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Analyzing Driver Response in Real-World Fatal Crashes Using the Event Data Recorder (EDR)

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ABSTRACT – *Using the information stored in the Event Data Recorder (EDR), crash researchers have been able to offer objective analyses regarding vehicle performance and driver response in road crash events. Several research on the use of the crash data retrieval system in pedestrian accidents posited that EDRs had become an important source for crash researchers to investigate road crashes involving data recorder-equipped vehicles. In Malaysia, a previous MIROS study was able to determine the probable causes of various crashes involving a certain car brand using both the road crash event data obtained on-site and from in-vehicle EDRs. In this particular study, a total of 16 real-world fatal crash cases from 2019 to 2021 involving EDR-equipped passenger cars were investigated to retrieve the necessary information regarding the driver's response with regard to braking, accelerating, and steering control in the 5-second period prior to the crashes. The 16 cases represented 16 drivers who had been involved in the fatal crash. The in-vehicle event data was successfully retrieved using Crash Data Retrieval (CDR) tools either from the onboard diagnostics (OBD) system or through the 'direct method'. The study indicated most drivers (36.4%) applied the brake only one second before impact whereas 9.1% of them did not apply the brake. It was also found that 23.1% of the drivers pressed down the accelerator pedal and did not apply the brake upon impact while 15.4% of the drivers did not react before crashing (neither accelerated nor applied the brake). Unfortunately, data for steering control could not be retrieved as it was not stored in the EDR (older models). The findings are expected to help crash researchers to better understand the use of EDRs in determining the various calculations in car crashes.*

KEYWORDS: Delta-V (ΔV), Event Data Recorder (EDR), On-Board Diagnostics (OBD), AI Damage

1. INTRODUCTION

Dubbed the automotive black box, an Event Data Recorder (EDR) is installed on modern vehicles to collect the vehicle technical and occupant information over a short period (in seconds) before, during, and after a road crash event. The information can then be used to assess and improve vehicle safety performance.

Fugger et al. (2004) contended the EDR could increase our understanding of how vehicle systems including vehicle speed, engine revolutions per minute (RPM), throttle position, and brake switch status functioned during a road collision. Such information could then be used to complement physical evidence in crash studies.

Consequently, the use of EDRs has benefitted various parties including automobile manufacturers, automotive engineers, enforcement agencies, car insurers, and also the general public. With the EDR, road crashes involving vehicles equipped with the device can be thoroughly investigated to determine what actually happened several seconds prior to and upon impact (Correia et al., 2001)

The use of event data has also prompted the safety system of certain vehicles to be re-evaluated. As a result, aside from changes that can be introduced to vehicle regulations, the weaknesses of a vehicle model can be identified and rectified.

More importantly, based on EDR readings, researchers have been able to provide objective information regarding vehicle performance, vehicle handling, and driver response in crash events. Through their research on the use of the crash data retrieval system in pedestrian accidents, Fugger et al. (2004) posited that EDR had become an important source for crash researchers to analyze road crashes involving data recorder-equipped vehicles.

In Malaysia, Khairil Anwar et al., (2019) were able to determine the probable causes of various crashes involving a certain car brand based on both the road crash event data obtained on-site and from the EDR as shown in Figure 1.

FIGURE 1: An Event Data Recorder

Therefore, the current study has been undertaken to focus on the use of EDRs in various fatal crashes in Malaysia from 2019 to 2021 to analyze the drivers' reactions with regard to braking, accelerating, and steering control over the 5-second time frame prior to the impact.

Under normal road crash circumstances, it is not possible to ascertain the response of the driver who had died in a road crash using physical evidence. Nevertheless, recordings in the EDR can provide the much-needed assistance to deduce the driver's response within 5 seconds before the fatal incident.

1.1 Objectives of the Study

This study has been carried out to analyze driver response in the 5-second time frame prior to fatal road crashes from 2019 to 2021 based on information in the EDR of the vehicles involved. Utilizing the data retrieved from the device, the objectives of this study include:

i. To analyze the driver's braking behavior in the event of a crash.

ii. To determine the driver's accelerating and decelerating patterns before a crash.

iii. To understand the driver's steering control reaction prior to a crash.

1.2 Scope of the Study

The scope of the study covers an analysis of fatal road crashes from 2019 to 2021 involving car models equipped with EDRs in Malaysia and the driver's response in terms of braking, accelerating, and steering control. EDR data was successfully retrieved in 16 out of 22 road crash events during the period of study.

The paper shall be organized as follows: Section 2 will address the use of EDRs in various crash reconstruction studies. Section 3 will describe the methodology to identify the fatal crashes involving EDR-equipped vehicles from 2019 to 2021 and retrieve the EDR data to deduce the driver's braking, accelerating, and steering control patterns prior to the fatal crashes. Section 4 will contain the study results and discussion while Section 5 will provide the conclusion.

2. EDR IN CRASH RECONSTRUCTION STUDIES

This brief literature review is carried out to provide an overview of the use of EDRs in several crash reconstruction studies.

