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Feasibility Study of Worker Safety at Highway Emergency Lane

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Abstract. Safety procedures at highways are essential to ensure safe, clean and accessible roads and highways. The workers were often exposed to hazardous situations, as seen by numerous accidents involving highway workers on the road in recent years. Safety technologies in the highway construction work zone may help improve the roadway construction and maintenance workers' safety. This paper reviews the statistics of road accidents in Malaysia, highway work zone safety problems and existing applications of safety sensor systems as an improvement of safety technology in the construction work zones. As an

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improvement towards the safety technology, Signal Warning Detector (SWAD) system was developed to increase the safety at highway work zone especially on PLUS highways in Malaysia. The development of the SWAD system's parameter setting was discussed later in the methodology section of this paper.

INTRODUCTION

Highways are public roads that connect cities and towns. As it enables the quick supply of people and products to satisfy regional demands, the highway system was seen as a crucial piece of infrastructure in the growth of a nation. Additionally, because to their significance to a country's economic, society, and political growth, highway projects are sometimes viewed as high-risk projects in comparison to other forms of construction.[1,2]. Construction and maintenance of highways are commonly located near live traffic, which can create high safety risks for workers and motorists. They are also prone to accidents due to the improper positioning of cones and other equipment. Regardless of the reason, workers and motorists were exposed to serious hazards. Work-zone injuries and fatalities may occur due to distracted or speeding drivers, misplaced cones, and hazardous weather conditions[3].

Subsequently, Malaysia has more than 2,232 kilometres of highways[4], and the highway operators or workers are responsible for maintaining them. In addition to providing excellent and safe roads for transportation purposes, highway operators must maintain all roadside and highway assets in a functional state. The downside of this issue was that the highway operators are more likely to be exposed to various risks and hazards at construction sites. According to the Department of Occupational Safety and Health (DOSH) and Social Security Organization (SOCSO), fatal accidents have been increasing from 231.9% to 125.8% over the last seven years[5]. Several types of major accidents may lead to fatality as shown in Table 1 and one of the major accidents includes caught-in or in-between. This kind of serious accident was brought on by a person being squeezed, caught, crushed, pinched, or compressed between two or more objects[5].

The PLUS Expressway in Malaysia was well recognised for being the nation's longest expressway. Peninsular Malaysia's North-South Expressway spans approximately 748 kilometres from Bukit Kayu Hitam, close to the Thai border, to Johor Bahru, close to the Singaporean border. This includes the section from Senai to Johor Bahru to the Kempas Spur Road[6]. In 2020, PLUS reported that 19,218 objects were collected along the PLUS highway that year[7]. This shows clearly the amount of labour that the PLUS highway employees had to complete in a hazardous setting. PLUS Malaysia Berhad (PLUS) developed the 3E formula, which stands for engineering, enforcement, and education, as a strategy to promote highway safety on all of the roads they are in charge of maintaining[8]. Therefore, to compliment the 3E formula, this study provides a structured insight into the development of a Signal Warning Detector System (SWAD) as a technology to reduce the risks of possible accidents that may occur to motorists and highway workers.

Highway construction has consistently reported extremely high death rates due to the significant exposure of workers to moving traffic. To address this anomaly, traffic management planners must make decisions to decrease the dangers caused by passing vehicles and construction equipment. It is important to acknowledge the growing usage of technology to enhance worker safety while designing traffic control [9]. Technologies for safety have the potential to significantly contribute to risk reduction. The usage of safety equipment is made even more necessary by the outrageous costs associated with accidents in construction work zones. Despite any advantages of using technology in construction, there is need for improvement in terms of awareness, acceptance, and execution[10,11].

Road Accidents in Malaysia

Road traffic accident statistics have been used as a guideline for determining the probability of an accident[12,13]. The latest WHO figures show that 6,855 people died in road traffic accidents in Malaysia in 2018, accounting for 4.87 percent of all fatalities. With an age-adjusted Death Rate of 23.40 per 100,000 people, Malaysia is ranked #65 globally. [14]. In addition, the Royal Malaysian Police (PDRM) accident case investigations and accident investigation and reconstruction operations based on research procedures carried out by the Malaysian Road Safety Research Institute, according to the Ministry of Transport Malaysia, were used as data collection methods (MIROS).

