EASTJ Engineering, Agriculture, Science and Technology Journal

e-ISSN: 2948-4065
Volume 3 Number 1 July 2025, 15 ~ 22
DOI: https://doi.org/10.37698/ea7d5n59

Radar Technology Advancements in Traffic Data Collection in Malaysian Urban Expressway

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ARTICLE INFO

Article history:

Received May 05, 2025
Revised Jun 06, 2025
Accepted Jul 15, 2025

Keywords:

Radar technology,
Traffic data collection,
Urban Expressway,
Speedlane ProTM,
Multi-Lane

Clonflict of Interest:

None

Funding:

None

ABSTRACT

Today, given the rapid global population growth and increased urban infrastructure development, the task of collecting, monitoring, and analyzing traffic data has become increasingly challenging. Highway practitioners are tasked with ensuring that the capacity design, planning, monitoring, and operational analysis of existing and future expressways are sustainable, allowing for accurate transportation infrastructure assessments suitable for local conditions. This paper introduces a new methodology for collecting, monitoring, and analyzing traffic data on multi-lane roads using advanced radar technology known as the Speedlane ProTM Counter Classifier. This technology can record and detect individual vehicle lanes, speeds, and vehicle classifications. As a case study, traffic movement on one of Malaysia's urban expressways was examined, providing preliminary analysis of traffic data such as lane-specific volume, vehicle classification, and speed data. The introduction of this multi-lane traffic data collection and monitoring system, along with data analysis, creates significant opportunities. Consequently, the study's findings will contribute to future research and development by highway professionals and researchers, enhancing the approach to collecting, monitoring, and analyzing traffic data on local urban expressways in Malaysia. In conclusion, this new traffic data collection methodology holds significance for professionals across the field, as advanced radar technology offers real-time, precise traffic information.

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1. Introduction

The most important goal of any traffic engineering study is to gather and evaluate correct and sufficient traffic data information in accordance with the study goals. There are several technique methods for collecting traffic data from fieldwork: manual, semi-automated, and automatic. Modern technology has moved away from manual processes and toward semi-automated and automatic ones, which are seen as more practical and cost-effective for gathering and reducing traffic statistics. But for calibration reasons, the manual approach is still needed.

The fast rise of the global population, along with the enhanced development of existing infrastructure in urban areas, has increased the number of vehicles on urban expressways and led to traffic congestion. With these issues, highway professionals need to ensure that the capacity design, planning, monitoring, and operational analysis of current and future expressways are sustainable to ensure that accurate transportation infrastructure evaluations are suitable for the local circumstances. Furthermore, evaluating and forecasting traffic data flow allows it to effectively manage traffic congestion in urban areas with limited facilities and resources.

The techniques for managing traffic data compromise between the survey's objectives, the resources at hand, the coverage that can be achieved, and the volume of data that must be gathered. Therefore, one of the available methods for data collecting may be chosen based on objectives, reasonable prices, and quality criteria.

This paper aims to describe a new methodology for collecting, monitoring, and analyzing traffic data on multi-lane urban expressway traffic using advanced radar technology. In addition, the paper proposes a research gap related to further study, especially in collecting data on traffic at the Malaysian urban expressway.

2. Literature Review

2.1 History of the Traffic Data Collection

Data collecting has been employed on transportation networks since the 1930s and has evolved alongside technology. The gathering technique was generally manual counts in the 1930s; however, there was a move to mechanical measurement in the 1940s, which modified the approach to data integrity. Finally, in the 1970s, computerized pneumatic traffic counters changed traffic data collecting. Radars, video processing, and artificial intelligence (AI) are continuously transforming traffic data, enhancing dependability and cost-effectiveness. Nonetheless, many traffic engineering agencies continue to rely on expensive, unreliable earlier generation systems such as manual data gathering, pneumatic tubes, etc.

The purpose of traffic collecting data is to obtain data that correctly reflects the area's real-world traffic condition. As a result, traffic data may be collected in several ways and via various sources. Not only is traffic data valuable for calculating certain conventional traffic statistics, but these statistics are also used for traffic control signal optimization, level of service assessment, and traffic calming. In addition, these data are used by local transportation authorities and federal ministries to aid in road network planning, design, construction, and operation. Finally, traffic data collection and statistics are a global endeavor used to assess current traffic patterns and predict future traffic trends.