In-vehicle Event Data Recorders or automatic recording devices have been used in the transport industry since before the 1950s as a means to collect information related to crash events to assist in vehicle handling and optimize vehicle performance (Correia et al., 2001). On present-day vehicles, EDR that is contained in the Supplemental Restraint System (SRS) Airbag Electronic Control Unit is now supplied as standard equipment by several car manufacturers. On most vehicles, the device can be found under one of the front seats or under the center console.

Information in the EDR can be downloaded using Crash Data Retrieval (CDR) tools through two methods; namely using the On-Board Diagnostics (OBD) or Airbag Control Module (ACM) system or through the 'Direct Method' (Abu Kassim et al., 2019). Yet, according to Gabler et al. (2004), the most important data element contained in EDRs is delta-V versus the time history of the vehicle during the crash. Delta-V, which refers to crash severity, represents the total change in vehicle velocity over the duration of the crash event, whereby larger changes in velocity correlate with a higher tendency for occupant injury.

Calculations of delta-V for the impacting vehicle can be derived using different methods (Fugger et al., 2004). Meanwhile, Abu Kassim et al. (2019) in a MIROS research report explains that delta-V can also be estimated using the measured vehicle post-crash damage in tandem with computer codes such as Ai Damage. The calculation used in the MIROS report (Khairil Anwar et al., 2019) is as follows:

$$\Delta v = v_{after} - v_{before}$$

where delta-V is the difference between pre-collision velocity and post-collision velocity. Among the data required by Ai Damage to calculate delta-V is the value of certain measures on post-collision vehicles, vehicle weight including passengers, median offset damage, and the Principle of Directional Force (PDOF).

Because vehicle kinematics information is normally unavailable for real-world crashes, researchers have resorted to using delta-V as a surrogate metric to relate gross vehicle kinematics to resultant occupant injury (Gabauer & Gabler, 2006). Aside from information related to delta-V, the crash parameters contained in the EDR also include airbag trigger times and seatbelt status; whereas some EDRs also store 5 seconds of precrash recordings of vehicle speed, engine throttle position, and engine revolutions per minute (Gabler et al., 2004).

Further, Correia et al. (2001) explain that the following parameters are also recorded, namely brake status to indicate whether the brake pedal was pressed down; and data validity to indicate if any of the pre-crash parameters are out of range or if any faults are diagnosed. Based on the information retrieved from the device, researchers have conducted various crash reconstruction studies involving EDR-equipped vehicles. In their study, Gabauer & Gabler (2006) managed to produce injury risk curves to estimate the likelihood of serious occupant injury in frontal crashes using Occupant Impact Velocity (OIV) and delta-V in EDRs as predictors. They also argued, based on their analysis involving 200 real-world crashes, that both OIV and delta-V were evenly sound predictors of overall occupant injury (Gabauer & Gabler, 2006).

Analyzing frontal impacts using EDRs, German et al. (2007) noted the device was able to provide valuable information on the collision performance of airbags based on deployment characteristics data. Further, Gabler et al. (2004) examined the viability of using EDR information to assist in crash reconstruction. They concluded that EDRs had the capability to recover unknown delta-V and accurately collect seatbelt buckle status. Nevertheless, the device was unable to capture the entire event owing to limited recording times (Gabler et al., 2004).

In another study, Correia et al. (2001) investigated the benefits and weaknesses of EDRs. Utilizing the data retrieved from the device, the researchers were able to reveal that in a crash event, the impacted car was driven at an average acceleration of 0.1g and its brake pedal was applied up to 1 second prior to impact. They suggested EDRs had made a common recording of crash event data more feasible. More recently, Wu et al. (2013) conducted a study to determine the capability of a prototype driving behavior-based event data recorder (DBEDR) to provide information on driving behaviors and the corresponding danger level. Employing the Hidden Markov Models (HMMs), the researchers were able to correctly identify seven driving behaviors including acceleration, deceleration, approaching the car in front, and others based on information stored on the event data device at the rate of 95%.

3. METHODOLOGY

This study employed a systematic approach to obtaining crash investigation data from real-world fatal crashes in Malaysia from 2019 to 2021 involving EDR-equipped passenger cars. Further, the study sought to gather information on the driver's behavior seconds before the crash occurred. One such information is the driver's reaction with regard to pedal application, either braking or accelerating, which was recorded. In addition, the timing of braking and pedal acceleration was also analyzed to observe the driver's reaction in the event of a crash.

3.1 Research Framework

Figure 2 illustrates the systematic approach of this study to obtain the relevant crash data. The first step was identifying the relevant crash events from various notification channels. The cases were filtered according to the study requirements (e.g., involvement of EDR-equipped vehicles). If a case fulfilled the requirements, the research team would be dispatched for data collection.

