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Research Article

Speed Behaviour Analysis of Vehicles on Highway using Spot Speed Studies - Case Study of NH44

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Abstract:

Speed is one of the most significant traffic stream parameters affecting highway capacity, operational efficiency, travel time, and road safety. On high-speed corridors such as National Highway-44 (NH-44), understanding the prevailing speed characteristics is essential for evaluating driver behaviour, identifying speeding trends, and recommending appropriate speed management strategies. The present study aims to analyse the speed characteristics of vehicles along the 75 km stretch of NH-44 between Devanahalli Toll Plaza and Bagepalli Toll Plaza in Karnataka. This highway is a divided four/six-lane access-controlled corridor carrying heterogeneous traffic comprising cars, buses, trucks, multi-axle vehicles, light commercial vehicles and two-wheelers. The study employs spot speed studies at selected representative locations using Vehicle Counter with Pneumatic Road Tubes techniques under free-flow traffic conditions. Statistical parameters such as mean speed, median speed, modal speed, standard deviation, variance, 15th percentile speed, 85th percentile speed, pace speed, and speed distribution curves are determined for each vehicle category. The results are compared with the posted speed limits and design speed of the highway to identify speed violations and speed variability. The study also evaluates the relationship between roadway geometry, traffic composition, and operating speeds. The findings provide valuable insights for establishing scientifically justified speed limits, improving enforcement strategies, enhancing geometric design, and implementing effective road safety measures on NH-44. The study contributes towards developing safer highway transportation systems and reducing crash risks associated with inappropriate vehicle speeds.

1. Introduction

National Highway-44 (NH-44) is the longest National Highway in India, extending from Srinagar to Kanyakumari. The Karnataka section between Devanahalli and Bagepalli serves as an important corridor connecting Bengaluru with Hyderabad and carries a large volume of passenger and freight traffic. The study stretch, approximately 75 km in length, consists predominantly of divided four-lane and six-lane carriageways with controlled access and relatively high design speeds. It experiences mixed traffic conditions including passenger cars, buses, trucks, multi-axle vehicles, light commercial vehicles, and two-wheelers. This same corridor has also been used in previous road safety assessments and iRAP studies.

Vehicle speed is a fundamental parameter in traffic engineering because it directly influences highway capacity, travel time, fuel consumption, environmental impacts, and accident severity. While higher speeds reduce travel time, excessive speed increases stopping distance, crash probability, and crash severity. Therefore, understanding prevailing operating speeds is essential for designing safe highways and implementing effective speed management measures.Spot speed studies provide instantaneous speed measurements of vehicles

passing a selected point on the roadway under free-flow conditions. These studies help traffic engineers determine:

- Average operating speed
- Speed distribution
- 15th and 85th percentile speeds
- Pace speed
- Speed variability
- Compliance with posted speed limits
- Driver behaviour under prevailing roadway conditions

The 85th percentile speed is widely accepted as an important indicator for determining appropriate speed limits because it represents the speed below which approximately 85% of drivers travel under normal conditions. Speed studies also assist in identifying locations requiring engineering improvements, speed enforcement, warning signs, or traffic calming measures.

The Devanahalli–Bagepalli corridor contains several roadway features such as toll plazas, service roads, grade separators, median openings, villages, intersections, and industrial developments that may influence vehicle operating speeds. Furthermore, heterogeneous traffic composition and varying traffic demand create speed differences among vehicle classes, thereby affecting highway safety and efficiency.

Therefore, analysing spot speed characteristics along NH-44 provides valuable information for:

- Evaluating traffic operating conditions.
- Identifying speeding behaviour.
- Assessing speed consistency.
- Improving road safety.
- Supporting scientific determination of speed limits.
- Assisting highway authorities in implementing effective traffic management strategies.

