Analysis of Heavy Goods Vehicle (HGVs) Operating Speed Exiting Meru Tunnel

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ABSTRACT

Heavy goods vehicles (HGVs) play a crucial role in the movement of goods within regions and countries. Despite their importance to economic well-being, the increasing volume of HGVs raises safety concerns, as their distinctive characteristics, such as length and mass, significantly influence traffic performance. The Meru Tunnel on the North-South Expressway is a major link for goods transportation in Malaysia, but little is known about HGV operations in this area. This study aims to analyse HGV operating speed and the influence of their proportion in the traffic flow when exiting the tunnel. Spot speed and volume data were collected at two locations, including the tunnel exit and 50 meters ahead. Statistical analyses of the data were performed using Minitab software. Findings revealed that the majority of HGVs adhere to the speed limit of 80 km/h. Moreover, a multiple regression model indicates a reduction in speed with an increasing proportion of HGVs. However, paired t-test findings show no significant speed difference between the two locations. This lack of significance is attributed to high traffic volume during data collection, forcing drivers to be more cautious, resulting less variations in speed. The findings provide valuable insights, that can serve as the basis for practical measures to enhance the safe operation of HGVs in this area.

Keywords: heavy goods vehicle, speed, multiple regression

INTRODUCTION

Heavy goods vehicles (HGVs) are a crucial component of the logistics industry, as they play a significant role in the movement of goods within regions and countries. In the European Union (EU), HGV can be defined as any motor vehicle constructed for the carriage of goods with a gross vehicle weight (GVW) exceeding 3,500 kg (Evgenikos et al., 2016). As of 2022, there were a total of 1,390,676 goods vehicles registered in Malaysia, making up 4% of total vehicle registrations (MOT, 2023). In Malaysia, road traffic crashes involving HGVs are exhibiting an increasing trend. According to statistics from MOT (2020), crashes involving HGVs have increased by 2.65% between 2018 and 2019. Despite minor increments, HGVs are responsible for over 1,000 fatalities each year in this country (Hamidun et al., 2019).

The North-South Expressway stands as the backbone of Malaysia's goods transportation industry, facilitating the seamless movement of goods across the country. An expressway in Malaysia was designed in accordance with ATJ 8/86 (2015). It was designed for long trips and provides a higher speed of travel and comfort. The speed limit for HGVs on Malaysian expressways is set at 90 km/h, while the speed limit for passenger cars is set at 110 km/h. Speed is an essential measurement of traffic performance on the road. Understanding speed and its role is important in assessing the overall performance of a transportation system. One frequently used measure is the 85th percentile of the distribution of observed speed. The percentile serves as an indicator of the typical operating speed associated with a particular location or geometric (AASHTO, 2011).

Despite their importance to economic well-being, the increasing volume of HGVs raises safety concerns. The risky behaviour among HGV drivers, particularly speeding, poses risks to the drivers and other road users. The potential for high-speed collisions involving HGVs may increase, leading to severe consequences due to the massive kinetic energy they have. Furthermore, their presence on expressways will have a significant impact on traffic performance due to their substantial weight and length. These features limit their operational capabilities, resulting in noticeable speed differences compared to other vehicles, thus causing traffic conflict and increasing the risk of collision.

PROBLEM STATEMENT

The Meru Tunnel, located at the North-South Expressway, is a major link for efficient goods transportation. However, the constant presence of HGVs in this area poses a safety concern. Their distinctive characteristics, including substantial size and weight, significantly impact their surrounding traffic. Despite their importance, the operating speed of HGVs and the impact of their proportion in the traffic stream in this area remain unclear. This study seeks to analyse HGVs operating speed when exiting the Meru Tunnel and understand the influence of their proportion in the traffic. Using statistical analysis, the study aims to address these matters, providing insights to enhance road safety and the efficiency of goods transportation.