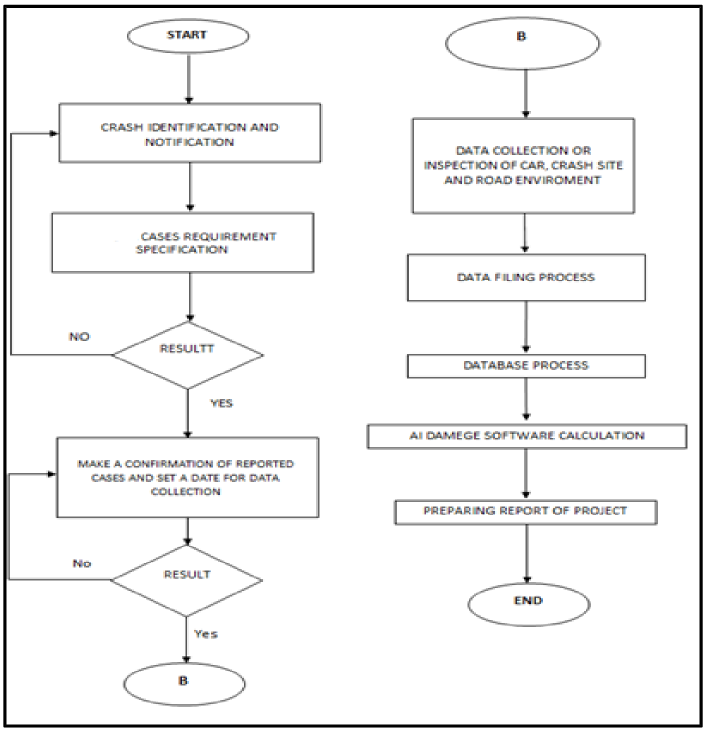

FIGURE 2: Flow chart of the systematic approach taken during the investigation

3.2 Crash Identification

Identification of both retrospective and prospective crash events was done from 2019 to 2021 as shown in Figure 3 (Jawi et al., 2015). At this stage, fatal crashes over the study period were filtered according to several specifications. Only if such specifications were fulfilled would the research team be dispatched to collect the necessary data.

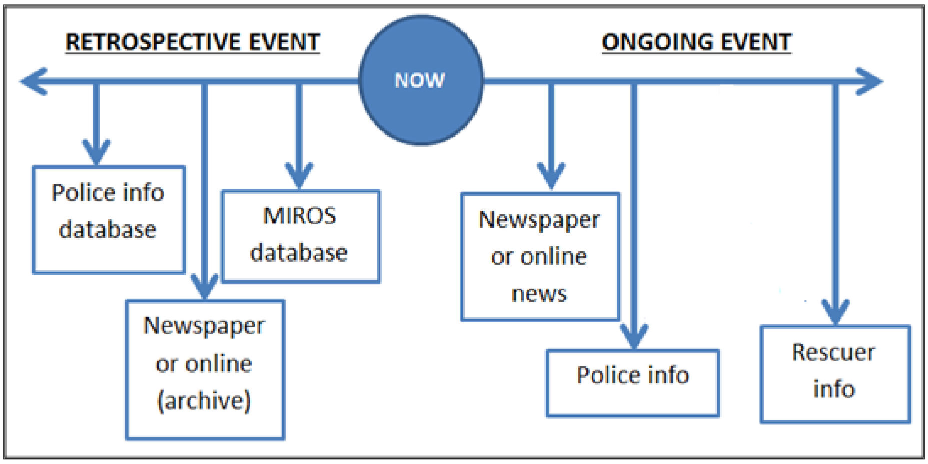

FIGURE 3: Crash identification / notification

This data collection process allowed the research team to gather the necessary information for each fatal crash involving EDR-equipped vehicles.

3.3 Data Collection

Data collection is an important aspect of road crash investigation whereby all the information obtained shall become evidence in a crash case. Figure 5 illustrates the data collection process and sources.