2. Material and Methods

Traffic data were collected using the MetroCount RoadPod® VT portable vehicle counter and classifier, which uses two pneumatic tube sensors to detect and time-stamp individual vehicle axle movements. The system automatically records important traffic parameters such as traffic volume, vehicle speed, vehicle classification, direction of travel, and traffic gaps. The RoadPod® VT was selected as a portable and automated traffic monitoring system capable of reliable operation under varying weather conditions.

During the survey, vehicle axle detections were continuously recorded and stored in the internal memory of the RoadPod® VT. The equipment can store up to 4 million axle hits, corresponding to approximately 1 million vehicles. After completion of the data collection, the recorded observations were downloaded and processed using MetroCount Traffic Executive (MTE®) software to obtain the required traffic characteristics. The system incorporates an accurate internal clock and automatic-ranging sensors for reliable data collection.

The collected traffic data were subsequently used for traffic analysis based on the required parameters. The manufacturer reports that the RoadPod® VT has been independently tested against video surveillance, with the cited test results indicating 100% accuracy, supporting its application for automated traffic monitoring.

The methodology adopted for analysing the speed characteristics of vehicles on the NH-44 corridor between Devanahalli Toll Plaza and Bagepalli Toll Plaza comprises a systematic approach involving study area selection, survey location identification, data collection, processing, and statistical analysis. The selected study corridor extends approximately 75 km and consists predominantly of divided four-lane and six-lane carriageways carrying heterogeneous traffic, including passenger cars, buses, trucks, multi-axle vehicles, light commercial vehicles, and two-wheelers. Representative spot speed survey locations were selected based on roadway geometry, traffic conditions, and safety considerations, including straight sections, horizontal curves, approaches to junctions, village influence zones, toll plaza approaches, accident-prone locations, and uninterrupted highway stretches. Spot speed data were collected using Vehicle Counter with Pneumatic Road Tubes, which automatically records vehicle speed, classification and traffic volume under free-flow traffic conditions. Surveys were conducted during morning peak (08:00–10:00 hrs), mid-day off-peak (11:00–13:00 hrs) and evening peak (16:00–18:00 hrs) under favourable weather conditions, dry pavement, and normal visibility to ensure reliable measurements. The collected speed data were grouped into 10 km/h speed intervals and analysed using descriptive statistical techniques. Important speed parameters, including mean speed, median speed, modal speed, standard deviation, variance, 15th percentile speed, 85th percentile speed, pace speed and pace percentage, were estimated to evaluate operating speed characteristics. Furthermore, frequency distribution tables, speed histograms, speed bin charts, cumulative frequency curves, and normal distribution curves were developed to understand the speed distribution of different vehicle categories. Finally, highway sections exhibiting higher operating speeds, greater speed variability, and frequent speed-limit violations were identified as

potential high-risk locations requiring suitable engineering improvements and speed management measures to enhance traffic safety and operational efficiency along the NH-44 corridor.



Figure 1. *RoadPod® VT Portable vehicle counter & classifier*

3. Results and Discussions

A. Spot Speed Survey Locations

To obtain representative operating speed characteristics along the NH-44 corridor, five spot speed survey locations were selected between Devanahalli Toll Plaza and Bagepalli Toll Plaza. The locations were chosen based on roadway geometry, traffic volume, accessibility, and the presence of uninterrupted free-flow traffic conditions. Care was taken to avoid the influence of intersections, traffic signals, toll plazas, bus stops, and pedestrian crossings so that the measured speeds represented the natural operating speeds of drivers.

The selected locations include straight highway sections, village influence zones, and semi-urban areas, providing a comprehensive representation of traffic conditions along the study corridor. Spot speed data were collected using the Metro Count Roadside Traffic Classifier, which automatically records vehicle speed, classification, and traffic volume with high accuracy.