RESEARCH QUESTION

The growing presence of the HGVs on the road influences traffic conditions. Consequently, two research questions were formulated to address the issue: (1) What is the operating speed of the HGVs at the tunnel exit and 50 meters downstream? (2) How does the proportion of HGVs influence the speed 50 meters ahead of the tunnel exit?

OBJECTIVE

Two objectives of this study were derived based on the research questions: (1) to evaluate HGV operating speed when exiting the Meru Tunnel, and (2) to examine the influence of HGV proportion and speed at the tunnel exit on overall speed 50 meters ahead. Understanding the operating speed of HGVs and their influence is crucial to ensuring safe and efficient traffic flow.

THEORETICAL BACKGROUND AND HYPOTHESES

The traffic condition in Malaysia is mixed traffic, featuring a variety of vehicle types such as passenger cars, motorcycles, buses, vans, and lorries. The presence of HGVs is likely to influence the flow of traffic due to their size and weight, compared to other types of vehicles. Their characteristics will limit their operational capabilities, with respect to acceleration, deceleration, and the ability to maintain speed on upgrades (HCM, 2011).

The speed of vehicles on the road is influenced by various factors, such as the driver’s and vehicle’s performance, geometric design, roadside interference, weather conditions, the presence of other vehicles, and speed limitations (AASHTO, 2011). The transition from a tunnel environment to an open highway will affect driver behaviour. Therefore, the exit point of the tunnel serves as a point where factors such as HGV proportions play a role in determining the speed 50 meters ahead. From the theoretical background, two

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hypotheses were developed to guide data analysis, as follows:

H1: The speed at the tunnel exit significantly influences the speed 50 meters ahead.

H2: An increase in the proportion of HGVs significantly reduces the speed 50 meters ahead of the tunnel.

LITERATURE REVIEW

Speed is a fundamental measurement of traffic performance on the road and is defined as a rate of motion, in distance per unit of time (HCM, 2011). There are different types of speed to measure traffic performance with different terminology, as shown in Table 1:

Table 1: Speed terminology

Type of Speed	**Terminology**
Operating speed	The speed at which drivers are observed operating their vehicles during free-flow conditions. (AASHTO, 2011)
85^{th} percentile speed	The speed of traffic is determined by measuring the speeds of a sizable sample of vehicles, and it is usually within the “pace” or speed range used by most drivers at a particular road location or geometric features (AASHTO, 2011).

Speed is also an important parameter in road safety. Driving at a higher speed may reduce the visual field, restrict peripheral vision, and limit the time available for drivers to receive and process information (AASHTO, 2011). Risky driving behaviour, such as speeding, has been identified as contributing factor to road traffic crashes. According to MIROS (2022), Malaysian drivers tend to drive 20 km/h faster than the allowable speed limit. The situation also applies to HGV drivers. A study by Hashim et al. (2016) on the Federal Highway found that HGVs tend to speed above the speed limit during non-peak hours. This finding is supported by Ho & Manan (2019), who found that 85% of commercial vehicles travelled above the speed limits for different road hierarchies in Malaysia. Speeding among HGVs increases their likelihood of colliding with other vehicles due to their characteristics. A study by Zhu and Srinivasan (2011) revealed that speeding among HGV drivers increased the probability of most severe outcomes by 21.5 %, compared to when the speed limit was obeyed. Collisions involving HGVs result in greater impact due to the unique characteristics of the vehicles themselves. Their distinct characteristics, compared to other types of vehicles, contribute to the severity of crashes. HGV features, such as their size and weight, make them difficult to control, manoeuvre and stop, increasing the likelihood of crash severity (Behnood & Mannering, 2019).