The PDRM's inquiry was based on the requirements of the Road Transport Act of 1987, which covered all phases of a road accident. Meanwhile, MIROS' accident investigation and reconstruction based on research methodologies intended to uncover the variables that cause accidents and injuries to victims from the perspectives of users, cars, roads, and the environment. Depending on the scope of an accident case, MIROS performed investigations using two methods: retrospective and on-the-spot. The findings were given to the Ministry to recommend preventative actions and improvements from stakeholders[15].

Figure 1 illustrates the rise in Malaysia's accident rate during the last ten years. Meanwhile, as shown in Figure 2, the number of fatalities resulting from traffic accidents in Malaysia has fluctuated between the greatest number in nine years, in 2016, with a total of 7,152 deaths, and the lowest number in 2018, with 6,284 deaths. While a total decrease of 12.1% over three years (2016–18) was reported [15].

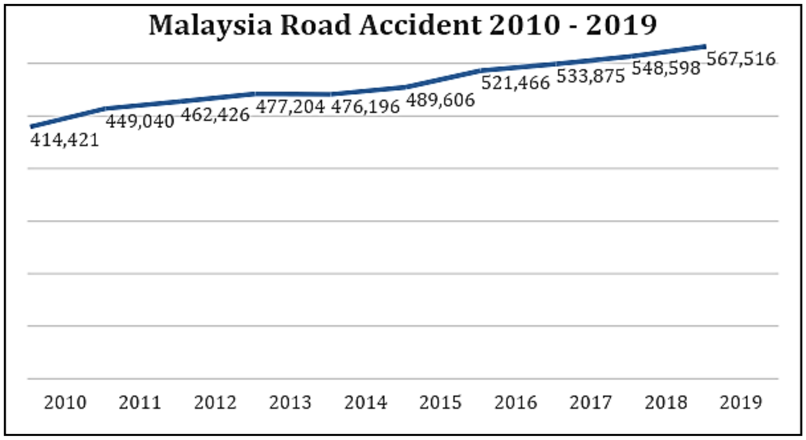

FIGURE 1. Malaysia Road Accident (2010-2019) (Malaysia M. of T, 2022)

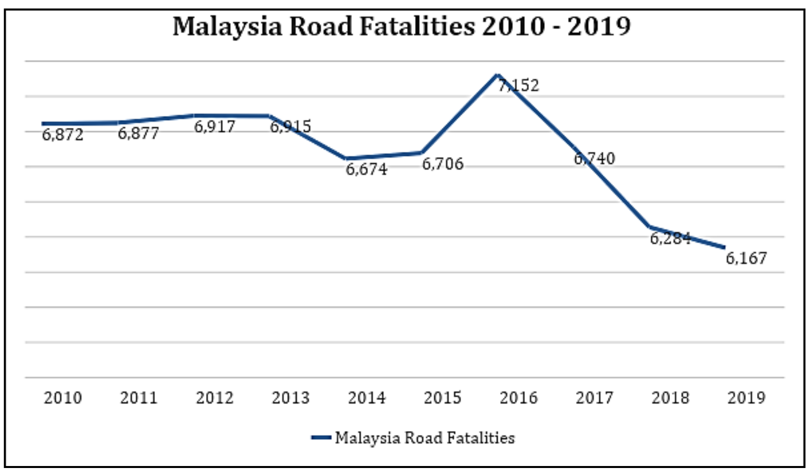

FIGURE 2. Malaysia Road Fatalities (2010-2019) (Malaysia M. of T, 2022)

According to a study of accident data from Malaysia and expressways managed by PLUS Expressways Berhad,[12] the lowest number of accidents occurred in PLUS expressways in 2013, with 11,052 accidents compared to 477,204 in Malaysia for a proportion of 2.4%. While the peak moment for the period 2013 to 2018 came in 2015, when 14,210 accidents on PLUS expressways outnumbered 489,606 in Malaysia, resulting in a 2.9% rate. This demonstrates that the number of traffic accidents in Malaysia is rising yearly as the country's road and vehicle network expands.