The first survey location was selected at Devanahalli Toll Plaza (Chainage 0 km), representing a six-lane divided highway near the southern end of the study corridor. The second location was established at the Chikkaballapur Bypass (Chainage 25 km), characterised by a straight divided carriageway that permits uninterrupted vehicle movement. The third and primary survey site was located at Aruru Gate (Chainage 45 km; Latitude 13.571858° N, Longitude 77.780607° E), where a MetroCount Roadside Traffic Classifier was installed to continuously record vehicle speed, classification, and traffic volume. The fourth location was selected near Gudibande (Chainage 60 km) to represent a rural highway section with moderate traffic flow. The final survey point was established at Bagepalli Toll Plaza (Chainage 75 km), representing the northern end of the study corridor and capturing vehicle speeds approaching the toll plaza. Together, these five locations provide a representative sample of urban, semi-urban, and rural highway conditions, enabling a comprehensive assessment of speed characteristics and driver behaviour along the NH-44 corridor.

Table 1. *Spot Speed Survey Locations*

Sl. No.	Location	Approximate Chainage (km)	Latitude (N)	Longitude (E)
1	Devanahalli Toll Plaza	0	13.24821	77.71352
2	Chikkaballapur Bypass	25	13.43510	77.73225
3	Aruru Gate	45	13.571858	77.780607
4	Green Park Dhaba	60	13.68125	77.70434
5	Bagepalli Toll Plaza	75	13.78450	77.79643

B. Operating Speed Characteristics of NH-44

The objective of this study is to evaluate the operating speed characteristics of vehicles along the NH-44 corridor between Devanahalli and Bagepalli using spot speed studies. Operating speed represents the speed at which drivers naturally travel under free-flow traffic conditions without being influenced by congestion or traffic control devices. Spot speed data will be collected at selected representative locations covering straight sections, curves, junction approaches, village influence zones, and toll plaza approaches. The collected speed data will be analyzed to assess the prevailing speed distribution, speed variation among different vehicle categories, and compliance with posted speed limits. The analysis will help identify locations exhibiting high operating speeds or significant speed variability, thereby providing insights into driver behaviour, roadway performance, and potential safety concerns.

The results will support the development of appropriate speed management strategies and engineering interventions to improve the operational efficiency and safety of the NH-44 corridor. IRC recommends that speed management measures should be implemented at locations where higher operating speeds are observed near intersections, village access roads, pedestrian crossings, or other conflict points. Appropriate engineering measures include installation of retro-reflective speed limit signs, advance warning signs, transverse rumble strips, lane markings, and road studs to improve driver awareness. Periodic speed monitoring using

automatic traffic counters or speed detection devices is also recommended to ensure continued compliance with regulatory speed limits. Furthermore, the observed speed distribution suggests that speed enforcement should primarily target the small proportion of vehicles travelling at excessively high speeds rather than the majority of compliant drivers.

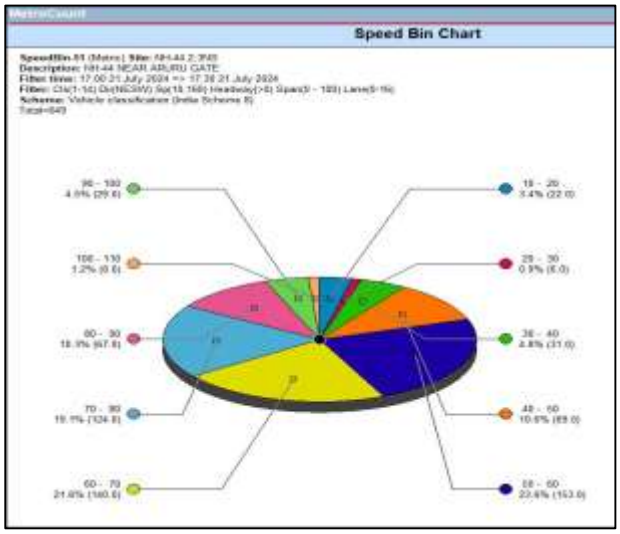

Figure 2.*. Speed bin distribution of vehicles observed on NH-44*

C. Speed Histogram Analysis

Figure 3, presents the speed histogram of vehicles observed on NH-44 near Aruru Gate during the survey period (17:00–17:30 hrs on 21 July 2024). The histogram illustrates the frequency distribution of vehicle speeds and provides an understanding of the prevailing operating speed characteristics under free-flow traffic conditions.