2.2 Review of Relevant Studies

The relevant related methodology of data collection for traffic studies and the measured traffic parameters used by Malaysian researchers are tabulated in Table 1 below:

Table 1: Chronological order by year on the methodology for traffic data collection and related measured traffic parameters

Authors & Year	**Type of Facilities**	**Area**	**Methodology Data Collection**	**Parameters**			
				S	**F**	**D**	**O**
Roshandeh *et al.*, 2009	Two-lane highway	Sub-urban	Radar gun detector & traffic counter	√	√	*n/a*	*n/a*
Saifizul *et al.*, 2010	Two-lane highway	Rural	Weigh-In-Motion (WIM)	√	*n/a*	*n/a*	heavy vehicle
Leong & Awang, 2011	Two-lane highway, Multi-lane highway	Rural & Sub-urban	Laser gun detector	√	√	*n/a*	*n/a*
Mashros & Ben-Edigbe, 2014	Two-lane highway	Rural	Pneumatic tubes and electromagnetic loops & Automated traffic counter	√	√	√	weather condition
Che Puan *et al.*, 2014a	Two-lane highway	*n/a*	*n/a*	√	√	√	*n/a*
Che Puan *et al.*, 2014b	Two-lane highway	*n/a*	Global Position System (GPS) with Video Velocity VBox (VBox)	√	√	*n/a*	*n/a*
Abdurahman *et al.*, 2015	Two-lane highway	Rural	Video recording method	√	√	*n/a*	*n/a*

Hashim *et al.*, 2016	Expressway	Urban	Video recording method & extracted using TRAIS software	√	√	*n/a*	heavy vehicle
Sanik *et al.*, 2017	Expressway	Urban	Video recording method & extracted using computer software	√	√	*n/a*	*n/a*
Leong & Muhammad, 2019	Four-lane, Six-lane, Freeway	Rural	Video recording method & extracted using image processing	√	√	√	headway
Leong *et al.*, 2019	Multi-lane highway,	Rural Suburban	Video recording method & extracted using computer software	√	√	√	*n/a*
Leong & Mohd Shafie	Two-lane, two-way highway,	Rural	Video recording method & extracted using computer software	√	√	*n/a*	headway
Leong *et* al., 2020	Multi-lane highway,	Rural Suburban	Video recording method & extracted using computer software	√	√	*n/a*	*n/a*
Mohd Azwari & Kadar Hamsa, 2021	Expressway	Urban	Radar gun detector	√	√	*n/a*	*n/a*

n/a = information was not provided.

S = Speed; F = Flow; D = Density; O = Others

From Table 1, there are various methods for collecting the traffic data. The methods can be grouped into three categories; 1) handheld, manually operated instruments that are portable and may be utilized almost anywhere, e.g., stopwatch, radar gun, and laser gun; 2) in-road devices that are placed into or on top of the road surface, e.g., pneumatic road tube; 3) out-of-the-way devices that are located above or to the side of the highway, e.g., radar recorders. Each method has various benefits and disadvantages for gathering and interpreting data, which may be considered when deciding which device to utilize in a particular place.

According to Stinson ITS, the technologies used to collect traffic data are divided into intrusive and non-intrusive. Intrusive devices are any traffic data gathering equipment that needs installation on or under the roadway's surface. For installation and maintenance, traffic lanes must be closed. At the same time, the non-intrusive devices are traffic data gathering devices that do not need installation on or under the roadway's surface. These devices are often fixed on poles built near the shoulders or medians, and they seldom need road closures for installation or maintenance. Wisconsin Statewide Speed Management summarizes the comparison of traffic data collection methods in Table 2 below:

Table 2: Comparison of traffic data collection methods.

