'dangerous goods' incidents [1]. In view of the Occupational Safety and Health, this impending accident can be influenced by external factors and internal factors. External factors such as traffic accidents as mentioned above and can lead to a major disaster. Meanwhile, internal factors are concentrated on the human factor that maintains the tunnel itself and it can also be responsible in causing a crash in the catastrophe if no awareness and preventive measures are implemented. The negligence of workers in handling a maintenance activity can result in significant impacts, which may also cause a tunnel fire. Accidents that occur not only cause fire, but can lead to other risks such as falling from high, exposed to harmful chemicals to health, flashover, electrocuted and others depending on the type of maintenance activities being carried out. Fortunately, all the risks of these internal factors can be overcome and controlled by the organization that manages such maintenance as opposed to the unregulated external factors.

For the last two decades, there has been a large increase in the number of a road tunnel in the world and this number is expected to continue to increase in the years to come. However, the increasing number of these infrastructures can also be responsible for the severity of accidents that may occur [2]. A safe tunnel operation is very important because the tunnel is a special engineering structure, built to shorten transport routes and improving road safety [3]. Most of the accidents on the tunnel are vehicle collision and the vehicle caught on fire. Maintenance works, especially in the tunnel as well as electrical work can contribute to a fire or an accident would be substantial if the risk assessment is not carried out and given consideration. Risk assessment is an important process for each tunnel project to determine the actual risk [4]. In this study, the risk assessment acted as independent variables and it is divided into a few elements known as human behavior, safety system, ventilation conditions, risk calculation, risk level [5]. Other than that two more elements are needed in developing the Bowtie analysis namely threat, consequences and safety barriers [6].

2. Methodology

The risk assessment has various tools to assess the risks based on qualitative or quantitative method. The tools used in the risk assessment is made up of Hazard Identification, Risk Assessment & Risk Control (HIRARC), System-Theoretic Accident Model and Processes (STAMP), Hazard and Operability (HAZOP), Bow-Tie, Risk Matrix and much more that can be used to suit the activity and the inherent risks. In this study, Bow-Tie method and Risk Matrix are used as appropriate tools for risk assessment in electrical maintenance activity on the tunnel.

A Bow-Tie structure represents a risk assessment model, starting from the main contributing factors that lead to disastrous events [5]. This concept has gained popularity because it offers a good overview of accident scenarios [7]. In addition, hazard identification and assessment methodology taking into account the following documents and information such as hazardous occurrence investigation reports, first aid records and minor injury records, workplace health protection programs, results of workplace inspections, employee complaints and comments, government or employer reports, studies and tests concerning the health and safety of employees, reports made under the regulation of Occupational Safety and Health Act, 1994, the record of hazardous substances, and any other relevant information.

Figure 1 shows the risk matrix of 4x4 that categorizes the likelihood and consequences by nominal textual description as references. This figure shows the use of qualitative methods for determining the probability and consequences of each of the fault tree and event tree of the critical event. As a result, the level of severity will be based on every each causal pathway as shown in Figure 2.

	Insignificant Consequences	Significant Consequences	Serious Accident	Major Accident
Frequent				
Probable				
Improbable	No personal harm		Single Fatality and several injured	Critical Event
Very Improbable				Several Fatalities and many injured

Fig. 1. The risk matrix 4x4 that will categorize the likelihood and consequences

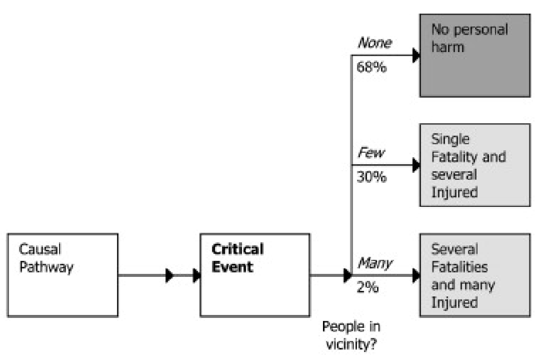

Fig. 2. Level of severity based on every each causal pathway [8]

The hazard or risk identification technique is based on observation audit and inspection of the work area, reviewing all related documents such as HIRARC, Safe Operation Procedure, Work Instruction, Emergency Response Plan and Procedure, as well as Incident Investigation Record. This study is conducted on 15 technicians from maintenance team at Menora Tunnel, Perak. Based on Krecjie and Morgan's sample size calculation, for population of 15 people, the sample size is estimated to be 14 people. Interview sessions with 14 technician staff were conducted to complete the assessment. Interviews are particularly useful to delve into technician's experiences to obtain in-depth information around the topic. Interviews may be useful as follow-up to certain respondents to questionnaires, e.g., to further investigate their responses [9] and to explore their perspectives on a particular idea, program or situation [10].