The speed distribution exhibits an approximately bell-shaped (near-normal) distribution, indicating that most vehicles travelled within a moderate speed range while relatively few vehicles operated at very low or very high speeds. The highest concentration of vehicles is observed between 50 km/h and 75 km/h, with the peak frequency occurring around 55–65 km/h. This suggests that the majority of drivers selected operating speeds that were comfortable and consistent with the prevailing roadway and traffic conditions.The histogram indicates a posted speed limit of 60 km/h, shown by the blue vertical line, while the 85th percentile speed is approximately 81 km/h, represented by the black dashed line. Since the 85th percentile speed is considerably higher than the posted speed limit, a substantial proportion of drivers are travelling above the regulatory speed. This difference may indicate that the existing speed limit is lower than the prevailing operating speed or that enhanced speed enforcement measures are required at the study location.The distribution also reveals that relatively few vehicles travelled below 40 km/h or above 100 km/h, indicating the absence of significant congestion and only a small proportion of excessive-speed vehicles. The gradual decline in frequency on both sides of the peak demonstrates moderate speed variability among drivers and reflects stable traffic flow conditions on the divided highway.

Overall, the speed histogram confirms that traffic operations on the selected section of NH-44 are generally uniform, with most vehicles travelling within a narrow operating speed range. The estimated 85th percentile speed of approximately 81 km/h provides an important statistical measure for evaluating the suitability of the existing speed limit and for developing scientifically based speed management strategies. The histogram further supports the estimation of operating speed parameters, including the mean speed, modal speed, standard deviation, and percentile speeds, which are essential for highway safety assessment and traffic engineering analysis.

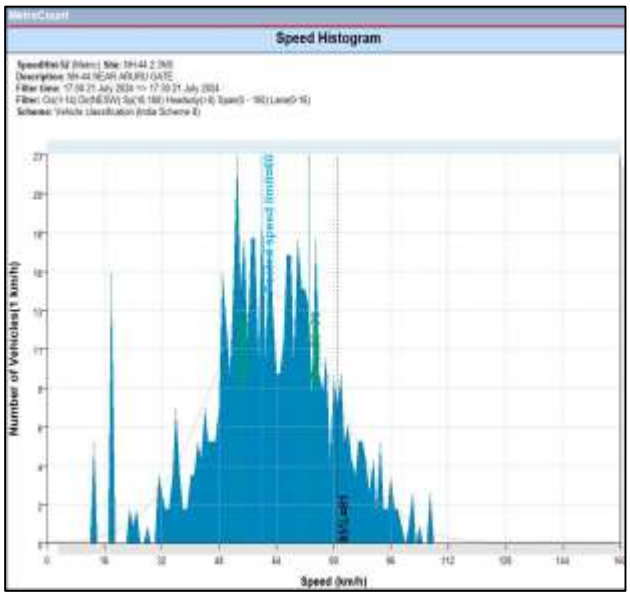

Figure 3*. Speed histogram of vehicles observed on NH-44*

Figure 3 presents the speed histogram for vehicles observed on NH-44 near Aruru Gate during the 17:00–17:30 hrs survey period on 21 July 2024. The histogram illustrates the frequency distribution of vehicle speeds under free-flow traffic conditions, along with the posted speed limit of 60 km/h and the estimated 85th percentile speed of 81 km/h. The distribution exhibits an approximately bell-shaped pattern, indicating that vehicle speeds are concentrated around the mean operating speed with relatively few extremely slow or excessively fast vehicles.