Instruments Methods	**Parameters**	**Advantages**	**Disadvantages**
Radar Recorders	Spot speed / instantaneous speed, traffic volumes, vehicle class, traffic flow gaps	Data collection and tabulation involve little effort; Capable of collecting data over extended periods of time; Other traffic-related data may be obtained concurrently.	The user cannot choose vehicles at random for the data set. Some sensors may not gather data correctly for multi-lane highways or establish the directionality of observed cars. Equipment-intensive technique; Required maintenance/calibration.
Pneumatic Road Tube	Spot speed / instantaneous speed, traffic volumes, vehicle class,	Little work is needed to gather and tabulate data; data may be collected for extended periods of time; other traffic-related data can be managed concurrently.	Visible to the general public, which may influence driving behavior; The user cannot choose automobiles randomly for the data set. When snowplows are present, use is

	traffic flow gaps		discouraged. The most resource-intensive approach; Requires maintenance and calibration.
Laser Gun	Spot speed / instantaneous speed.	Compared to radar, the equipment is readily portable; the user controls the vehicles sampled since a more concentrated laser beam restricts the readings for non-target vehicles.	The cosine error restricts horizontal and vertical deployment. Scopes and sights may be challenging to operate. Laser beams are more sensitive to environmental changes than radar beams. Required maintenance and calibration.
Radar Gun	Spot speed / instantaneous speed.	The equipment is conveniently transportable; the user controls the vehicles being sampled and; Method for collecting accurate data; The widespread availability of equipment has reduced its cost.	Cosine error limits vertical/horizontal deployment. Closely spaced and heavier cars may generate readings for unintended vehicles. Required maintenance/calibration
Stopwatch	Speed (travel time over distance)	There is little equipment to buy and maintain; the data collecting procedure is simple.	Labor-intensive; gathers time data that must be transformed to speed data; often has poor precision.

Based on Table 2 above, the different instrument methods were given advantages and disadvantages in the traffic data collection methods. In urban expressway areas, the process of collecting, monitoring, and analyzing traffic data are very challenging due to the high traffic volume with the rapid development surrounding urban areas that will affect driver behavior, vehicle conditions, and roadway characteristics. Thus, this will influence operational traffic performance. Therefore, the process of collecting, monitoring, and analyzing traffic data in urban areas might be different compared to the previous study.

3. Method

The review of literature conducted in the previous study helps the authors in direction-finding on research gaps for the new process of collecting, monitoring, and analyzing traffic data on the Malaysian urban expressway. In previous studies, most traffic data collection methodologies used video recording techniques and extracted traffic data using special computer software. Thus, all the traffic survey methodologies compromise the traffic survey's objectives, available resources, practical coverage, and the amount of data to be collected. Therefore, the traffic data collection in this study is proposed using advanced radar technology. Radar is a detecting technology that employs radio waves to measure objects' distance, angle, and radial velocity in relation to a given location. In the past 15 years, radar technology has grown increasingly widely employed. As a result, the technology has evolved and has shown to be a dependable and accurate source of traffic data.

One of the urban expressways in the Klang Valley served as a case study for collecting, monitoring, and analyzing traffic data using the Speedlane ProTM Counter Classifier device. The device possesses the capability to record and detect data twenty-four hours a day, seven days a week, for individual vehicle lanes, capturing information on speeds and classes. Additionally, the device computes per-lane volume, occupancy, gap data, average speed, 85th percentile, and headway data for up to 16 lanes in both directions. The technology incorporated in the device utilizes multi-lane and bi-directional traffic data gathering through accurate dual-beam and low-power frequency-modulated continuous-wave radar. Consequently, the radar effectively tracks different vehicles at various speeds simultaneously, ensuring it does not miss any vehicles within its visibility range. Figures 1 and 2 illustrate the device and provide an example of its setup at a specific location on the urban expressway.