In a traffic stream, each vehicle moves at a different speed, resulting in a distribution of individual speed rather than a single characteristic speed (HCM, 2011). The presence of HGVs introduces a range of speeds within the traffic flow, affecting the overall distribution of speed. Their presence affects the surrounding traffic both physically and psychologically (Zainuddin et al., 2023). A study by Moridpour et al. (2015) found that heavy vehicles have a substantial impact on macroscopic and microscopic traffic flow characteristics such as car-following patterns and lane changing behaviour. Similarly, a study by Hashim et al. (2016) emphasized that speed is one of the traffic parameters that influence the car-following patterns involving HGVs, as they are typically driven at a lower speed compared to other vehicles. Car following decisions are complex as they involve speed-control modification (AASHTO, 2011). The following driver has to assess the speed of the lead vehicle and constantly modify their speed to maintain a safe gap. Moreover, the speed differences between HGVs and other vehicles will lead to lane changing behaviour and frequent overtaking attempts (Chen et al., 2020 and Zainuddin et al., 2023). According to Chen et al. (2020), the increasing proportion of HGVs will make these activities more challenging, thus increasing traffic conflict and the risk of crashes.

Existing literature has found that HGV's presence may have a negative impact on traffic conditions. However, their presence in the traffic stream is inevitable. Therefore, it is crucial to understand the unique characteristics of this type of vehicle and how their proportions influence the surrounding traffic, so that proactive measures can be implemented to mitigate the risks they pose and minimize disruptions.

METHODOLOGY

There are nine tasks to meet the objectives of this study, including identifying site location, collecting spot speed data, and performing statistical analysis. The methodological framework is shown in Figure 1.