The highest frequency of vehicles was observed within the 50–60 km/h and 60–70 km/h speed intervals, indicating that most drivers selected operating speeds within this range. A substantial

number of vehicles also travelled between 70 km/h and 80 km/h, demonstrating that drivers generally preferred speeds higher than the posted speed limit when roadway and traffic conditions permitted. This behaviour is typical on divided multi-lane highways where the roadway geometry provides good visibility, adequate lane width, and a high level of driving comfort.

The estimated 85th percentile speed of 81 km/h indicates that approximately 85% of the observed vehicles travelled at or below this speed, while only 15% exceeded it. Since the 85th percentile speed is considerably higher than the posted speed limit of 60 km/h, the results suggest a noticeable difference between regulatory speed limits and actual driver operating behaviour. Such differences may arise due to favourable roadway geometry, low traffic interference, and drivers' perception of a safe operating speed. This finding highlights the importance of periodically reviewing posted speed limits based on field observations and operating speed studies.

The histogram also reveals a low proportion of vehicles travelling below 40 km/h or above 100 km/h, indicating that traffic flow was stable and uninterrupted during the survey period. The absence of multiple peaks in the distribution suggests that the traffic stream was relatively homogeneous and free from congestion or significant speed disturbances. The moderate spread of vehicle speeds further indicates good speed consistency among drivers, which is generally associated with smoother traffic operations and a lower probability of speed-related conflicts.

From a road safety perspective, vehicles operating significantly above the posted speed limit contribute to increased stopping distances, greater crash severity, and higher collision risk, particularly near access points, junctions, and settlement areas. Therefore, the observed speed characteristics suggest that appropriate speed management measures, including periodic speed monitoring, enhanced enforcement, improved speed limit signage, and engineering countermeasures at critical locations, should be considered to improve safety and maintain efficient traffic operations along the NH-44 corridor.Overall, the speed histogram demonstrates that NH-44 operates under stable free-flow conditions, with the majority of vehicles travelling between 50 km/h and 75 km/h. The analysis confirms that the 85th percentile speed serves as an effective indicator of prevailing operating speeds and provides valuable information for evaluating speed limits, designing traffic control measures, and developing evidence-based road safety improvement strategies.

However, IRC also emphasizes that speed limits should not be based solely on operating speed. Road safety considerations, land use, pedestrian activity, roadside development, access frequency, and crash history must be evaluated before revising speed limits. Where higher operating speeds are considered unsafe, IRC recommends implementing traffic calming and speed management measures rather than simply increasing the regulatory speed limit. Such measures include enhanced enforcement through speed cameras, improved speed limit signage, variable message signs (VMS), roadway delineation, rumble strips near conflict points, and public awareness programmes. Continuous monitoring of operating speeds and periodic safety audits are also recommended to evaluate the effectiveness of these interventions and maintain safe traffic operations.

D. Interpretation

Table 2. *Spot Speed Survey Information for NH-44 near Aruru Gate*

Parameter	Description
Study Corridor	NH-44 (Devanahalli–Bagepalli)
Survey Location	NH-44 near Aruru Gate
Coordinates	13.571858° N, 77.780607° E
Survey Instrument	MetroCount Vehicle Counter with Pneumatic Road Tubes
Survey Duration	19 July 2024 (16:48 hrs) to 22 July 2024 (10:21 hrs)
Analysis Period	21 July 2024, 13:00–14:00 hrs
Vehicle Classification	India Scheme 8 (Class 1–14)
Speed Range	10–160 km/h
Vehicles Analysed	340
Total Survey Vehicles	1,827
Percentage Used	18.61%

The selected one-hour dataset represents vehicles travelling under relatively uninterrupted traffic conditions, making it suitable for analyzing operating speed characteristics. The recorded speeds will be used to determine key statistical parameters, including the mean speed, median speed, modal speed, standard deviation, variance, coefficient of variation, 15th percentile speed, 85th percentile speed, and pace speed. These parameters will be used to evaluate driver speed behaviour, assess compliance with the posted speed limits, identify speed variability, and recommend appropriate speed management measures for the NH-44 corridor.