Common Highway Construction Safety Issues

Regarding workplace accidents and economics, the construction industry is regarded as one of the most hazardous. In the construction sector, accidents happen on almost every project. When an accident occurs, it usually has a high cost and temporal effect, as well as the loss of human life. According to the DOSH Occupational Accident Statistics by Sector until March 2022, a total of 1703 accidents were reported [16]. A total of 51 accidents occurred in the construction industry. There were 16 fatalities, making it the industry with the most fatalities among the other industries. According to these figures, the construction industry is a sector with a high risk of fatal accidents. Typically, an accident that might result in death is classified by category [5], as illustrated in Table 1.

TABLE 1. Different Types of Accidents (Hamid et al., 2019)

Types of Accidents	Definition
Fall	• Fall hazard injuries are those that result from a collision between the affected person and the source of the injury when the motion that caused the contact was caused by gravity. • Example: Falling from a higher level to a lower level or from elevation, falling through an opening floor or area, falling on the same level, and jumping from structures and equipment.
Struck-by	• Forcible contact or collision between the afflicted person and an object or piece of equipment causes struck-by injuries. • Struck-by hazards are divided into four categories: falling things, flying objects, swinging objects, and rolling objects.
Caught in between	• A person is squeezed, caught, crushed, pinched, or squished between two or more things, or between components of an item, resulting in this form of injury. • Individuals trapped or crushed in operational machinery, between a moving and stationary item, between other mashing things, or between two or more moving objects are included in this category.
Electrocution	• When a person is exposed to a fatal amount of electrical energy, electrocution occurs. • Example: Burns, electrocution, shock, arc flash/arc blast, fire, and explosions.

APPLICATIONS OF SAFETY TECHNOLOGY

The use of technology to improve administrative safety measures has recently gained a lot of attention. In terms of training, technology has been used in a variety of ways to improve safety training programs. Workers can be alerted to possible workplace risks via safety warning systems. Heavy construction equipment, for example, can be connected to a proximity warning system that emits audio and visual warnings when employees come too close to the equipment. Another form of warning system used on highway construction was the work zone intrusion alert technology that alerts workers on vehicle intrusion hazards at the work zone [17]. This type of alert helps construction workers to prepare and protect themselves during upcoming risks. Therefore, the construction industry has been adopting advanced technologies as a part of engineering control to reduce workplace safety risks [17]. This section provides a brief discussion towards the review of existing safety technologies that were developed as part of work zone safety improvements.

Traffic Guard Worker Alert System (WAS)

The WAS was a three-part pneumatic alarm system that includes a pneumatic hose, a base unit, and a worn safety device. A signal is delivered to the base unit and WSD when a vehicle travels over the pneumatic hose. The base unit emits audible, haptic, and visual alarms once the signal is received. The base unit might be placed on the ground or on a piece of machinery [9]. These auditory, visual, and vibratory alerts allow workers to move away from any risks caused by the entry of a vehicle into the work zone as promptly and safely as possible. However, depending on the project location and site configuration, there may be limits connected with network extension[18].

Intellistrobe System

The Intellistrobe system was primarily used as either an automated flagger assistance device (AFAD) in the work zone or an intrusion alert technology[19]. The Intellistrobe system is armed with audio alerts, a pneumatic tube, a gate arm, and signal lights. An operator controls the unit electronically from a safe distance using a transmitter. An audio and visual alert is produced when an intruding vehicle pressurizes the pneumatic tube. However, there were no studies that examined the system's effectiveness as an intrusion alarm device at the time, according to the researchers[9].

WSN-Based Intrusion Alarm System

In a distinct line of study, numerous systems based on Wireless Sensor Networks (WSNs) have been presented in the subject of traffic control and road safety[20,21]. WSNs have been used in a wide range of applications in recent years due to their low cost, great scalability, and ease of implementation. However, the authors claimed that there were no existing intrusion detection systems that utilize WSNs. Therefore the authors [22] had proposed an intrusion alarm based on two elements: vehicle detectors that monitors perimeter and warning devices that individually alert workers.

