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STAMP-Based Analysis on the Safety Management System of Bus Operators

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Abstract – *Road accidents involving commercial vehicles are showing an alarming trend from year to year. Ironically the accidents involving heavy vehicles would involve the third party such as cars, motorcycles and other vehicles; due to several factors such as fatigue, speeding, tire defect, road defect, road design issue and risky driving. When occurred, it normally involved higher number of fatalities. Therefore, in order to improve the situation with regards to road accidents involving heavy vehicles, especially buses, a holistic road safety strategy is necessary and vital towards better road safety in the future. This paper aims to understand Safety Management System of bus operators using Systems-Theoretic Accident Model and Processes (STAMP) by analysing three case studies namely Genting, Tapah and Pagoh bus crashes in 2013, 2015 and 2016, respectively. Hazard analysis and causal factors were carried out on the bus operators' Safety Management System by using STPA (Systems-Theoretic Process Analysis) and CAST (Causal Analysis based on STAMP). The results of the analyses showed that the operating process could be revised or redesigned to improve the existing safety system. Moreover, STAMP could be a very useful approach to understand the whole safety system that may involve several complex factors.*

Keywords: System safety, Malaysia bus crash, OSH ICOP, STAMP, road safety

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1.0 INTRODUCTION

Road accidents in Malaysia are showing an increasing trend from 760,433 in 2010 to 960,569 in 2016. On the other hand, the number of road accidents involving commercial vehicles such as bus remains on a static figure in between 9,500 and 10,600 accidents per year (Royal Malaysia Police, 2016). Ironically, despite the lower number of road accidents compared to motorcycles and passenger vehicles, road accidents involving heavy vehicles would sometimes involve third party vehicles such as cars, motorcycles and other vehicles. The situation is more worrying since the number of lives and passengers involved in commercial vehicle accidents are normally higher than those involving private vehicles. There are various factors that may contribute to road accidents and these include human, environment, road design and vehicle factors.

The previous study by Fernández-Muñiz et al. (2007) defined the Safety Management System (SMS) as the practice, policy, procedures and person that could improve workers' behavior and attitude in relation to hazards. The elements and main standards of SMS include policy, planning, implementation and evaluation (Law et al., 2006). A study on fleet management by Haworth et al. (2000) showed that occupational health and safety management system (OHSMS) was less focused as compared to asset management. So as to improve fleet safety and work-related road safety, human factors such as individual driver, management factors and leadership is important in shaping safety culture in an organisation (Newnam et al., 2008; Davey et al., 2007; Wills et al., 2006). Additionally, Murray et al. (2009) and Stuckey et al. (2007) suggested that driver, vehicle and journey that were arranged in a system-based approach will result in better organisation system.

Many studies have been conducted worldwide to examine the benefit of implementing OHSMS. The benefit could vary according to different humans and companies (Lafuente & Abad, 2018). Humans benefit from OHSMS by experiencing better working conditions, increase of safety awareness, increase of security during working and reduced fatigue risk. This is supported by a research done by Santos et al. (2013) which indicated that OHSMS would bring benefit to working conditions improvement, regulation compliance, better understanding of risk and hazard among workers.

Under the Occupational Safety and Health Act (OSHA) 1994, the Minister of Human Resources Malaysia in 2010 has approved to gazette the Industrial Code of Practice for Occupational Safety and Health (OSH ICOP) in Road Transport Activities of the same year. The main purpose of the Industry Code of Practice is in accordance with the OSHA Act 1994 which is to ensure the safety and health of its employees as general and public in particular. In addition, OSH ICOP in the field of transport focuses on risk management especially involving vehicle, route and driver management.

This study utilized Systems-Theoretic Accident Model and Processes (STAMP) to analyse bus accidents in Malaysia. As the transportation sector comprises several elements such as authorities, bus operators, vehicles used and drivers, a holistic approach is needed to be conducted so as to ensure that all these elements interact and are being appropriately addressed. In these cases, the operating process of bus operators are being discussed. STPA (Systems-Theoretic Process Analysis) was used to analyse hazard based on STAMP while CAST (Causal Analysis based on STAMP) was carried out for accident and incident analysis. The case study includes Genting crash in 2013, Tapah crash in 2015 and Pagoh crash in 2016 that killed 37, 7 and 14 people, respectively. The following sections discuss the safety assessment conducted for all the accident cases. During the safety assessment, unsafe safety action and safety constraints were being identified and defined. Next, the causal factors for all the cases were determined. Finally, several recommendations to improve the safety system of bus operators are highlighted.

2.0 HAZARD ANALYSIS AND RISK ASSESSMENT

Hazards in the transportation sector may derive from office, ticket counter, terminal or depot, workshop and during travelling. Examples of hazards in office are electrical hazards, slips, falls, fire hazards, ergonomic injuries and manual handling. As for in workshop, the hazards include chemical handling, working at height, noise, lighting, sharp equipment and manual handling.