E. Recommendations

a. Revision of Speed Limits: The existing posted speed limits should be periodically reviewed using the 85th percentile speed, roadway geometry, traffic composition, roadside development, and crash history, in accordance with IRC guidelines, to establish realistic and safe speed limits.
b. Installation of Speed Limit Signs: Adequate retro-reflective speed limit signs and advance warning signs should be installed at regular intervals and at critical locations such as intersections, village approaches, curves, and toll plazas to improve driver compliance.
c. Speed Enforcement Cameras: Automatic speed enforcement cameras should be deployed at locations with frequent speed violations and accident-prone sections to monitor vehicle speeds continuously and discourage excessive speeding.
d. Variable Message Signs (VMS): Variable Message Signs (VMS) should be installed at strategic locations to provide real-time information regarding speed limits, traffic congestion, weather conditions, road works, and emergency situations, thereby enhancing driver awareness.
e. Rumble Strips Near Settlements: Transverse rumble strips should be provided near village settlements, pedestrian crossings, schools, and other conflict zones to encourage gradual speed reduction and improve pedestrian safety.
f. Improved Pavement Markings: Well-maintained lane markings, edge lines, directional arrows, and raised pavement markers should be provided to improve lane discipline, visibility, and driver guidance, particularly during night-time and adverse weather conditions.

4. Conclusions

a. The spot speed study successfully determined the operating speed characteristics of vehicles on the NH-44 corridor between Devanahalli and Bagepalli under free-flow traffic conditions.
b. Statistical speed parameters, including mean speed, median speed, modal speed, standard deviation, variance, 15th percentile speed, 85th percentile speed, and pace speed, effectively described the speed behaviour of different vehicle categories.
c. The 85th percentile speed proved to be a reliable indicator for assessing the suitability of existing speed limits and for establishing scientifically justified speed regulations.
d. Speed distribution analysis identified variations in operating speeds among different vehicle classes, reflecting the heterogeneous traffic conditions prevalent on NH-44.
e. Sections exhibiting high operating speeds and greater speed variability were identified as potential locations requiring enhanced speed management and road safety interventions.
f. The study demonstrated that spot speed surveys are an effective and economical method for evaluating driver behaviour, traffic operations, and speed compliance on high-speed national highways.
g. The findings provide valuable inputs for highway authorities in implementing engineering improvements, speed enforcement measures, traffic signage, and roadway safety enhancements to reduce crash risks.
h. The methodology and results of this study can serve as a reference for future traffic engineering and road safety studies on NH-44 and other National Highways, supporting data-driven transportation planning and sustainable highway safety management.

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References

[1]Yagar, S. (1984). Predicting speeds for rural 2-lane highways. *Transportation Research Part A: General.* 18(1):61-70. DOI:10.1016/0191-2607(84)90094-3.

[2]Yagar, S., and Van Aerde, M. (1983). Geometric and environmental effects on speeds of 2-lane highways. *Transportation Research Part A: General.* 17(4):315-325. DOI:10.1016/0191-2607(83)90094-8.

[3]Polus, A., Fitzpatrick, K., and Fambro, D.B. (2000). Predicting operating speeds on tangent sections of two-lane rural highways. *Transportation Research Record.* 1737(1):50-57. DOI:10.3141/1737-07.

[4]Donnell, E.T., Ni, Y., Adolini, M., and Elefteriadou, L. (2001). *Speed prediction models for trucks on two-lane rural highways. Transportation Research Record.* 1751(1):44-55. DOI:10.3141/1751-06.

[5]Schurr, K.S., McCoy, P.T., Pesti, G. and Huff, R. (2002). Relationship of design, operating, and posted speeds on horizontal curves of rural two-lane highways in Nebraska. *Transportation Research Record.* 1796(1):60-71. DOI:10.3141/1796-07.