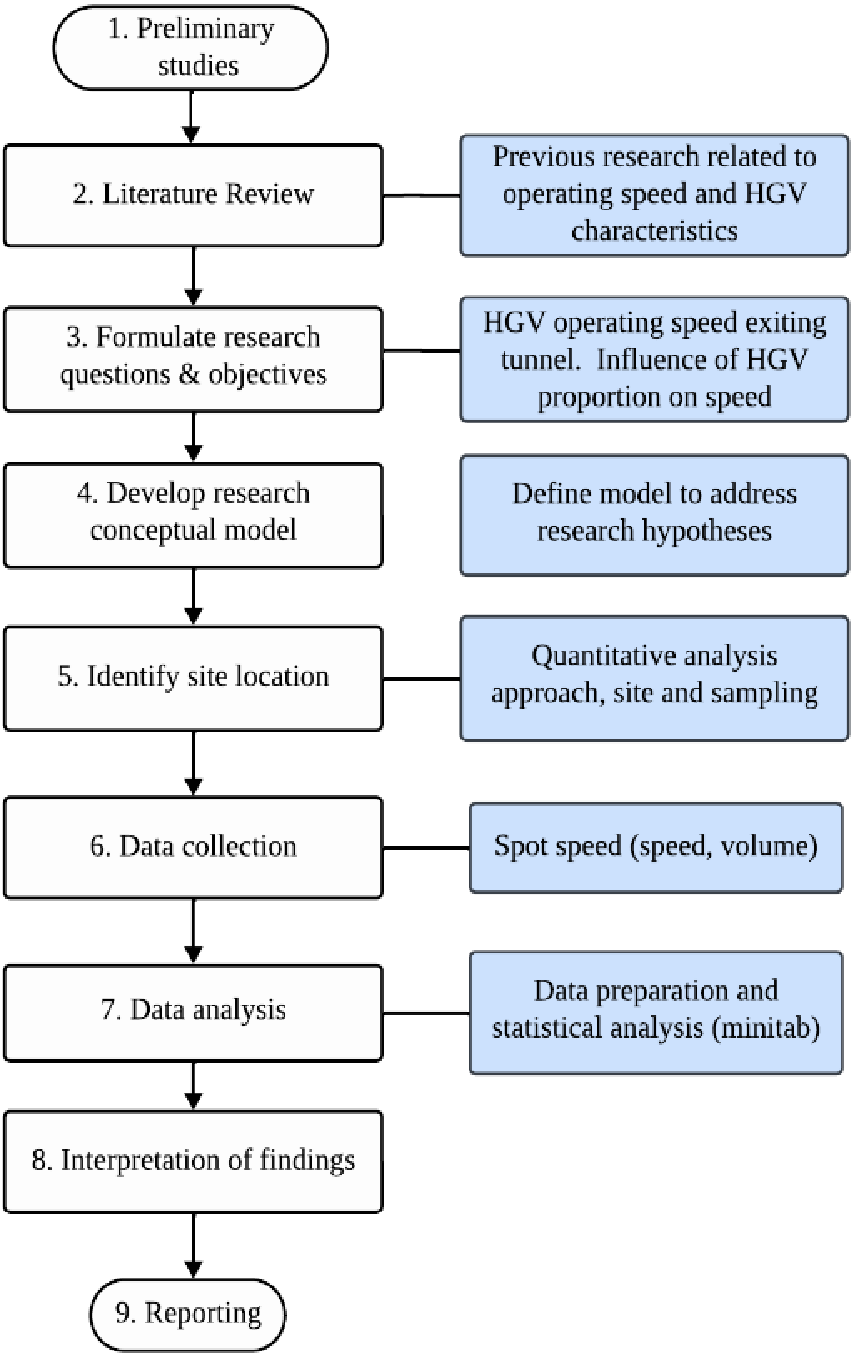

Figure 1: Methodological Framework

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Site location

The location of this study was Meru Tunnel, which is located on the North-South Expressway in Perak. The location was constructed with R6 design standards and features four (4) lanes, two (2) dedicated for each direction. The posted speed limit is 80 km/h, and the length of the tunnel is 800 meters with a clearance of 5 meters.

Data collection

The study was conducted on 16th December 2023, over the weekend, and divided into two sessions, for a total of 75 minutes. The first session went from 12.30 pm to 1.30 pm, and the second session from 1.40 pm to 1.55 pm. Two locations were chosen for this study: 1) Location A: at the tunnel exit, and 2) Location B: 50 meters ahead of the tunnel exit, as shown in Figure 2. Spot speed data was collected for every five-minute interval at each location, differentiated by vehicle classification and lane.

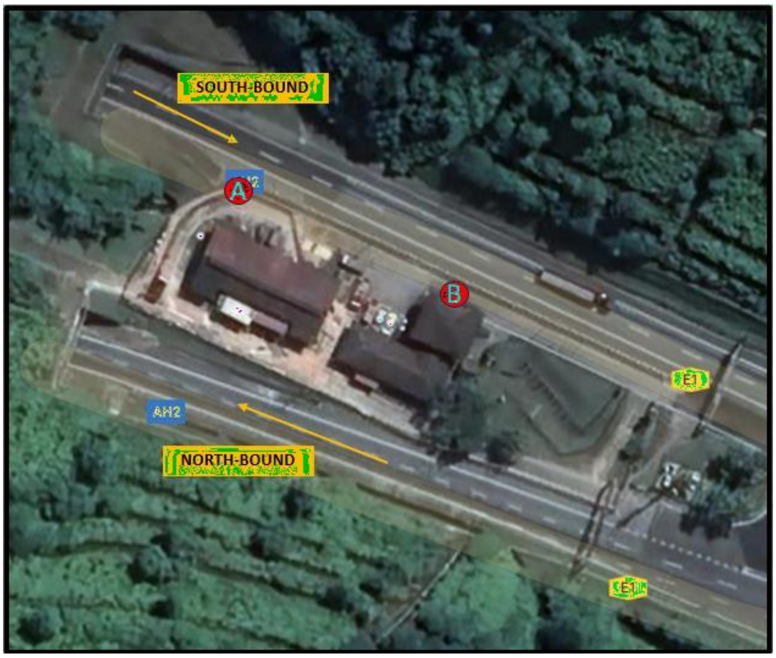

Figure 2: Study location

There are six (6) classifications of vehicles based on the Road Traffic Volume Measure (RTVM) shown in Table 2. Lanes were divided into two, with the first lane situated near the shoulder and the second lane situated closer to the median. Traffic volume data was sourced from the Data (Traffic and Toll) Unit, Department of Traffic Safety, PLUS. The data was gathered from 12.00 pm to 2.00 pm and was categorized into five (5) different classes of vehicles based on definition by PLUS shown in Table 2.