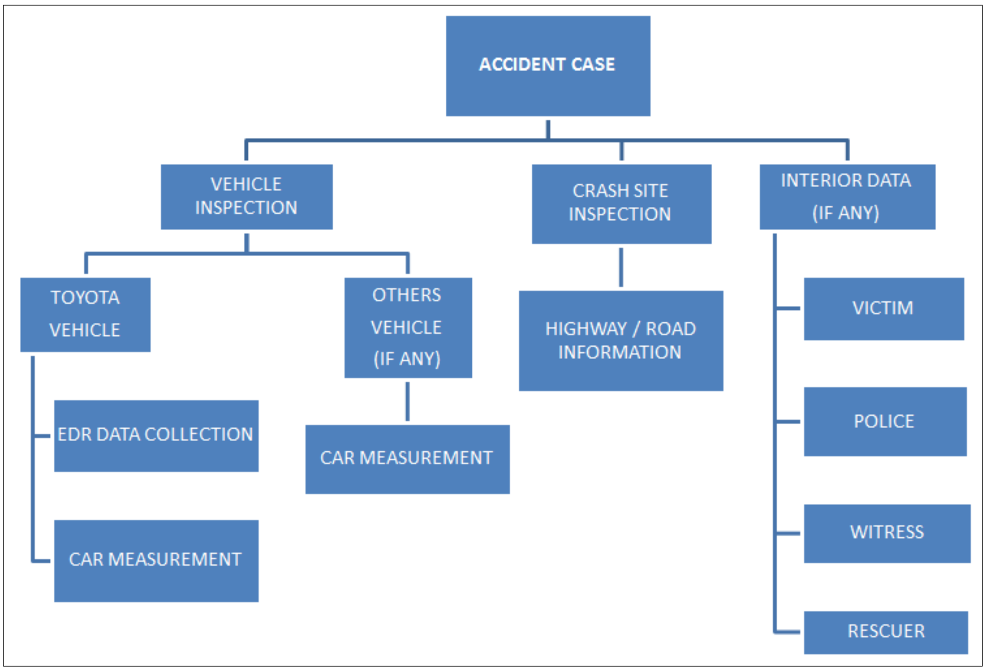

FIGURE 4: Data collection process

In this study, the process involved three main parts namely vehicle inspection, crash site inspection, and a series of interviews. In the vehicle inspection process, the EDR-equipped vehicle and also its crash partner (if any) were inspected. The research team used the MIROS Crash Investigation Form to fill out the data. The overall process followed the MIROS Crash Investigation Procedure. Further, for the EDR-equipped vehicle involved in the crash, information in the EDR was retrieved using CDR tools as shown in Figures 6 and 7.

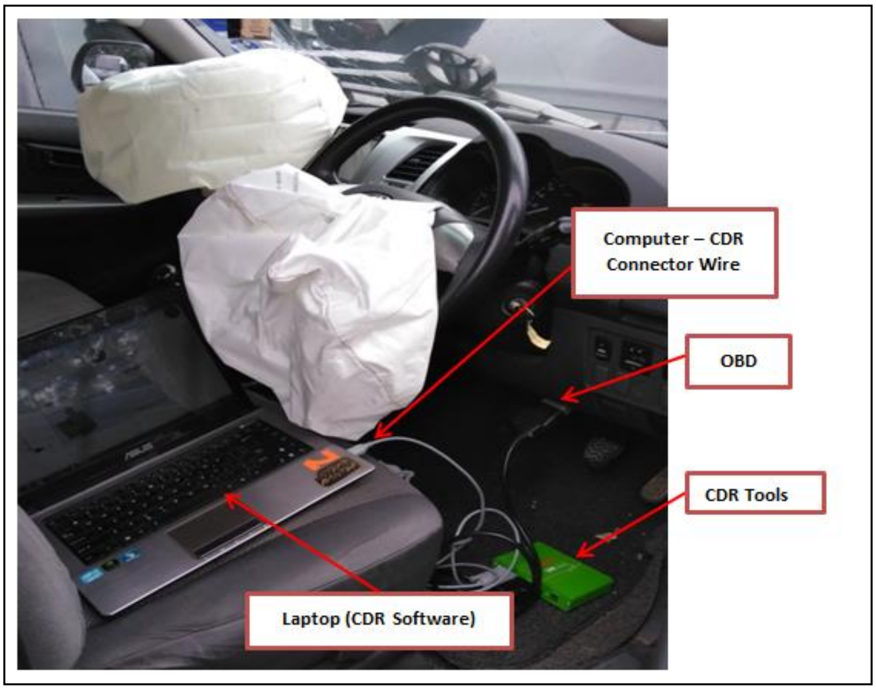

FIGURE 5: 'OBD Method' to retrieve EDR data from a crashed vehicle

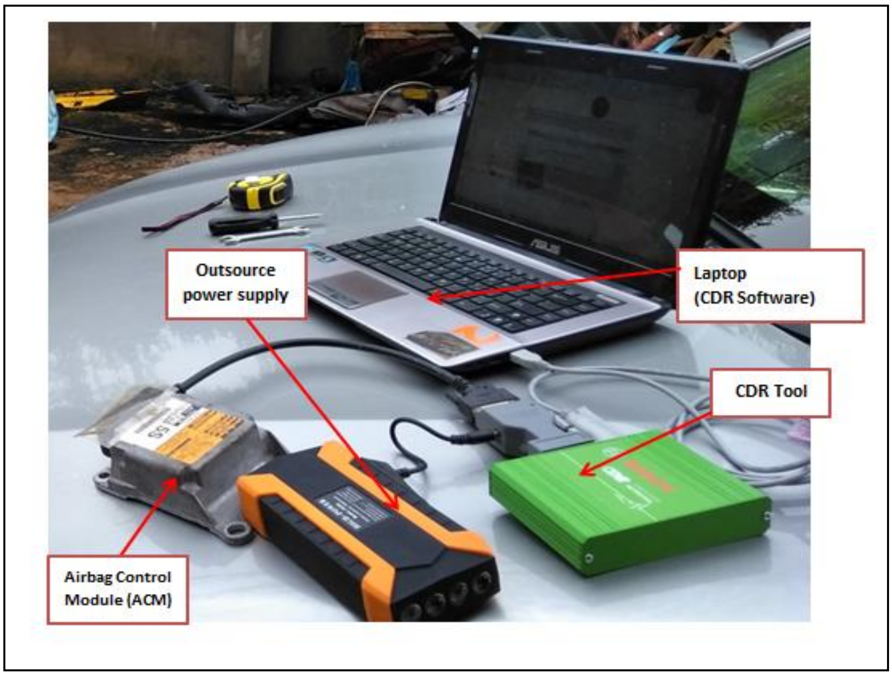

FIGURE 6: 'Direct Method' to retrieve EDR data from a crashed vehicle

3.4 Data Analysis

Each crash event identified and attended by the research team was reported using the format in Table 1 below.