Hazards for travelling purposes can be categorized into three main hazards that are related to the vehicle, human and routes. Human factors include driver's speeding, competency, fatigue and dangerous driving. In terms of vehicle factors, several issues of daily inspection before and after trip and bus maintenance could be the potential hazard to road crash. In addition, the route factors such as road design and signage could also contribute to the crash occurrence.

The risk of getting involved in a road crash is higher when the management of drivers, vehicles and routes is insufficient. All the road accidents in the case study were having similarity in term of inadequate monitoring of drivers, vehicles and routes management. Inadequate control from the operations department on driver, vehicle and routes increased the risk of crash happen during travelling.

According to Burns and Wilde (1995), the higher crash risk was based on driver's personality. Studies by Sumer (2003) and Lamber-Belanger et al. (2012) revealed that health conditions could influence driving quality and cause an accident. In addition, working environment may also affect driving quality (Jayatilleke et al., 2009; Chang & Yeh, 2005) and the risk of accident was found to be higher among traffic offenders. This is supported by Lantz and Blevins (2001) in their study that traffic offense criterion could be used to identify high-risk carriers among commercial vehicle drivers.

Other than the factors mentioned earlier, bus vehicle conditions can also be a cause for road accidents. Zegeer et al. (1993) stated that older buses could pose higher risks. Chang and Yeh (2005) showed that the bus operated company characteristics and accident rates were significantly associated. Poor maintenance service may be one of the important factors leading to the bus accident. Last but not least, Wang et al. (2011) stated that 80% of traffic accidents were closely significant to the road design and environment.

3.0 IDENTIFICATION AND IMPLEMENTATION OF MEASURES

3.1 Bus Accidents

The bus accidents used for the case study are Genting, Tapah and Pagoh crash cases that took place in 2013, 2015 and 2016, respectively. Table 1 summarizes details of all the bus road crashes.

3.2 STAMP Socio-technical Diagram

Accidents can occur when there is less enforcement or inadequate control over each operating structure and system development stage. STAMP implements a continuous improvement approach to ensure that each stage of the operating structure is given the appropriate constraints rather than simply preventing the occurrence of component failures alone. In safety management, STAMP emphasizes the importance of constraints to reduce the risk of accidents (Leveson, 2004).

The Malaysia transportation sector was governed by two separate bodies which are the Ministry of Transport and Ministry of Human Resources. The related laws are Road Transport Act 1987, Occupational Safety and Health Act 1994 and Land Public Transport Act 2010. Road Transport Department (RTD), Department of Occupational Safety and Health (DOSH) and Land Public Transport Commission (*SPAD*) are the authorities to monitor the industries via two main guidelines that are OSH ICOP and SPAD Safety ICOP. In addition to the abovementioned agencies, Malaysian Institute of Road Safety Research (MIROS) is responsible for conducting research on road safety and introducing voluntary programme named MIROS Safety Star Grading (SSG). Since its establishment in November 2013, the programme has helped to differentiate operators based on their safety level. SSG acts as a consumer-based programme aimed to provide general public with knowledge and indicator on the safety performance of bus operators in making the best decision in selecting the safest transport by considering safety aspects.

Next, the operators should be liable to establish their safety policy, develop the safety procedures according to their nature of business, set up an effective OSH Committee, perform Hazard Identification, Risk Assessment and Risk Control (HIRARC) in the workplace, monitor and review each process whenever necessary. The areas of concern in these cases are the operating process. Figure 1 shows the STAMP socio-technical diagram for bus industries.

Table 1: Important details of Genting, Tapah and Pagoh bus road accidents

Details	Genting	Tapah	Pagoh
Date and Time	21 August 2013 (Wednesday) at 2:15pm	15 January 2015 (Thursday) at 1:15am	24 December 2016 (Saturday) at 3:25am
Location	KM 3.6 Genting Highlands-Kuala Lumpur Road (Genting Sempah)	KM 326.3 North-South Expressway (NSE) southbound near Tapah exit	KM 137.3 North-South Expressway northbound near Pagoh
Type of collision	Single vehicle accident (SVA)	Single vehicle accident (SVA)	Single vehicle accident (SVA)
Casualties	37 fatalities (including driver), 16 injured (5 critical)	8 fatalities (including driver), 22 injured	14 fatalities (including driver), 16 injured
Passengers (at the time of the accident)	53 (overloaded as the allowable capacity was 44 passengers)	31	30
Operator	Genting Highlands Transport Sdn. Bhd.	LBS Travel Sdn. Bhd.	Billionstar Express Sdn. Bhd.