3. Results and Discussion

All data collection was gathered based on the qualitative and quantitative analysis approach through conducting observation, interview and survey questionnaire. Based on real-time observation and feedback from the staff and technician of the maintenance tunnel team, they were not aware of the risk that could be inflicted on them as there were no risk assessment has ever been conducted. The team were not aware of the risk of working at high, confine space, live power of 11 kilovolt-ampere (kVA) and energize transformers, as well as facing the live traffic of expressway users. Most of their work involves the use of live powers from 240 volt-ampere (VA) until 11 kilovolt-ampere (kVA) (maximum transformer capacity) which could lead to fire disaster on the expressway tunnel. One discussion was conducted to get the feedback from all staff whereby relevant safety and health concerns have been raised by staff and technician. One of the feedback was related to an accident that occurred during energized power causing a small flash over to the transformer however, without causing any injuries. It was also found that, any risks arising from electrical maintenance work were thought to be common risks associated with the field of work by the technicians and the presence of danger had been compromised without any proper source of guidelines. This is due to hazard identification and risk assessment are not sufficiently introduced in a basic level of work.

Table 1
The risk identified from data collection

Type of Risk/Hazard	No.	Description	*L	*S	Risk Rating (*Lx*S)
Safety (Acute Impact)	1.	Expose to unguarded moving mechanical part	2	3	Medium (6)
	2.	Integrity of Scaffold – Scaffolding topple	2	3	Medium (6)
	3.	Hand expose with the sharp object	3	2	Medium (6)
	4.	Moving vehicle – Hit by a moving vehicle during working on scissors lift	4	4	High (16)
	5.	Loose tools – falling object on road user	4	3	Medium (12)
	6.	Moving vehicle – Hit by moving vehicle while setting up Traffic Management Plan (TMP)	4	4	High (16)
	7.	Integrity of Fire Fighting System - Alarm system in the tunnel also not synchronize with the control room	3	5	High (15)
	8.	Flash Over/ Arc Flash during switch over transformer	3	5	High (15)
	9.	Unsafe Act due to the staff and contractor intended to cross the highway on live traffic – Hit moving vehicle while road crossing	4	4	High (16)
	10.	Diesel Filter compartment in USP Control Room caught on fire – No warning sign of fire hazard	2	4	Medium (8)
Health (Chronic Impact)	1.	Confined Space	4	4	High (16)
	2.	Unknown airborne dust	4	5	High (20)
	3.	Inappropriate PPE due to unknown airborne dust	4	4	High (16)

*L : Likelihood * S : Severity

All risks and hazards found during investigation have been divided into two elements; Safety Hazard and Health Hazard. There are 10 risks that have been identified in the safety hazard category that can contribute to acute impact injury while 3 risks are identified in the health hazard category that can have chronic impact to the health. Table 1 below tabulated the list of hazards and risks found in this study where *L represents the likelihood of occurrence while *S represents the severity of the hazard. The risk rating is calculated as *L multiply with *S.

From Table 1, the list of risks with the highest risk assessment with risk rating of 16 for safety hazard can be identified as hit by a moving vehicle during working on scissors lift, hit by moving vehicle while setting up Traffic Management Plan (TMP) and hit moving vehicle while road crossing during live traffic. For health hazard, the unknown airborne dust is the highest risk with risk rating of 20. These risks can be categorized as critical risk.

One of the incidents that is related to the critical risk on Health Hazard is the incident where one of the technicians was having difficulties to breath during working hour since early in 2017. The staff worked as tunnel maintenance team since 2012. Based on the record from a panel doctor, he has been frequently medically administered with a nebulizer from a clinic since February 2017 until July 2017 and was suspected of having asthmatic symptom. To rectify this problem and as part of the treatment, the technician was relocated immediately and the management has made an effective adjustment with their work environment. This recommendation is to ensure that the work area is free from harmful dust until all necessary action, testing and monitoring have been made. Confirmation from testing, sampling and monitoring of the work environment are needed to identify the type of unknown airborne dust at the tunnel by Health Assessor. Once the type of airborne dust has been identified, the affected technician was urged to carry out health monitoring based on the identified dust by the Occupational Health Doctor.