TABLE 1: Reporting structure for each case

Accident Narration (Summary of Case)	*Details of the crash event:* Location of crash scene Date and time
Vehicle Information	*Summary of vehicle(s) involved:* Detailed info & specifications Vehicle dimension (post-crash)
Driver Information	Detailed driver (V01) Travel information
Road/Highway Information	Detailed Road/highway scene Detail of lanes and direction
Physical Evidence	Detailed physical crash scene
Injury Information	Detailed occupant injury
EDR Result	EDR data information
Speed Calculation	Detailed info of impact speed calculated by field measurement using Ai Damage calculator
Accident Contributing Factor	Human Factor - Vehicle Factor - Road and Environment

The EDR is a piece of technology located in the Airbag Control Module (ACM) to store the vehicle delta-V. The ACM constantly monitors the vehicle sensors. During a road crash, the sensors alert the ACM which then records the information from up to eight seconds before impact in the memory storage that later can be accessed (downloaded). Nevertheless, the memory will be deleted after a certain period (auto-delete mode).

Following all the procedures, a descriptive analysis was done to summarize the selected fatal crash events involving the EDR-equipped cars.

4. RESULTS AND DISCUSSION

In the study period from 2019 to 2021, the research team was dispatched to investigate 22 fatal crash events involving EDR-equipped vehicles in Malaysia. Using the Crash Data Retrieval (CDR) tools, the research team was able to retrieve valid data in 16 crash cases.

Hence, this section shall comprise an analysis of the 16 fatal crash events involving car models equipped with EDRs to represent a total of 16 drivers' responses in terms of braking reaction, accelerator response, and steering control in a 5-second period before the impact.

4.1 Data Analysis for Drivers' Braking Reaction

As shown in Figure 7, it was revealed the number of fatal cases with drivers applying the brake was greater than those who did not brake, with a percentage of 68.8% (11 drivers) against 31.3% (5 drivers), respectively. In Figure 8, the study indicated most drivers in fatal crashes (36.4%) had applied the brake only one second before impact whereas 9.1% of them did not brake at all.

Based on information in Figure 9, in terms of drivers who applied the brake, 81.82% were in the multi-vehicle crash category whereas 18.18% of the drivers were in the single-vehicle crash category. As for cases where the drivers did not apply the brake, 80% of them were in a multi-vehicle crash whereas another 20% were involved in a single-vehicle crash.