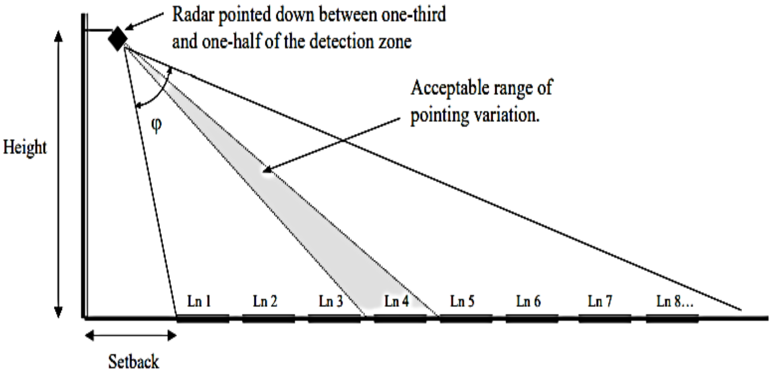

Figure 1:Height and Setback Installation of Speedlane ProTM Counter Classifier device.

Figure 2: The setup of the device at the location of the urban expressway.

4. Results and Discussion

The following section describes the study conducted on one of the Klang Valley's urban expressways. The traffic data collected is available in real-time (traffic cloud) plus historical data and stored in device memory. The traffic cloud is secure in the web-based ecosystem for managing and monitoring real and history traffic data. The traffic data results, such as vehicle classification, traffic volume, and speed were obtained as a preliminary study.

4.1 Vehicle Classification

The device Speedlane Pro^{TM} Counter Classifier defined different types of vehicle classifications on the urban expressway. According to the Malaysian Highway Capacity Manual 2011, the vehicle's classification was classified based on Class 1; motor cars & taxis, Class 2; small vans & utilities (light 2-axles), Class 3; lorries & large vans (heavy 2-axles), Class 4; lorries with 3-axles (heavy 3-axles & above), Class 5; busses, and Class 6; motorcycles & scooters. Figure 3 shows the histogram of vehicle classification on the urban expressway in both directions.

Figure 3: Histogram for vehicle classification on the urban expressway in both directions.

4.2 Traffic Volume

Speedlane Pro^{TM} Counter Classifier also collected all the traffic volumes simultaneously in both directions up to 16-lane in the urban expressway. The results volume can be retrieved in intervals of 1, 5, 15, 30, 60 minutes, a day, a week, and a month. Figure 4 shows the traffic volume in each respective lane in both directions.

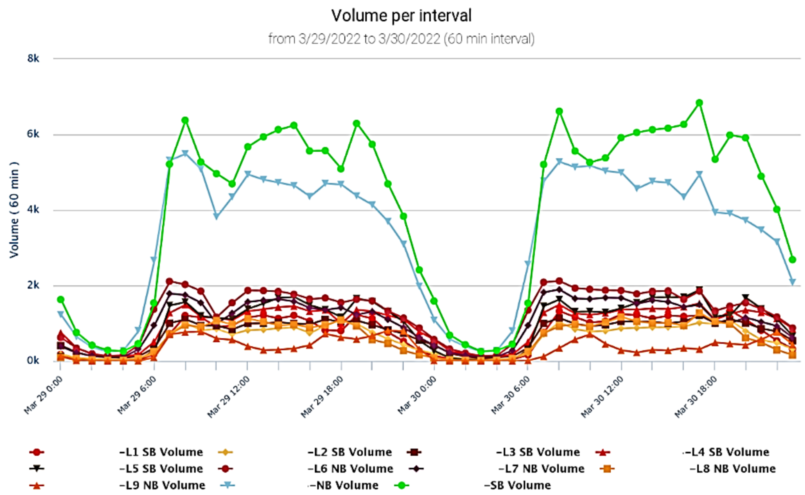

Figure 4: Traffic volume in 60 minutes interval in each respective lane.

4.3 Speed

Besides traffic volume and vehicle classification, speed is the most important parameter in any traffic study. Consequently, speed is typically referred to by multiple names when used in various contexts, such as a design criterion, a level of service (LOS) measurement, or an operational control element. Figure 5 shows the respective lane's speed vs. volume in a one-day interval.