3.3 Control Structure

The control structure in Figure 1 is based on the common hierarchical safety control structure. It has been divided into two hierarchical control structures that are for development and operations. For the development control structure, all planning from bus operator’s management should comply to the law and guidelines provided. As for the operation, the company's operation department shall follow all the standard operating procedures (SOPs) that have been developed by the top management. Any problems occurred during operations shall be reported and taken action by the management. The operation shall be monitored regularly and being audited to ensure safe practice is in place to avoid road accidents from occurring.

In terms of operating processes, the management shall follow the OSH ICOP for driver, vehicle, and route and risk management. As for the driver management, the operators shall ensure driver pre-recruitment procedure, driver categorisation, driving and working hours, and driver rotation are being followed. Furthermore, the OSH ICOP requires operators to certify pre-journey vehicle readiness and ensure vehicles are well-maintained. While, for the risk and route management, operators shall manage passengers and baggage as well as identify and manage risk and hazard along the routes (DOSH, 2010).

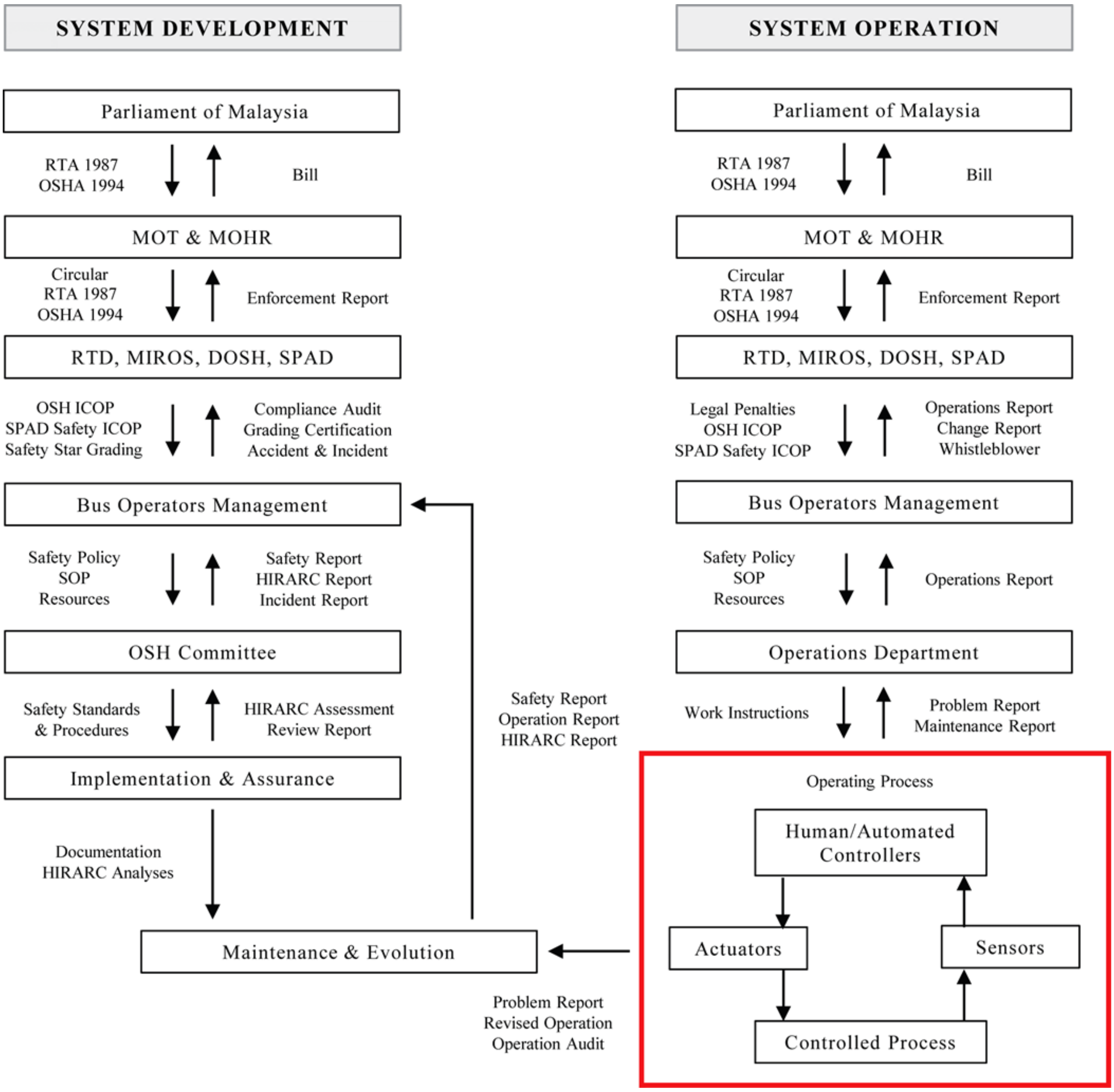

Figure 1: STAMP socio-technical diagram for bus industries

4.0 DISCUSSION ON SAFETY ASSESSMENT

There are various safety risks at work. These risks can be reduced by creating a safer process or handling of equipment. Additionally, one of the ways to reduce risk is by conducting a safety assessment. Safety assessment for transport industry mainly utilizes using OSH ICOP, SPAD ICOP Safety and Safety Star Grading Programme as guideline. Generally, the ultimate purpose of safety assessment is to control hazards from transport industries and indirectly reduce the number of road accidents involving commercial vehicles.

4.1 Unsafe Control Action

STPA was used to identify unsafe actions in all cases. Table 2 describes the identified unsafe control actions. For the purpose of this study, only key actions are presented here.

Table 2: Identifying unsafe control action

Action (Role)	Action required but not provided	Unsafe action provided	Incorrect timing / order	Stopped too soon / Applied too long
Pre- and post-departure vehicle checking	Vehicle checklist was not fill	No verification on vehicle condition	Increase hazard risk coming from vehicle problem	Not applicable
Pre-driving health declaration	Unhealthy driver proceeds to work	Working with an unhealthy condition	Risk of crash because of driver issue	Not applicable
Safety briefing on routes hazard	No update on new hazards on routes taken.	No information on new hazards	Driver not prepared for unknown route hazard	Not applicable