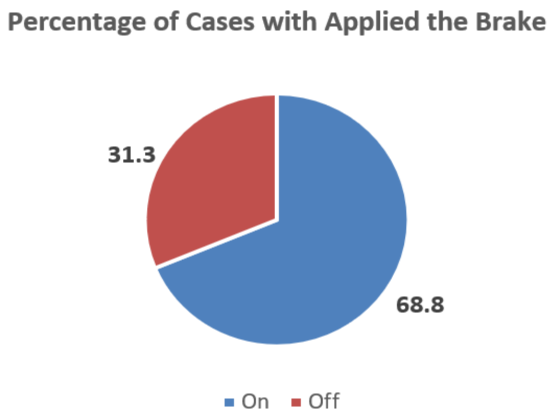

FIGURE 7: Percentage of braking among drivers

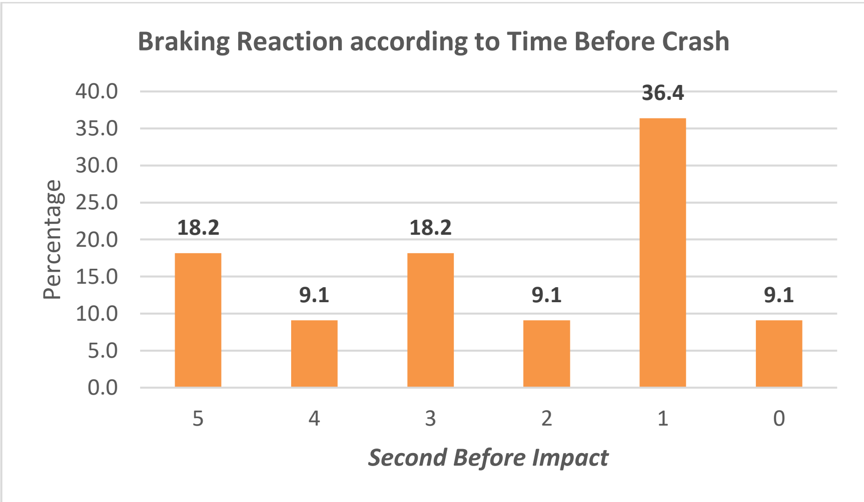

FIGURE 8: Drivers' braking reaction by time before crash

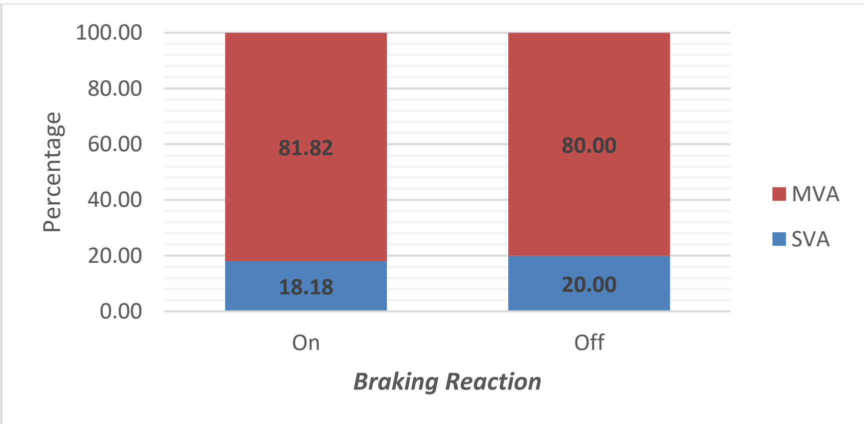

FIGURE 9: Driver's braking reaction percentage - MVA vs. SVA

4.2 Data Analysis for Accelerating Pattern

As depicted in Figure 10, the number of cases where the vehicles decelerated (62.5%) exceeded the cases where the vehicles accelerated (18.75%) or maintained their speed (18.75%). This accelerating and the decelerating pattern was recorded in the 5-second gap before the fatal impact.

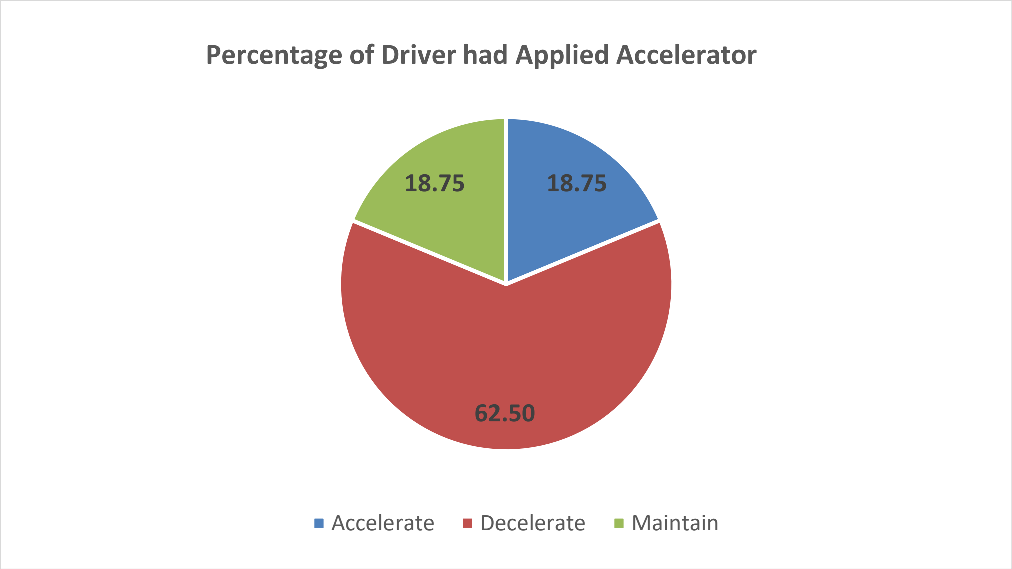

FIGURE 10: Percentage of drivers applying the accelerator

In Figure 11, the finding showed for cases where the vehicles accelerated, most of the drivers (66.7%) had their foot on the accelerator pedal in the two-second gap prior to the impact.

