Traffic Speed and Occupancy Occurrence on the Urban Expressway between Southbound and Northbound

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Abstract

Economic growth in developed nations often leads to a surge in transportation needs, particularly in large cities. This can manifest as increased accident rates, environmental degradation, social strain, and most notably, traffic congestion. Addressing these challenges requires a multifaceted approach, balancing social, environmental, and economic considerations while prioritising public safety and health. The study contributes to the search for solutions by investigating traffic flow patterns on urban expressways. The research compares southbound and northbound lane speeds, analysing the relationship between speed and vehicle occupancy in both directions. By leveraging secondary quantitative data collected over seven consecutive days with Speedlane Pro™ Counter Classifier radar technology, the study aims to identify potential causes of congestion. It is expected that the northbound lanes may experience higher traffic volume and greater variability compared to the southbound lanes. This research can inform traffic management strategies and contribute to reduced congestion in urban areas.

1.   Introduction

The expressway is one of the infrastructural structures in the transportation system that serves essential functions such as connecting locations to enable accessibility, mobility, and various benefits. Despite the insufferable traffic flow on the major highways in Klang Valley, the growth of the highway construction industry in Malaysia has escalated rapidly, thus increasing and resulting in a variety of serious problems on the highways, including traffic congestion. Other factors that can cause or intensify traffic congestion include population growth, economic growth, increased vehicle count, low road capacity, poor city planning and supervision, accidents, and natural factors (Ai et al., 2020).

Given the several reasons that contribute to traffic congestion, traffic congestion is commonly classified into two types: recurrent traffic congestion (RC) and non-recurrent traffic congestion (NRC). RC is a sort of traffic

congestion that happens often or regularly. One illustration is when busy times, such as those in the morning and evening, are what cause the traffic congestion itself. On the other hand, accidents, roadwork, special events, or bad weather are what cause non-recurring traffic congestion (NRC) (Sun et al., 2017). The NRC traffic congestion issue is a dynamic and complicated occurrence. NRC leaves people unprepared and has a significant impact on urban mobility in contrast to regular congestion, which frequently happens during peak travel times when the number of vehicles is simply beyond the capacity of the road design.

Furthermore, traffic congestion is a global phenomenon that is expected to worsen in the future. Not only may the traffic congestion be a cause for concern for Malaysia's economy, but it will also impact the society of varying ages and individual well-being (Vencataya et al., 2018). Congestion may result in financial losses that may trigger a country's economic development owing to unproductive and unreliable time on the road. In their previous article, Vencataya et al. (2018) claimed that traffic congestion causes commuters to arrive late at work, which reduces production and lowers productivity. This has had a particular impact on businesses that have implemented the fast services system, as it is difficult to make effective fast delivery (Kesuma et al., 2019).

In terms of society and individuals, traffic congestion has been said to affect people's social lives, as they are entitled to avoid traffic by starting their morning journey early in the morning and later than peak hours in the evening. Air pollution that is triggered by road congestion due to the static movement of vehicles on the road can also impact the health of an individual. For example, commuters who are suffering from asthma or other respiratory problems may be prone to more serious diseases because of it. To add to that, unmoving vehicles also led to non-material losses such as time and opportunity lost, mainly attributed to the psychological impact of considerable stress on human life. If neglected, traffic congestion would not only impair project productivity, but it would also reduce a country's competitiveness (Kocatepe et al., 2017).

Despite existing research on traffic congestion, a gap remains in understanding how traffic speed and occupancy specifically affect congestion in Klang Valley's urban expressways. This lack of knowledge highlights the urgency of addressing the steadily increasing traffic congestion, considering its significant negative impacts on the economy, society, and individuals. Traditionally, traffic management assessments have relied on common indicators like traffic volume and travel time, often due to limitations in data collection methods. This study aims to contribute to a more comprehensive understanding by investigating the relationship between speed, occupancy, and congestion on Klang Valley expressways (Syed Abbas et al., 2022a). To address traffic congestion in Klang Valley, this study utilises advanced radar technology. The Speedlane Pro™ Counter Classifier measures both traffic speed and occupancy, providing valuable data for congestion evaluation on urban expressways. This approach aligns with recent research by Syed Abbas et al. (2022b), who explored a new methodology for traffic data collection on multi-lane highways in Malaysia using similar radar technology. Their preliminary findings serve as a foundation for further research and development, benefiting professionals and researchers dedicated to improving traffic data collection, monitoring, and analysis, particularly for local urban expressways in Malaysia.