For all these cases, safety constraints should be determined to ensure that hazards and risks are being controlled accordingly. In ensuring the risks have been minimized and to avoid accidents, security constraints should be enforced or fully controlled. This is to guarantee the safety system that has been designed and integrated is well-functioning. Table 3 shows the safety constraints for these cases.

Table 3: Defining safety constraints

Unsafe control action	Safety constraints
No verification on vehicle condition	The supervisor must verify the vehicle's condition before departure.
Working with an unhealthy condition	The supervisor needs to replace with fit driver.
No information on new hazards	The supervisor must regularly conduct safety briefing.

4.1 Causal Factors

CAST was used to determine the causal factors for the cases. The processes started from compulsory safety briefing from the supervisor to the driver. Besides, the driver or foreman needs to ensure that the vehicle is in good condition prior to departure. At the same time, drivers also need to declare their fitness to drive pre-departure. Lastly, prior to departure, the supervisor must ensure and verify the driver's health and vehicle's condition. The controller process model, control path and feedback path are shown in Figure 2.

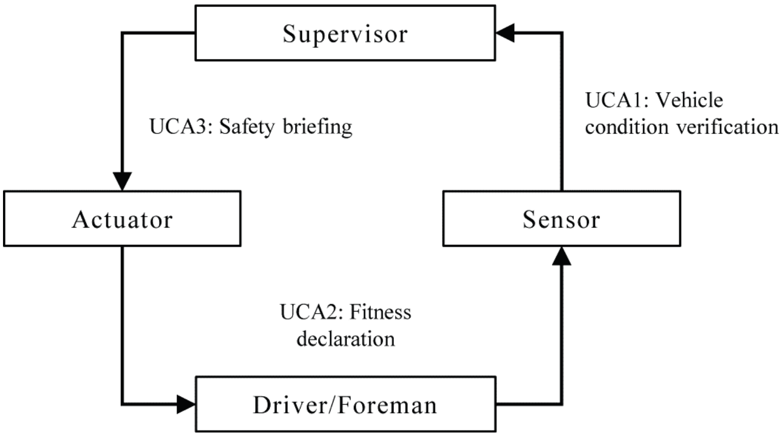

Figure 2: Causal factors of the accidents

4.0 CONCLUSION

From this study, it shows that the operating process for driver, vehicle, and routes management are related to hazard and risk during travelling. Unsafe actions caused by the supervisor, driver and foreman could contribute to road crash. Insufficient control of all these three processes had contributed to the case study accidents.

To increase the safety process, besides human controller, automated system could be installed in the bus to prevent process abuse caused by humans. Buses with new technologies may have additional features to indicate the condition of the bus before departure rather than depending on humans. Furthermore, technologies like lane changing assistant, eye tracker for driver fatigue detection and massage chair for driver have been widely used to minimize human error while driving.

The pre- and post-departure safety checks could also be done by using phone applications so that the conventional way of using paper could be replaced. As an advantage, all information can be centralized and assisted by software system to help the human decision-making process. Moreover, the access will be faster via the Internet of Things (IoT) and database will be more systematic compared to old method of merely using files (manual hardcopies). To conclude, STAMP could be a very useful approach for understanding the whole safety system that may involve several complex factors.

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