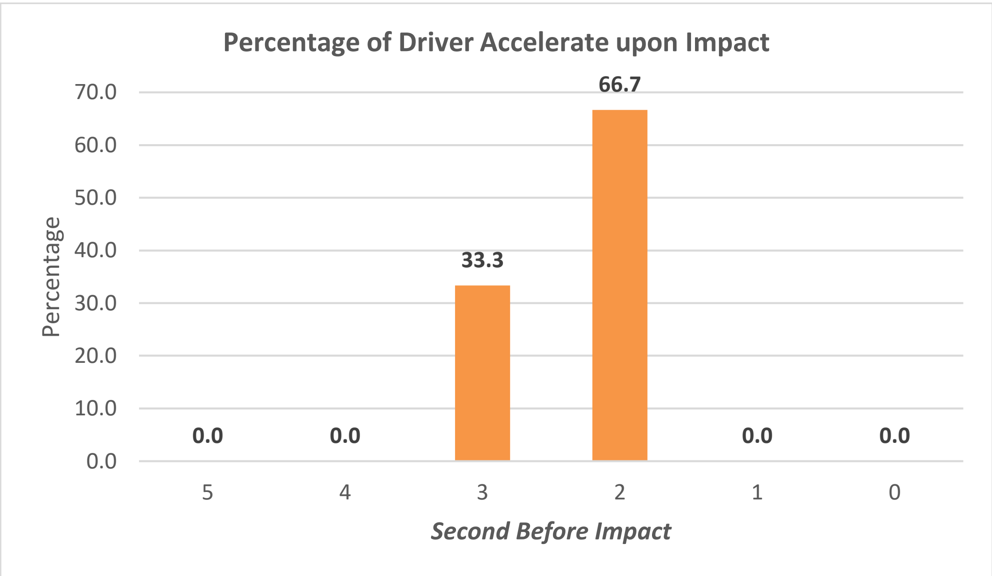

FIGURE 11: Percentage of drivers accelerating upon impact

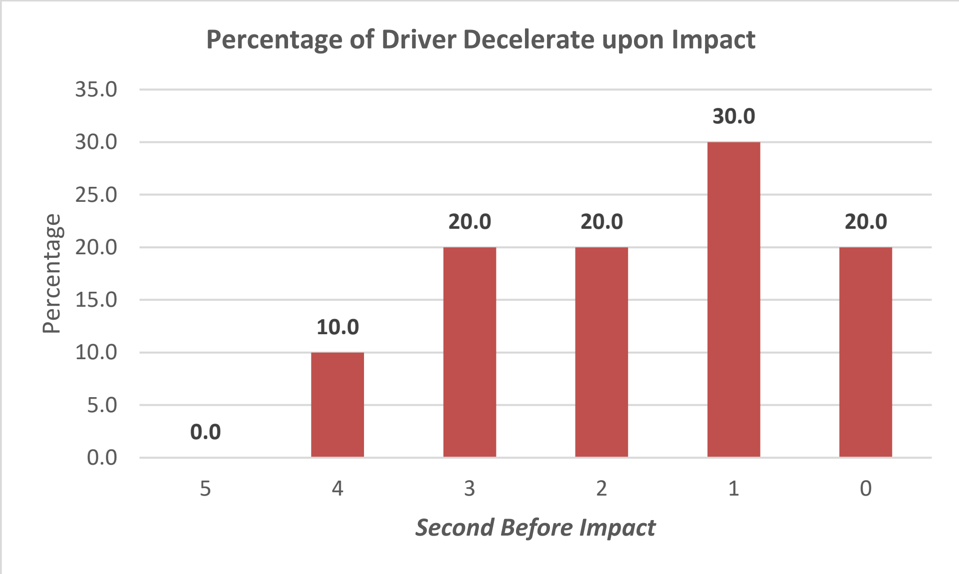

FIGURE 12: Percentage of vehicles decelerating upon impact

As per the percentage in Figure 12, the study also found in cases where the vehicles decelerated, most drivers (30.0%) had released the accelerator pedal in the one-second gap before the crash. Figure 13 illustrates the vehicle accelerating and decelerating pattern in both single-vehicle crashes and multi-vehicle crashes. For cases where the vehicle accelerated, the study showed that 66.7% of the drivers were involved in a single-vehicle crash (SVA) while 33.3% were in a multiple-vehicle (MVA) crash. For vehicle decelerating cases, the data showed 90% of the drivers were involved in MVA whereas another 10% were in the SVA category. As for cases of the vehicle maintaining speed, all the drivers were involved in a multi-vehicle crash.