2.   Methodology

The study concentrated on assessing the speed and occupancy of the urban expressway, giving importance to monitoring and collecting data. Historical data was processed to create a database for studying the impact of traffic speed and occupancy on congestion under normal conditions. Below, Figure 3.1 displays a flow diagram illustrating the data gathering and measuring process for analysis.

2.1   Site Selection

The study area is a section of the urban expressway, Lebuhraya Damansara-Puchong (LDP), spanning approximately 40 km to connect various neighbourhoods in Kepong, Bandar Sri Damansara, Bandar Utama, Taman Tun Dr. Ismail, Petaling Jaya, Sunway, Subang Jaya, Puchong, and Shah Alam. The chosen research

site is in Subang Jaya, Selangor, specifically indicated as Location 1 in Figure 2. This location features four southbound lanes (from Subang Jaya to Putrajaya) and three northbound lanes (from Putrajaya to Subang Jaya). The study area has characteristics of mixed traffic flow, accommodating all vehicle types on the same road. The analysis considered both weekdays and weekends as the time frame for evaluating traffic flow on this urban expressway.
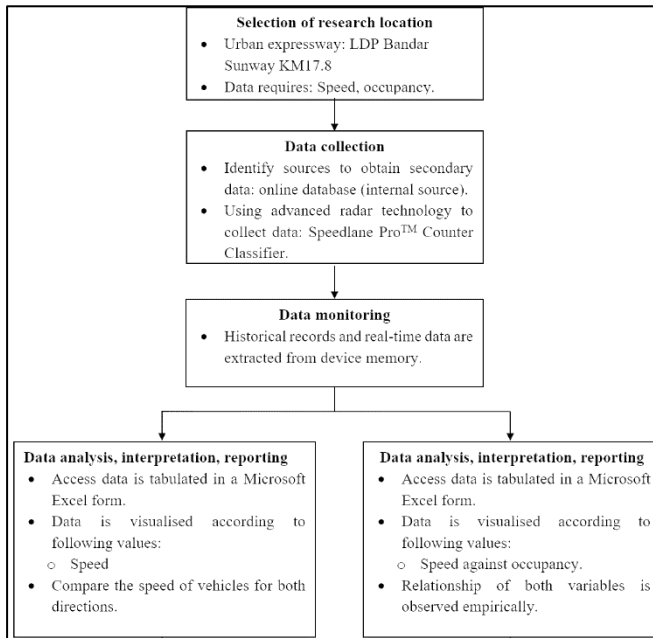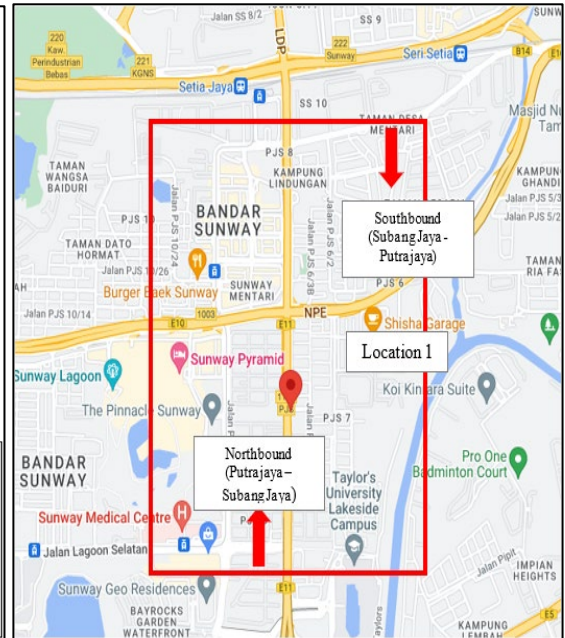

Figure 1. Methodological framework.

Figure 2. Map of Damansara-Puchong Expressway, LDP (Google Maps, 2022)

2.2   Overview of Speedlane Pro^{TM} Counter Classifier

The study utilised the Speedlane Pro^{TM} Counter Classifier, shown in Figure 3, to collect, monitor, and analyse traffic data parameters. This equipment operates 24/7, recording individual vehicle lanes, speeds, and classifications. Its precise dual beam and low-power frequency enable the detection of different cars at varying speeds and the computation of up to 16 lanes in both directions simultaneously.