The system allows the workers to be alerted of the hazard approaching by an individual device that is wearable to the workers at the work zone. Other than that, invasions within the perimeter of the work zone could also be detected by the vehicle detector of the system. The authors performed different tests to observe and detect the system’s functionality. It was later found out that the distance, speed and angle were the main variables affecting the system’s performance [22].

METHODOLOGY

Based on the previous researches that have been reviewed, further methodology was addressed. This research aims to upgrade the level of safety for maintenance worker at the highway or any site. Therefore, a Signal Warning Detector (SWAD) System has been developed as an improvement of highway work zone safety especially in Malaysia. This research focuses on the development of the SWAD system which consist of uRAD sensor that compliments the functions of the SWAD system to measure the velocity and distance of vehicles ahead. For this study, the configuration of the uRAD will be done by entering different parameters of the uRAD shield (MTI and Mth) that will be configured inside the SWAD system. The configuration will be sent from Arduino to uRAD to ensure a more convenient application of the SWAD system. This configuration acts as a root to the complete information of the detection range provided by uRAD in the SWAD system itself.

Other than that, field tests will be pursued along the development of the SWAD system. Similar to the previous researches that had been reviewed, physical parameters including the length, height and angle of the SWAD device will be determined by conducting field tests at highways. It is expected that the SWAD system may detect upcoming vehicles at the highway emergency lane at a minimum distance of 50 meters by transmitting signal from the transmitter which sends signal in a form of vibration to the SWAD receiver. Significantly, the siren and rotation lamp which are connected to the transmitter will give an alert every time an upcoming vehicle is approaching the SWAD device.

Arduino Software Development

The Arduino Integrated Development Environment (Arduino IDE) was used to create the simulation of the Signal Warning Detector System (SWAD). By using support from the USB connection with the external computer, Arduino board ran the Arduino IDE, that used special rules of coding structure. This method was applied to find the optimum angle, distance (m) from emergency lane to uRAD sensor and to determine the suitable height(m) of uRAD sensor placed on the PLUS Ronda vehicle. This was a cross-platform approach application that was written in the programming language Java.

This research aimed to write and upload programs to Arduino board to act upon the wireless sensor system hardware. The Arduino IDE supported the languages C and C++ using special rules of coding structuring. C is a high-level and general-purpose programming language that is ideal for developing firmware or portable applications.

SWAD Set-Up

The SWAD that consists of uRAD sensor was attached on the PLUS Ronda vehicle as shown in Figure 3. The SWAD was connected to 12 V battery as the power supply for the system. Meanwhile, for the output of the SWAD, a siren and a rotation lamp are connected to the transmitter using 12 V battery as the power supply.

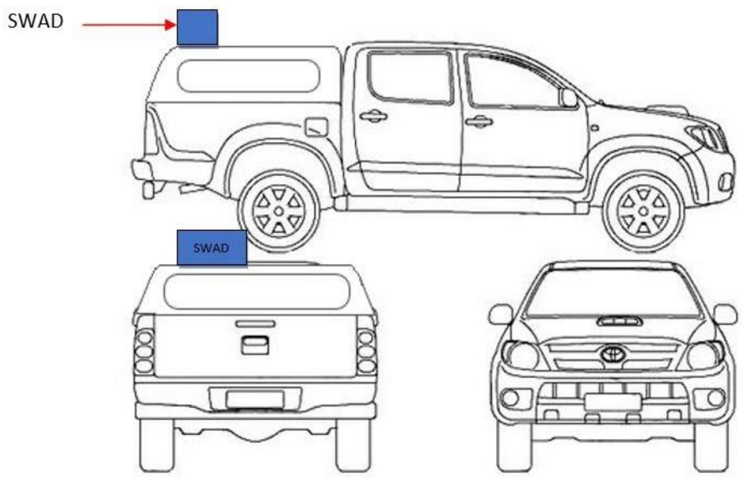

FIGURE 3. SWAD device placement on PLUS Ronda vehicle

At this stage, the design of the safety system was based on the highway workers safety requirement in order to ensure their safety at the highway. Figure 4 shows the outline of the safety system.