[6]Fitzpatrick, K., Miaou, S.P., Brewer, M., Carlson, P., and Wooldridge, M.D. (2005). Exploration of the relationships between operating speed and roadway features on tangent sections. *Journal of Transportation Engineering.*131(4):261-269. DOI:10.1061/(ASCE)0733-947X(2005)131:4(261).

[7]Figueroa Medina, A.M., and Tarko, A.P. (2005). Speed factors on two-lane rural highways in free-flow conditions. *Transportation Research Record.* 1912(1):39-46. DOI:10.1177/0361198105191200105.

[8]Misaghi, P., and Hassan, Y. (2005). Modeling operating speed and speed differential on two-lane rural roads. *Journal of Transportation Engineering.* 131(6):408-418.
DOI:10.1061/(ASCE)0733-947X(2005)131:6(408).

[9]Gong, H., and Stamatiadis, N. (2008). Operating speed prediction models for horizontal curves on rural four-lane highways. *Transportation Research Record.* 2075(1):1-7. DOI:10.3141/2075-01.

[10]Cruzado, I., and Donnell, E.T. (2009). Evaluating effectiveness of dynamic speed display signs in transition zones of two-lane, rural highways in Pennsylvania. *Transportation Research Record.* 2122(1):1-8. DOI:10.3141/2122-01.

[11]Pérez-Zuriaga, A.M., García García, A., Camacho Torregrosa, F.J., and D'Attoma, P. (2010). Modeling operating speed and deceleration on two-lane rural roads with Global Positioning System data. *Transportation Research Record.* 2171:11-20. DOI:10.3141/2171-02.

[12]Castro, M., Sánchez, J.F., Sánchez, J.A., and Iglesias, L. (2011). Operating speed and speed differential for highway design consistency. *Journal of Transportation Engineering.* 137(11):837-840. DOI:10.1061/(ASCE)TE.1943-5436.0000309.

[13]Himes, S.C., Donnell, E.T., and Porter, R.J. (2011). New insights on evaluations of design consistency for two-lane highways. *Transportation Research Record.* 2262(1):31-41. DOI:10.3141/2262-04.

[14]Montella, A., Pariota, L., Galante, F., Imbriani, L.L., and Mauriello, F. (2014). Prediction of drivers' speed behavior on rural motorways based on an instrumented vehicle study. *Transportation Research Record.* 2434(1):52-62. DOI:10.3141/2434-07.

[15]Montella, A., Galante, F., Mauriello, F., and Aria, M. (2015). Continuous speed profiles to investigate drivers' behavior on two-lane rural highways. *Transportation Research Record.* 2521(1):3-11. DOI:10.3141/2521-01.

[16]Pal, S., and Roy, S.K. (2016). Impact of roadside friction on travel speed and LOS of rural highways in India. *Transportation in Developing Economies.* 2:9. DOI:10.1007/s40890-016-0011-z.

[17]Lobo, A., Couto, A., and Rodrigues, C. (2016). Flexible stochastic frontier approach to predict spot speed in two-lane highways. *Journal of Transportation Engineering.*142(8):04016032. DOI:10.1061/(ASCE)TE.1943-5436.0000862.

[18]Lobo, A., Rodrigues, C., and Couto, A. (2018). Modelling the operating speed in segments of two-lane highways from probe vehicle data: A stochastic frontier approach. *Journal of Advanced Transportation.* 2018:1-10. DOI:10.1155/2018/3540785.

[19]Wang, X., Guo, Q., and Tarko, A.P. (2020). Modeling speed profiles on mountainous freeways using high resolution data. *Transportation Research Part C: Emerging Technologies.* 117:102679. DOI:10.1016/j.trc.2020.102679.

[20]Kumar, S., and Maitra, S. (2024). Investigating speed characteristics of vehicles for creating safe speed environment: A case on Indian highways. *Journal of the Eastern Asia Society for Transportation Studies.* 15:271-289. DOI:10.11175/easts.15.271.