The collected traffic data, available in real-time and historically, is stored in the device memory. Users can remotely access the device via any internet connection, generate and share reports for evaluation, and monitor interference and battery power. Adjusting the radar position is sometimes possible to eliminate false targets created by beam bounce and multi-pass propagation. This can be done by moving the false targets outside the user-defined lanes or those in the opposite direction. Figure 4 shows the equipment set up on-site.

Side-fire radar in multi-lane systems needs a clear view of traffic. Therefore, it should be mounted higher than the tallest vehicles in nearby lanes. An exception is when only the closest lane (turn lane or exit) is detected, as visualised in Figure 5 (Houston Radar, 2018). In such cases, the radar can be positioned at target height and aimed sideways. This also applies to areas with very low traffic and a minimal chance of cars in neighbouring lanes.

According to the True Dual Beam Side-Fire Traffic Sensor and Collector User Manual and Installation Guide (Houston Radar, 2018), the radar beam should be positioned 90 degrees to the road, directed across the traffic. Avoid deviating from this angle, as it significantly limits signal intensity. Typically, radars are placed in a side-firing position at a 90-degree angle to the road, covering one or more lanes. This mode is essential for effective traffic detection at average highway speeds. During installation, ensure the secure placement of the Speedlane Pro, avoiding wind-affected support structures, as shown in Figure 6, as swaying can impact radar performance by altering the field of vision.

Figure 3. Speedlane Pro^{TM} Counter Classifier Device.

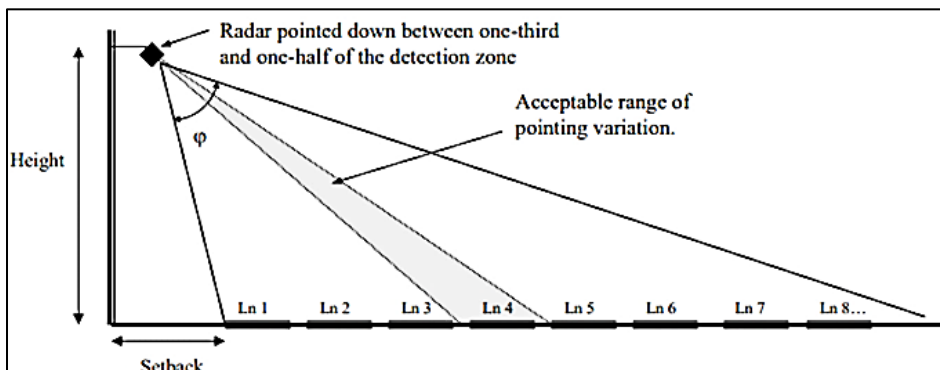**Figure 4.** Installation location of the device.

Figure 5. Height of device installation (Houston Radar, 2018).

Figure 6. Installation of the mounting bracket (Houston Radar, 2018).

3. Results and Discussion

3.1 Vehicle Speed Comparison on the Southbound and Northbound Urban Expressway

Based on Figures 7 and 8, the graph displayed a comparison of traffic speed patterns for three major lanes during the week using a bar graph in southbound and northbound. On a weekday, the road traffic from Subang Jaya to Putrajaya has an adaptable characteristic of traffic speed ranging from 79 to 89 km/h on a fast lane, 69 to 75 km/h on a middle lane, and 54 to 61 km/h on a slow lane.

The discrepancies between these three lanes on weekdays reveal a minor gap due to the consistent speeds between each lane, indicating that traffic flow remained uninterrupted. It means that congestion is minimal or nonexistent at this specific site. However, it is crucial to note that traffic conditions can change promptly and grow due to a variety of circumstances, so uninterrupted traffic flow in one instant does not ensure its absence in the near future. On Saturday and Sunday, the speed values for all three lanes are slightly higher than the rest of the day, and the fact that the fast lane speed value almost reaches the federal road speed limit of 90 km/h indicates that traffic was cleared, causing road users to speed out of the city and away from the business centre. As a result, the fast lane speed is 94 km/h. Aside from that, it is evident that the southbound road traffic is smoother because the majority of businesses are largely conducted in the city.
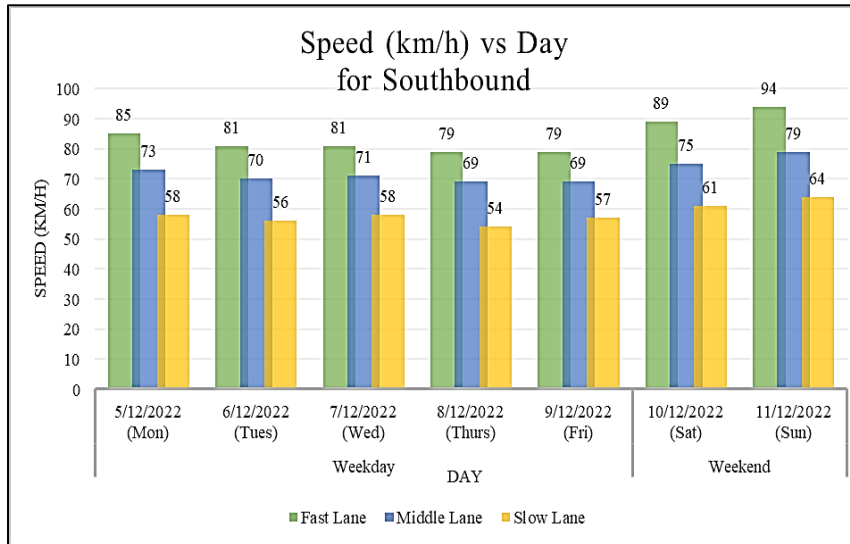
Figure 7. Comparison of southbound speed traffic analysis for a week.