Table 2: Vehicle Classification

Class	Type of vehicle (RTVM)	Type of vehicle (PLUS)
1	Motorcars, taxis, and small MPVs	Motorcars with 2 axles and 3- or 4-wheels excluding taxis
2	Small Vans, big MPVs & utilities (light 2 axles)	Lorries with 2 axles and 5- or 6-wheels excluding buses
3	Lorries & large vans (heavy 2 axles)	Lorries with 3 or more axles
4	Lorries with 3 axles (heavy 3 axles and above)	Taxis

5	Buses	Buses
6	Motorcycles & scooters	NA

For this study, laser meter detectors equipped with LIDAR technology were used for precise data collection. This instrument emits invisible pulses that bounce off approaching vehicles and instantly calculate their speed based on the reflected light's time of return. The laser meter detector used for this study is shown in Figure 3.

Figure 3: Laser meter detector

Data analysis

HGV is classified into class 3 and 4, according to the RTVM. For this study, speed data for both of these classes will be utilized for the analyses. Based on the data collected, most HGVs occupied the first lane. Due to data constraints, only data in Lane 1 will be assessed for this study. Traffic volume data showed that the percentage of HGVs (class 2 and 3) during the data collection period ranges between 5% and 7%. These percentages were used to identify the relationship between HGV proportion and speed. The statistical software named Minitab 21.0 was utilized to meet the objectives of the study. Multiple linear regression shown in equation (1), is a statistical technique used to analyse the relationship between a single dependent variable (Y) and several independent variables (X) (Minitab, 2017). The variables for this study are set below:

$$Y = \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_P X_P + \varepsilon \qquad (1)$$

Where;

Y = Speed at Location B

X_1 = Speed at Location A

X_2 = HGV proportion

RESULT AND ANALYSIS

Descriptive statistics

The following abbreviations are used in the process of data analysis:

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HGV = HGV proportion

GV_A = HGV speed at location A

GV_B = HGV speed at location B

V_A = speed at location A

V_B = speed at location B

Before further analysis was performed, the data was screened by removing any ambiguities and problematic data. Some of the issues during data collection were due to instrument malfunctions and adverse weather conditions. Then, the descriptive statistical analysis was run to find the value of skewness and kurtosis, making sure the data were normally distributed. The value of the ideal condition for a perfectly symmetrical distribution is close to 0. However, the range of -2 to +2 is acceptable, as it suggests slight asymmetry but may not significantly impact normality for statistical tests. Based on the results of the descriptive statistical analysis shown in Table 3, the skewness and kurtosis are within the acceptable range, which is between -1.40 and 1.41.

Table 3: Descriptive statistical analysis result

Variable	N	Mean	SE Mean	StDev	Min	Med	Max	Skewness	Kurtosis
GV_A	126	57.68	0.823	9.24	32	57.5	91	0.16	1.41
GV_B	92	57.1	1.06	10.21	34	58	82	-0.39	0.12
V_A	11	60.56	1.18	3.91	52.07	61.43	66.13	-0.95	1.18
V_B	11	63.526	0.621	2.061	60.9	63.53	66.33	0.25	-1.40

HGV operating speed

Results for the descriptive statistical analysis of HGV speed are shown in Table 3. A total of 218 HGVs were observed at both locations. From the analysis, the minimum and maximum GV_A were recorded at 32 km/h and 91 km/h, respectively. For GV_B, the minimum was recorded at 34 km/h and 82 km/h. The mean speed of GV_A is 57.68 km/h, while GV_B is 57.1 km/h. The findings show that most HGVs obeyed the speed limit of 80 km/h at the locations. The HGV cumulative frequency distribution of speed for each location was plotted to determine the 85th percentile speed, as shown in Figure 4 and Figure 5. From the graph, the 85th percentile speed at location A is 64 km/h and location B is 64.3 km/h.