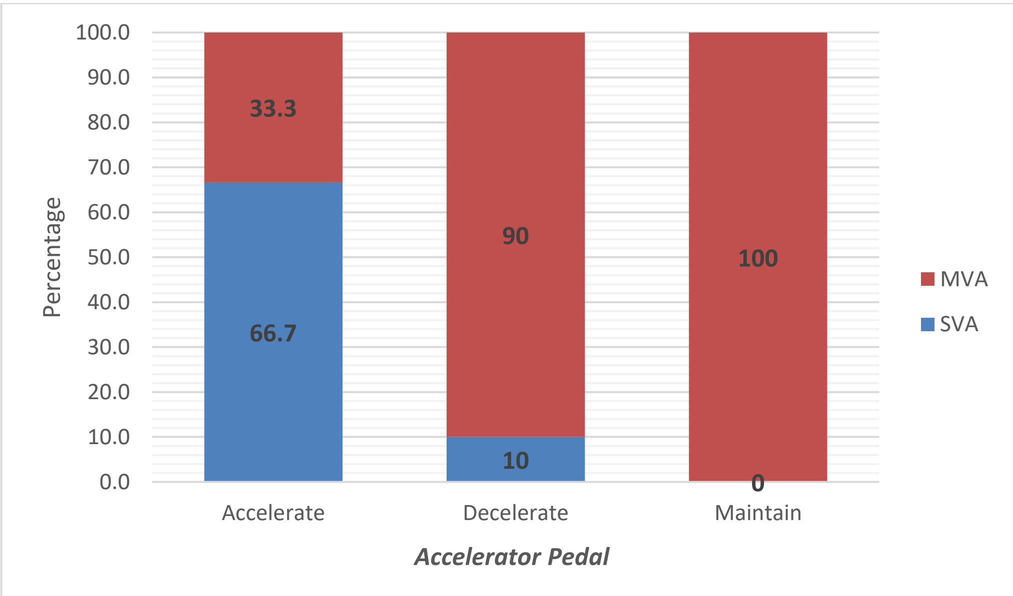

Figure 13: Accelerating and decelerating – MVA vs. SVA

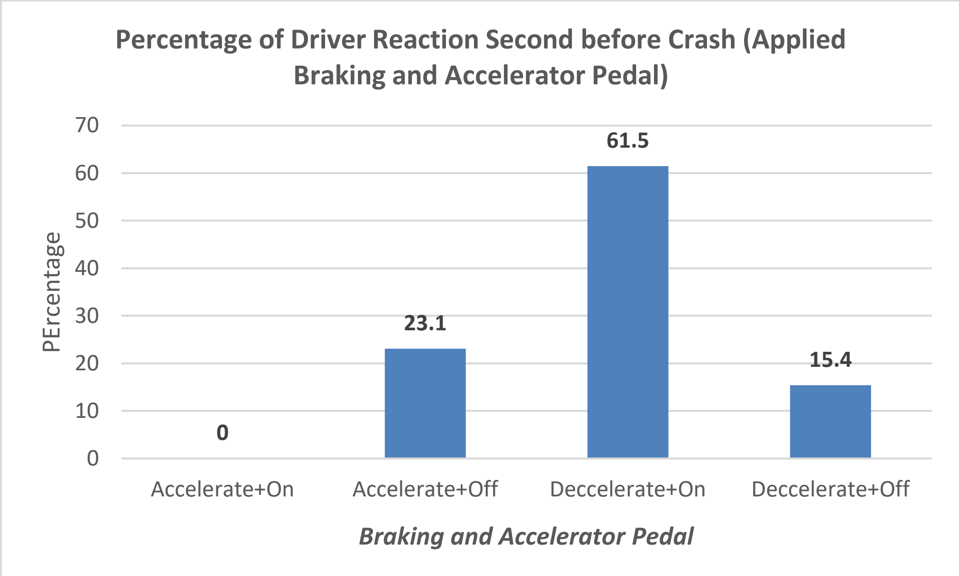

FIGURE 14: Diver's reaction seconds before the crash

Based on information in Figure 14, the study indicated most drivers (61.5%) applied the brake and released the accelerator pedal upon impact, whereas none of the drivers applied the brake and pressed down the accelerator pedal simultaneously. It was also found that 23.1% of the drivers pressed down the accelerator pedal and did not apply the brake upon impact. Finally, the study also revealed that 15.4% of the drivers did not react at all whereby they neither pressed down the accelerator pedal nor applied the brake before crashing.

4.3 Study Limitations

The study included the following limitations. Out of the total 22 fatal crash cases identified within the study period, valid EDR information was only obtained in 16 cases. Thus, an analysis could only be provided on the braking and acceleration data retrieved from EDRs of the vehicles involved in the 16 cases. The drivers' steering control in the 5 seconds prior to the crashes was unable to be analyzed due to insufficient data. Most of the cars were not equipped with an event data recording system to store the steering control input.

Several researchers including Gabler et al. (2004) have mentioned that certain EDRs may not capture all the events in a crash whereas other EDRs were only capable of capturing a single event (such as airbag deployment). Therefore, it would be beneficial if EDRs were designed to record most events including steering input as well as rear impacts, which may not result in the airbag deploying.

5. CONCLUSION

Overall, the research team from MIROS managed to identify several crash events that fulfilled the study requirements. Information from 16 Event Data Recorders (EDRs) representing 16 drivers who had been involved in the fatal crash events was retrieved using CDR tools through the OBD system and the Direct Method. It was revealed the number of fatal cases with drivers applying the brake was greater than those who did not brake, with a percentage of 68.8% against 31.3%, respectively. Further, the number of cases where the vehicles decelerated (62.5%) exceeded the cases where the vehicles accelerated (18.75%) or maintained their speed (18.75%).

The findings, based on the EDR information, are expected to be helpful for crash researchers to assess the effectiveness of certain technologies to further enhance passenger car safety standards in the Southeast Asia region. In the future, more crash studies must be carried out using various methods including the use of EDRs to increase our knowledge and understanding of the causes of and factors in road crashes before proposing suitable measures and interventions to reduce the number of road traffic injuries and deaths.

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