Meanwhile, on the northbound route from Putrajaya to Subang Jaya, it appears that both weekday and weekend speed values are slowing down. The changes between the lanes from Monday to Sunday are insignificant, since all three major lanes have very comparable low speeds ranging from 55 to 65 km/h on the fast lane, 55 to 60 km/h on the middle lane, and 54 to 58 km/h on the slow lane.

According to the Malaysian Institute of Road Safety Research (MIROS, 2023), a 50 to 60 km/h speed applies in urban areas where the urban speed limit indicates that drivers should expect turning, slowing, or stopping vehicles. As a result, the slower-moving traffic for all lanes heading to Subang Jaya may be due to the presence of access points such as intersections, which result in more frequent disruptions and slower speeds, leading to congested conditions. Subang Jaya's heavily populated location and convenient location as a suburban link between two of Klang Valley's most recognised cities, Subang Jaya and Petaling Jaya, also contribute to this.
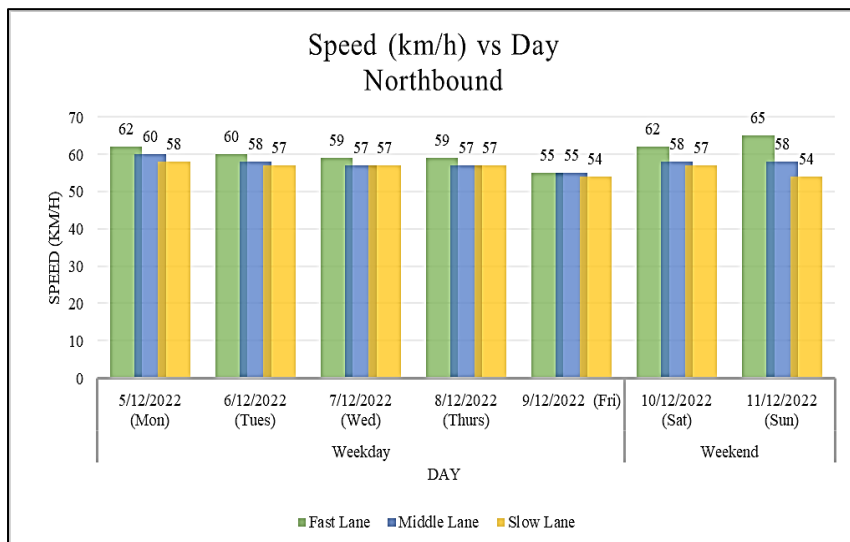

Figure 8. Comparison of northbound speed traffic analysis for a week.