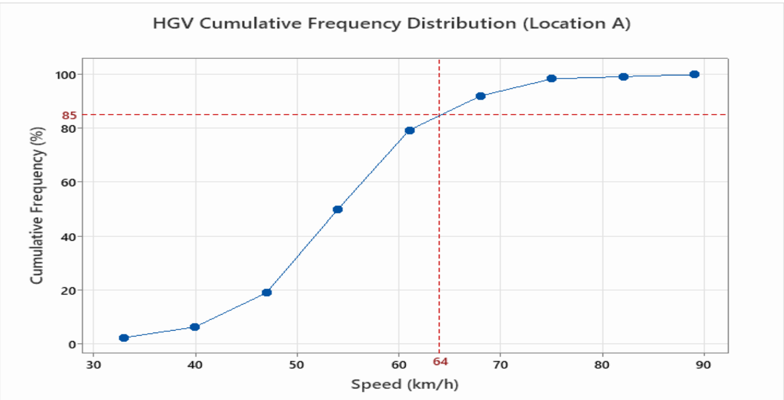

Figure 4: HGV 85th percentile speed at Location A

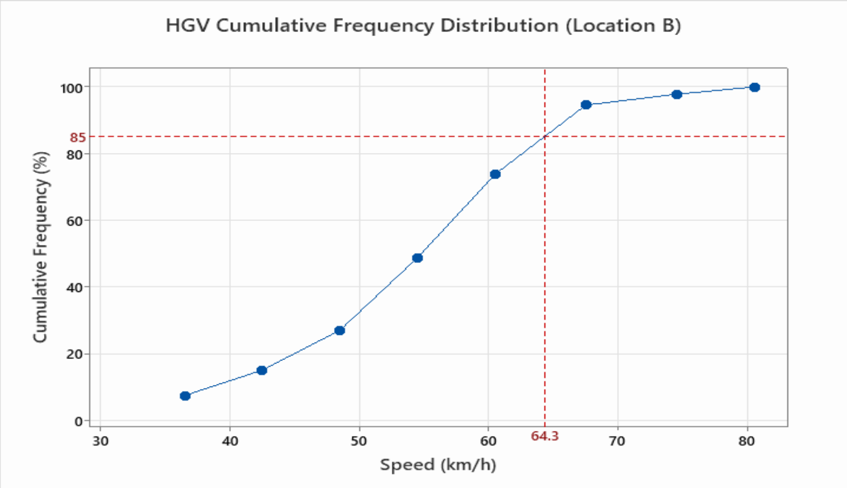

Figure 5: HGV 85th percentile speed at Location B

The influence of HGV proportion

The analysis of the relationship between V_A, V_B, and HGV proportions was modelled using the multiple linear regression technique shown in equation (1). The hypotheses are set as follows:

H_0 = There is no correlation between independent and dependent variables

H_1 = There is a correlation between independent and dependent variables

The result of multiple regression is shown in equation (2) and Table X. The R-squared value for the equation is 0.586. The result for the coefficients found that the p-values for both independent variables are greater than 0.05. Therefore, the null hypothesis, H_0 is accepted, showing that there is no correlation between independent and dependent variables.

$$V_B = 50.42 + 0.237\ V_A - 0.426\ HGV \quad (2)$$

Table 4: Regression analysis result

Term	Coef	SE Coef	T-Value	P-Value	R-Sq. (%)
Constant	50.42	5.50	9.17	0.001	58.59%
V_A	0.237	0.0996	2.38	0.076	
HGV	- .426	0.421	-1.01	0.369	

The mean difference

Further analysis was performed with a paired t-test to determine if there was a statistically significant difference between V_A and V_B. The hypotheses are set as follows:

H_0 = The mean difference between the paired is equal to zero

H_1 = The mean difference between the paired is not equal to zero

Table 5 shows the result of the test, where the p-value obtained is less than 0.05. Therefore, the null hypothesis, H_0 is accepted, suggesting that the speed difference between V_A and V_B is not statistically significant.