The Bow-Tie model has been established in accordance with the identified critical risks by evaluating its possible causes and consequences to the maintenance team as shown in Figure 7 and Figure 8 for safety hazard and health hazard respectively. In Figure 7, the causes or threats are all the activities that may lead to the critical event i.e. hit by a moving vehicle while the consequences are the effect of the critical event should it happened. The safety barriers on the both side of the bowtie diagram are taken as a control and prevention measure. This condition is known as Proactive Control before an accident occurs (causes) and Reactive Control to reduce the impact of the accident (consequences). The threats, safety barrier and consequences of a technician getting hit by a moving vehicle can be determined by referring to Occupational Safety and Health Act (1994) [11], Road Transport Act (1987) [12], Occupational Health and Safety Management System (OHSMS) based on Occupational Health and Safety Assessment Series [13], and Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC) [14]. The threats for this critical risk include incoming traffic encroaching onto the emergency lane and non-compliances on obligation with traffic regulation as stated in Road Transportation Act by road users. As a prevention, safety barriers for the first threat must be implemented such as Traffic Management Plan, placing reflective chevron stripes, beacon, strobe and directional light. Local authority enforcement is imperative in avoiding the second threat. The consequences of this critical event is identified as causing major injuries, fatalities and damages to the property as well as to the road users i.e., drivers and passengers. To minimise these consequences, Emergency Response Preparedness must be improvise, implement and responsive from the initial moment of the critical event that occurs. Other safety barriers suggested are the use of seatbelt and the fast response of the local authority to reduce the number of injured drivers and passengers.

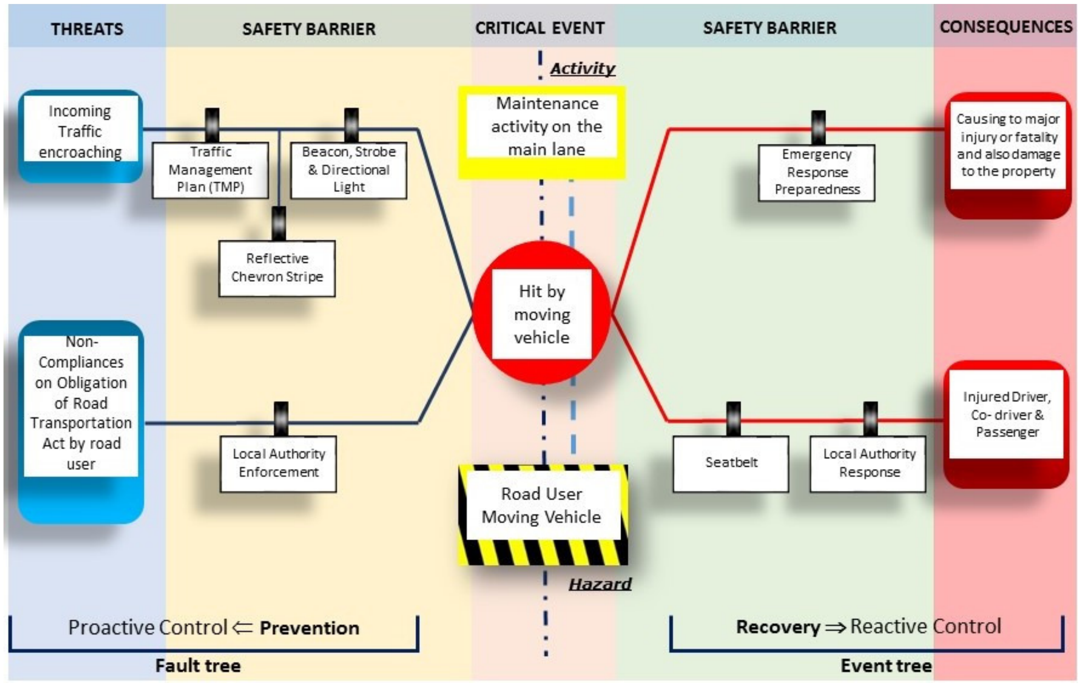

Fig. 7. Bow-Tie Model develop based on critical risk of getting hit by moving vehicle