3.2   Relationship of Speed and Occupancy on the Southbound and Northbound Urban Expressway

The scatter plot graph in Figure 9 shows that the speed and occupancy values are negatively associated, which implies that the speed value falls as the occupancy percentage increases. The trendline for all three southbound (Subang Jaya to Putrajaya) lanes is best fitted with R^2 values of 0.92, 0.89, and 0.87 for each fast lane, middle lane, and slow lane, respectively. The variations in occupancy account for 92% of the changes in vehicle speed in the fast lane, 89% in the intermediate lane, and 87% in the slow lane. This information indicates that the occupancy level for these lanes is low, allowing cars to drive smoothly as there are fewer disruptions on the road. That being said, the remaining variability may be influenced by other variables such as road type, road design and surroundings, road user behaviour, and so on.
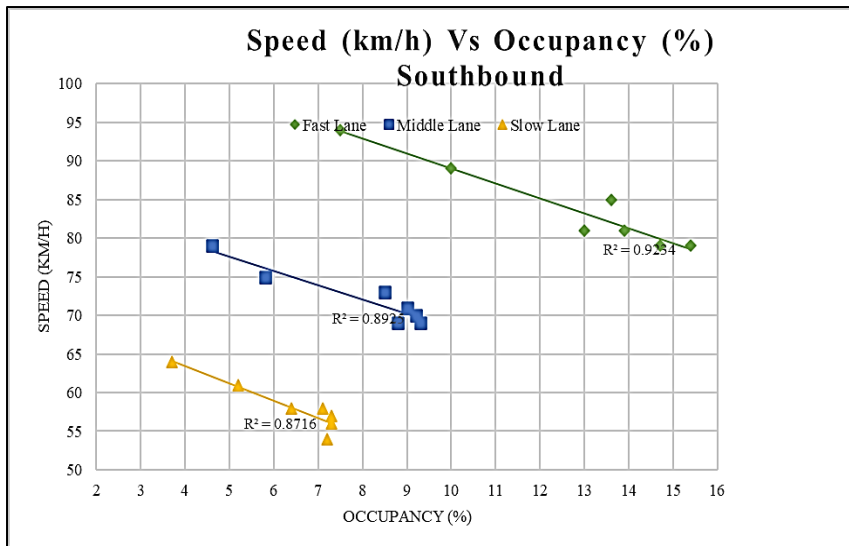

Figure 9. Speed and occupancy relationship for each lane in the southbound direction.

In Figure 10, the R^2 values for the three lanes vary: 0.85 for the fast lane, 0.20 for the intermediate lane, and 0.41 for the slow lane. This indicates that changes in occupancy account for 85% of variations in vehicle speed in the fast lane. However, the intermediate lane and slow lane had smaller percentage changes of 20% and 41%, respectively. This suggests that more than half of the scattered pattern may be limited when traffic is heavy, since the observed speeds are very different from what was expected. The data highlights that increased occupancy levels can impede the acceleration and merging process for vehicles entering intersections or changing lanes. Slower speeds may occur as vehicles wait for an opportune moment to enter or merge into traffic. Consequently, due to access points, the centre lane for northbound traffic appears to move at a reduced speed.
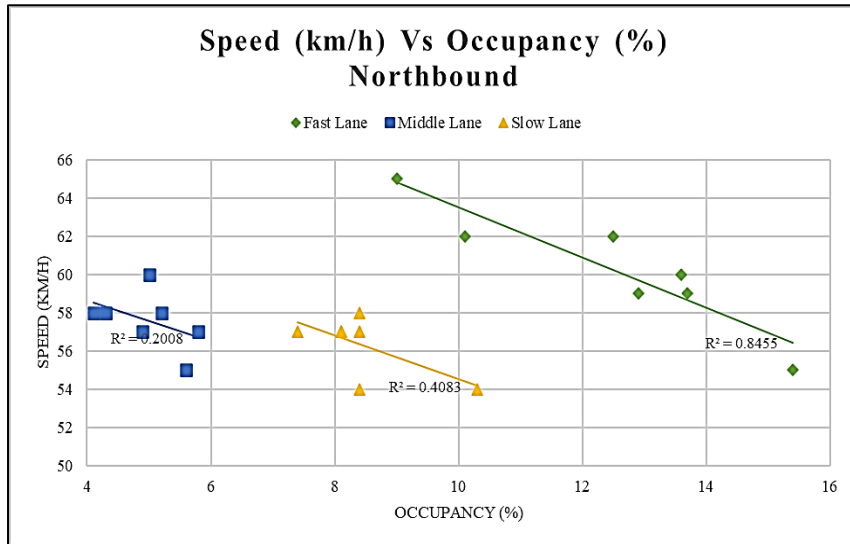
Figure 10. Speed and occupancy relationship for each lane in the northbound direction.

4.   Conclusion

This study investigated the speed and occupancy characteristics of traffic flow on an urban expressway, comparing southbound and northbound directions. Our primary objective was to identify any significant differences in vehicle speeds between the two directions and to understand the relationship between speed and occupancy in each direction.