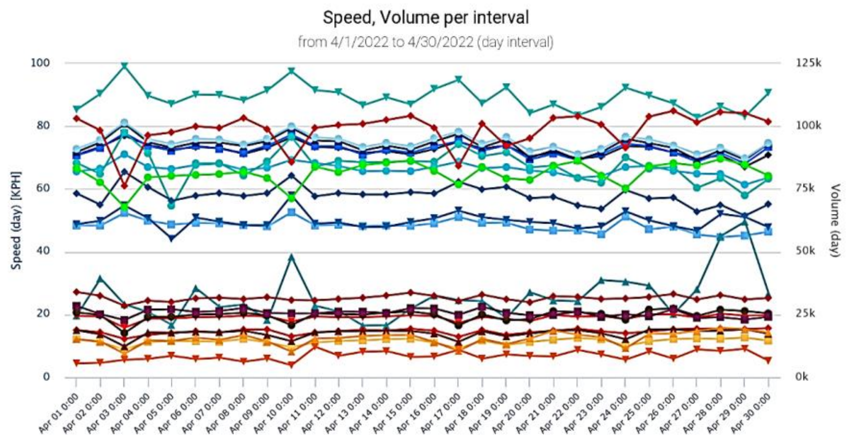

Figure 5:Speed vs. volume in a one-day interval.

The device Speedlane Pro^{TM} Counter Classifier can measure each speed by respective lane in the urban expressway. The results speed can be retrieved in intervals of 1, 5, 15, 30, 60 minutes, a day, a week, and a month. In addition, the speed data can be represented in terms of 85th percentile speed, speed vs. volume, speed vs. occupancy and speed histogram. Figure 6 shows the speed histogram in both directions.

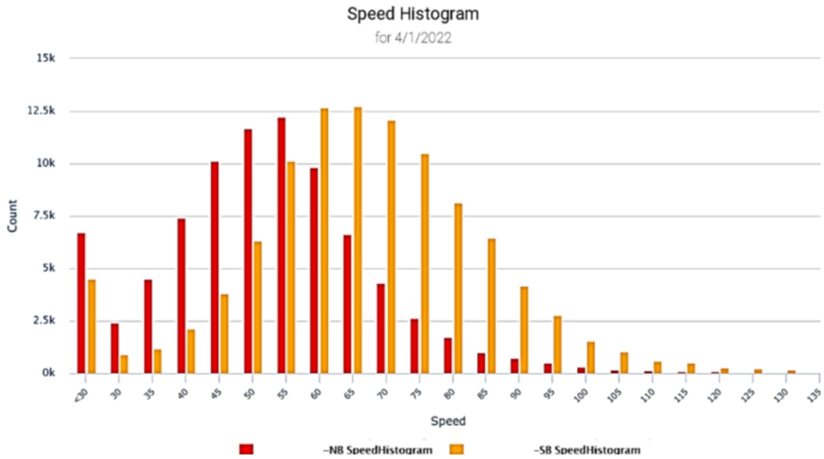

Figure 6:Speed histogram in both directions in the urban expressway.

5. Conclusion

The rapid development in urban areas will impact roadway features, vehicle conditions, and driving behavior, consequently affecting the efficiency of the traffic system. The introduction of this multi-lane traffic data collection and monitoring system, along with data analysis, presents a significant opportunity. The findings derived from the study's analysis will be instrumental in future research and development endeavors, serving professionals and researchers dedicated to enhancing the collection, monitoring, and analysis of traffic data, particularly on local urban expressways in Malaysia. In conclusion, the novel methodology for traffic data collection holds relevance for various professionals, given that advanced radar technology provides real-time and precise traffic information. These professionals include transportation engineers, traffic engineers, highway engineers in the transport and highway industries, authorities, and private consulting firms.

Acknowledgements

The authors express their gratitude to Perunding Atur Trafik Sdn. Bhd. for their financial support for the presentation of this conference paper. Additionally, appreciation is extended to Universiti Teknologi MARA (UiTM) and Kreatif Apps Sdn. Bhd. for their support under the University-Industry Collaboration (UIC 2021) grant project, with RMI File No: 600-TNCPI 5/3/DDF (FKA) (008/2021) & 100-TNCPI/PRI 16/6/2 (031/2023). The authors also acknowledge the reviewers for their valuable comments, contributing to the improvement of this paper.

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