In Figure 8, the critical event is determined as unknown airborne dust risk in confined space and tunnel which is associated with the health hazard. The threats, safety barrier and consequences of a technician getting hit by a moving vehicle can be determined by referring to Occupational Safety and Health Act (1994) [11], Occupational Safety and Health (Use and Standards of Exposure of Chemicals Hazardous to Health) Regulations (2000) [15], Industry Code of Practice for Safe Working in a Confined Space (2010) [16], Occupational Health and Safety Management System (OHSMS) based on Occupational Health and Safety Assessment Series [13], and Guidelines for Hazard Identification, Risk Assessment and Risk Control (HIRARC) [14]. The threats for this critical risk include unknown airborne dust and release of toxic gases in confined space or lack of oxygen. To prevent the unknown airborne dust threat, chemical hazardous risk assessment, chemical hazardous sampling and the use of complete respiratory protection must be conducted and implemented. For the second threat, the safety barriers can be listed as evaluation of Confined Space Procedure to qualify for safe working space, identify and train competence person to work in confined space and the management must comply with the DOSH and Industry Code of Practice (ICOP) for Confined Space (2010). The consequences of this critical event is identified as causing chronic health effect and in some serious cases can lead to death as a result of inhaling toxic gases or oxygen deficiency. To minimise these consequences, Emergency Response Preparedness and Self-Contained Breathing Apparatus (SCBA) must be prepared as a protective device from inhaling the oxygen deficient air. Similar recovery activities along with quick local authority response is vitally important in avoiding the unfortunate death of the affected employee.

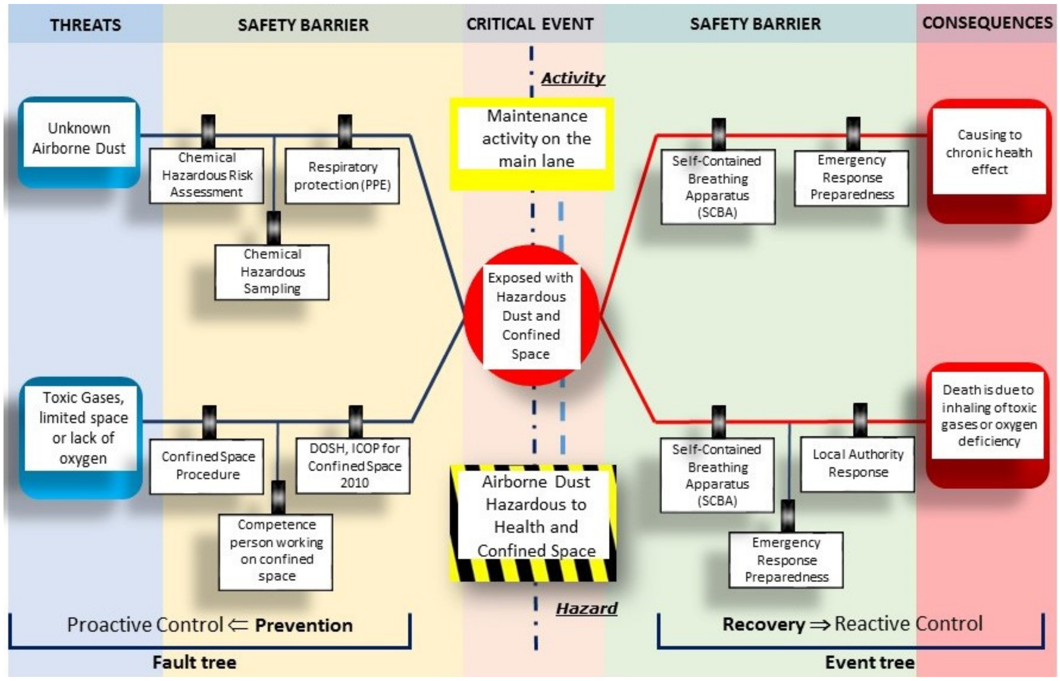

Fig. 8. Bow-Tie Model develop based on critical risk of unknown airborne dust hazard and confined space

4. Conclusion

This study focuses on the feedback given by the maintenance technicians in tunnel maintenance work of Menora Tunnel, Perak. It was found that all maintenance technicians were exposed to certain risks depending on the level of risk exposure itself. Based on the identified critical risks, safety barriers for proactive and reactive control have been determined to minimise and hopefully eliminate the threats and consequences of threats from occurring. This is a crucial step in order to protect employees and other road users in the vicinity, especially those in tunnel. However, a more in-depth study of the risks associated with the maintenance of the tunnel should be carried out. Detailed studies with bigger population have to be done to provide evidence that every parts of the tunnel are susceptible to confined space hazard. This is because the entire tunnel operation is not included in the Industry Code of Practice for Safe Working in a Confined Space 2010 issued by the Department of Occupational Safety and Health Malaysia. The outcomes of this study are expected to increase awareness among management and employees as well as to ensure that all associated risks for maintenance activities in electrical work at tunnel are acknowledged and appropriate action can be undertaken to control these risks.

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