Following that, the R^2 value was used to evaluate the link between speed and occupancy on an urban expressway in both directions. According to the results, occupancy on all southbound lanes is adversely correlated throughout the week.

However, because traffic lights frequently stop the expressway's traffic flow and because cars frequently brake, halt, and accelerate, the occupancy percentages of the middle lane and slow lane for northbound traffic vary significantly. Knowing that traffic flow was determined by the number of cars entering the zone, traffic and highway experts may have a better understanding of traffic behaviour and be able to apply traffic statistics to any future safety-related planning.

Hence, the study successfully achieved its primary objective of assessing vehicle speeds in both directions on an urban expressway. Identifying the side of the expressway experiencing more significant traffic issues can aid policymakers in pinpointing specific locations contributing to road congestion and formulating appropriate mitigation strategies.

5.   Future Research

Future research could enhance this study's findings and applicability to various related studies: -

1. Analyse data in finer time windows. Traffic trends can be unpredictable due to unforeseen events. Therefore, future research could analyse data in smaller increments, such as hourly intervals for a month. This would reveal how traffic patterns change throughout the day and how management strategies impact them. This deeper understanding can contribute to improved traffic reliability and the development of more effective traffic management plans.

2. Include additional traffic flow parameters. Analysing additional parameters, such as traffic volume, would further enrich the study. This information would provide a clearer picture of congestion levels on the highways, allowing for a more comprehensive understanding of traffic dynamics.
3. Expanding the study area. Collecting occupancy data across a wider area would provide valuable insights. This could reveal patterns in vehicle accumulation and their impact on traffic flow. Identifying these patterns could inform strategies to restrict vehicle entry into congested zones at specific times.
4. Analysing occupancy data in detail. Integrating occupancy data from the Speedlane Pro^{TM} Counter Classifier would provide a deeper understanding of traffic density. This data could reveal gaps in our current understanding of traffic flow dynamics, allowing for more targeted research in the future.

Acknowledgments

Declaration of Conflicting Interests

All authors declare that they have no conflicts of interest.

References

Ai, C., Jia, L., Hong, M., & Zhang, C. (2020). Short-Term Road Speed Forecasting Based on Hybrid RBF Neural Network with the Aid of Fuzzy System-Based Techniques in Urban Traffic Flow. *IEEE Access*, 8, 69461–69470. https://doi.org/10.1109/ACCESS.2020.2986278

Houston Radar. (2018). SpeedLane ® Pro. May 1–50.

Kesuma, P. A., Rohman, M. A., & Prastyanto, C. A. (2019). Risk analysis of traffic congestion due to problem in heavy vehicles: A concept. *IOP Conference Series: Materials Science and Engineering*, 650(1). https://doi.org/10.1088/1757-899X/650/1/012011

Kocatepe, A., Ozguven, E. E., Vanli, A., & Moses, R. (2017). Analysis of Speed Patterns on Inter-urban Parallel Highways: A Case Study in the Southeast Florida. *Transportation Research Procedia*, 22(2016), 479–488. https://doi.org/10.1016/j.trpro.2017.03.064

MIROS. (2023). *MRR No. 509 Speed Characteristics on Different Types of Roads in Malaysia*. Malaysian Institute of Road Safety Research (MIROS) Kajang, Selangor.

Sun, F., Dubey, A., & White, J. (2017). DxNAT - Deep neural networks for explaining non-recurring traffic congestion. *Proceedings - 2017 IEEE International Conference on Big Data, Big Data* 2017, 2018-Janua, 2141–2150. https://doi.org/10.1109/BigData.2017.8258162

Syed Abbas, S. K., Md Diah, J., Adnan, M. A., & Rosli, A. Y. (2022a). An overview of speed model study under different types of facilities in Malaysian roadway system. *IOP Conference Series: Earth and Environmental Science*, 1022(1). https://doi.org/10.1088/1755-1315/1022/1/012029

Syed Abbas, S. K., Md Diah, J., Adnan, M. A., & Rosli, A. Y. (2022b). A New Methodology Traffic Data Collection on Multi-Lane Traffic Measurement using Radar Technology at Malaysian Urban Expressway. *MRC 2022 Conference Proceeding*.

Vencataya, L., Pudaruth, S., Dirpal, G., & Narain, V. (2018). Assessing the Causes & Impacts of Traffic Congestion on the Society, Economy and Individual: A Case of Mauritius as an Emerging Economy. *Studies in Business and Economics*, 13(3), 230–242. https://doi.org/10.2478/sbe-2018-0045