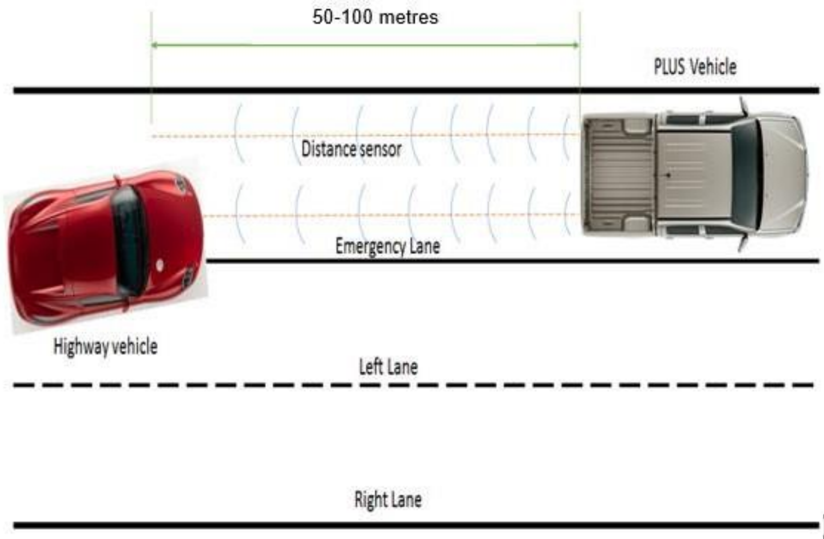

FIGURE 4. Design of Safety System

The design of experiment will be conducted to find the result as specific result. The type of design of experiment was based on the angle, speed range and presence. Different types of tables are designed to make sure the data was collected properly. This experiment will be conducted at normal lane and emergency lane since this experimental was related to the road. The type of car and weather were criteria of this experiment. The data based on different parameter will be recorded. The purpose of this experiment was to test the capability of the device including the receiver, output and transmitter

DISCUSSION OF FINDINGS AND FUTURE NEEDS

The result from the reviews of previous safety technologies proved that warning alerts are very useful when a dangerous scenario arises surrounding a work zone. Employees and vehicle drivers may have warning notifications during the hazardous situations. For government institutions to do business successfully for their workers, they must embrace new technology and innovation. The correct deployment of such systems is one of the primary challenges in capturing and exploiting the multitude of advantages offered by novel safety technology. Before the implementation of a safety technology, the users of the selected safety technology must be educated regarding the work zone safety technology values, the function of the system and how the devices should be maintained. The safety system set-up instructions and demonstrations should be thoroughly introduced so that the system is correctly implemented into the industry.

It is worth mentioning that the complexity and capacities of commercially available intrusion detecting technological solutions varies. This difference may or may not be reflected in the system's cost. Furthermore, it was not determined that commercially available solutions can be used in every circumstance involving highway work zones. Highway work zones provide unique obstacles that can lead commercially available solutions to fail. Highway workers in work zones can be warned when they are approaching a hazard by using a highway work zone intrusion alert system. Further testing in a range of settings will help to highlight the systems' benefits and limits for further improvement in the future. These technological solutions can provide an extra layer of safety protection for construction workers in dangerous work settings.

CONCLUSION

Various safety devices that satisfy the goal in preventing injuries caused by vehicle incursion have been found. From that, crucial information such as advantages, technological accessories, alert kinds, and triggering methods of the existing technologies will be well analysed in order to compare and contrast between the existing technology with the current SWAD System. This stage offers crucial information for the design and implementation of the following step on developing the SWAD system and device.

According to current statistics, construction safety performance is poor, and safety management in the industry lags well behind that of other key industries. According to previous research, incorporating new technologies into safety management processes has a significant impact on construction safety. Using technology as a safety control in phases with high consequences on performance outcomes – that is, using technology as part of the risk mitigation strategy to improve safety – is one method that technology deployment might improve safety management in construction. Future study should include a comprehensive evaluation of the current literature on the subject in order to find other viable safety management systems and assess their efficacy utilizing the hierarchy of controls. A panel of experts with industry knowledge can help with this type of study.

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