Table 5: Paired T-Test result

Sample	N	Mean	StDev	SE Mean
V_A	11	60.56	3.91	1.18
V_B	11	63.53	2.06	0.62
T-Value	-2.50			
P-Value	0.031			

DISCUSSION

To meet the first objective of the study, the operating speed of HGVs at both locations was evaluated. Recorded HGV speed ranging from a minimum of 32 km/h to a maximum of 91 km/h, indicating variability in HGV speed at both locations. Despite this variability, the mean speed at both locations remained below the speed limit of 80 km/h, indicating that the majority of HGV drivers adhere to the posted speed limit. However, the result contradicts the findings from Hashim et al. (2016) and Ho & Manan (2019). The contradiction suggests that factors such as study location and environmental conditions could play a significant role in influencing HGV's speed behaviour. Furthermore, the 85^{th} percentile speed at both locations ranges from 64 km/h to 64.3 km/h, suggesting that the majority of HGVs operate at speed comfortably below the speed limit, contributing to a consistent and controlled traffic flow.

The second objective aims to examine the influence of HGV proportions and speed at the tunnel exit, to the speed 50 meters ahead. The objective was addressed through the application of multiple regression analysis. The model is represented in equation (2), which shows a positive coefficient for V_A and a negative coefficient for HGV. This indicates that an increase in speed at the tunnel exit (location A) leads to an increment in speed downstream (location B), while the increasing proportion of HGVs leads to a reduction in the speed downstream of the tunnel exit (location B). This relationship aligns with the hypotheses developed for this study. However, the p-value (< 0.05) resulting from the model indicates a lack of significant correlation between the variables. The insignificance might be due to the limited sample size of the data used in the analysis.

The paired t-test was performed to further assess the significance of the mean speed difference between V_A and V_B, as per the first hypothesis. The p-value (< 0.05) obtained suggests that the speed at these locations was statistically insignificant, with a small mean speed difference of 2.97 km/h between V_A and V_B. The lack of significance could be related to the data collection period, which occurred at the beginning of the school holiday. High traffic volume was observed, causing drivers to be more cautious and maintain similar speed, resulting in smaller variations in speed between the locations. Moreover, the short distance between the two locations, which is 50 meters, might be too short to capture distinct speed changes.

CONCLUSION

Two objectives related to HGV operations at Meru Tunnel were formulated for this study. An evaluation of the HGV operating speed at this location found that the majority of HGVs adhere to the posted speed limit, which is 80 km/h. In addition to that, the multiple regression model (equation 2) aligns with the expectations of this study. The findings indicate that an increasing proportion of HGVs cause a reduction in speed, which could potentially lead to the car following and lane changing behaviour, as suggested by Hashim et al. (2016) and Moridpour et al. (2015). Even though statistical significance was not achieved for the speed differences between the point of tunnel exit and 50 meters ahead, the observed trend and influence of HGV proportions still provide valuable insights. Therefore, it is recommended for future research with a larger data sample and longer distances to help clarify the relationship between HGV proportion and speed changes in this area.

In conclusion, the study's findings offer a comprehensive understanding of the HGV operations at Meru Tunnel. It is also important to note that the speed of vehicles is not only influenced by the driver and vehicle's performance but by various other factors as well. The consistent presence of HGVs in this area raises safety concerns, requiring strengthening the enforcement and monitoring activities. The installation of an automated speed enforcement camera might serve as a practical measure to effectively mitigate potential risks associated with HGV operations and promote a safer environment at the Meru Tunnel.

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