International Journal on Engineering Technology (InJET)

www.kec.edu.np/kec-journal/
Volume 2, issue no. 1, Dec 2024, Page 187-194
Received Date: Aug 19, 2024
Accepted Date: Sept 29, 2024
ISSN: 3021-940X (Print)
DOI: https://doi.org/10.3126/injet.v2i1.72571

Assessment of Stratified Speed Characteristics and Compliance with Posted Speed Limit in an Urban Area: A Case Study of Section of Karnali Highway, Nepal

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Abstract

Speed is the fundamental element of traffic engineering which is related to safety, time, comfort, convenience, and economics of the transportation system. Speed tends to reduce while the vehicles enter the urban areas even within the highway. Urban areas even have posted speed limits to control the speed characteristics, but the obeyance of the posted limit is still questionable. This research examines the speed characteristics of various means of transportation within urban areas. Section of roads within urban areas of Surkhet district along Karnali Highway (NH58) is considered as a study area and a manual method of data collection was adopted. The stratified samples of speed covering all means of transportation were collected during off-peak hours. Even a small section of roads has varying speed limits ranging from 20 to 40kmph. The collected data were used to calculate different kinds of speeds for each category of vehicles and further combined based on volume proportion to come up with average speed. The road is divided into four lanes, which motivates speeding, and it was observed the average speed of 2-wheelers, cars, and utility vehicles was between 30-40kmph. Data assessment shows the average speed limit was within 40kmph, which is legally mandated by the Motor Vehicle and Transport Management Act 2049, which is even taught during the process of licensing to drivers. Hence, the installation of other speed limit signs needs proper education and awareness followed by proper enforcement techniques for effective implementation of the posted speed limit.

Keywords: Road Safety, Speed Studies, Average Speed, Posted Speed Limit, two-Wheeler

1. Introduction

Road Crashes take the life of an estimated 1.19 million people globally in 2021 and are the top cause of death globally for people aged between 5-29 years. More than 90% of deaths and serious injuries impact the vulnerable people from low- and middle-income countries (WHO, 2023). The report by the National Highway Traffic Safety Administration shows that 17 % of the drivers involved in crashes in 2017 were speeding, and 26 % of those killed were in a crash involving at least one speeding driver (National Center for Statistics and Analysis, 2019).

Speed is an important transportation consideration because it relates to safety, time, comfort, convenience, and economics. Speed impacts the driver's control over vehicles and can increase the chance of severity in case of crash. (National Highway Traffic Safety Administration, 2020). Speed management remains one of the biggest challenges facing road safety practitioners around the world and calls for a concerted, long-term, multidisciplinary response. The speed at which a vehicle travels directly influences the risk of a crash as well as the severity of injuries sustained, and the likelihood of death resulting from that crash. Reducing vehicle speeds in areas where the road user mix includes a high volume of vulnerable road users, such as pedestrians and cyclists, is especially important (WHO, 2018). Causes of road crashes are classified into three elements: human, vehicles and roadway/environment; and speeding is often considered within human factors. Speed is very crucial in enhancing the safety scenario around urban areas where there are significant service centers including school.

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A recent study suggests installing speed limit equivalent to 30kmph sign even helps to improve and even achieve the 3-stars in school zone (Tiwari and Luitel, 2024).

Spot speed studies are used to determine the speed distribution of a traffic stream at a specific location. The data gathered in spot speed studies are used to determine vehicle speed percentiles, which are useful in making many speed-related decisions. The quality of level and safety can be achieved by the speed on a given road system. Three forms of speed, viz. 85th percentile speed, time mean speed along with other parameters had a significant impact on road crashes (Tiwari H, 2015). Average Speed can be measured on space mean speed and time mean speed and often space mean speed is used to represent average speed. Additionally, speed increases with the decrease in vehicle density, and hence off-peak hours will have a higher value of speed (Tiwari &Marsani, 2014). Time mean speed (TMS) and Space mean speed (SMS) are two important parameters in traffic engineering used to measure the average speed of vehicles over a specific section of a road. These are relevant when analyzing spot speed data. TMS reflects the speed that individual drivers are experiencing at a specific location and is useful for understanding driver behaviour, whereas SMS represents the average speed of all the vehicles over a segment of the road. SMS provides insight into the overall traffic flow and is less sensitive to high-speed vehicles.

According to the Highway Capacity Manual, in the case of urban roads, free-flow speeds occur at off-peak hours in the central part of urban street segments where traffic control systems do not affect driver speed choice (Transportation Research Board, 2010). First, high-posted speed limits are highly associated with moderate speed limit violations compared to minor or major speed limit violations (Afghari et al., 2018). Hence, speed enforcement plays a large role in determining the speed of uninhibited drivers when traveling above the speed limit, and other significant variables such as gender, age, and ethnicity have a lesser impact (Mannering 2009).

2. Research Objective

The research objective is to analyze the means-specific speed characteristics in the urban areas along the multilane roads that pass through the dense settlements and the compliance with the posted speed limit.

3. Research Design

The research design is crucial for the finalization of research works and starts with the site selection followed by some literature review on volume study on the same study area, which is the sole basis of the speed data survey (Refer Figure 1). The collected data were analyzed for various forms of speed and further compared for posted speed limits and conclusions and recommendations were made based on the research.

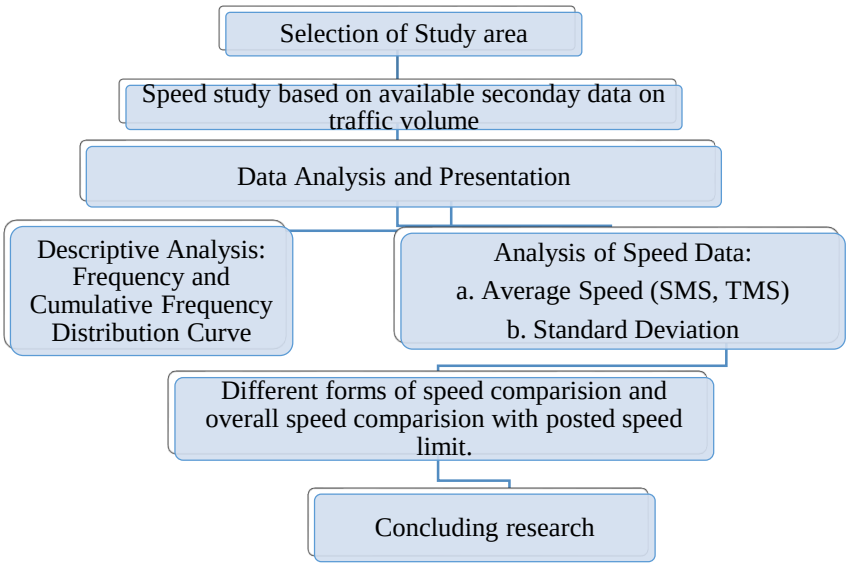

Figure 1. Methodological Flow Chart

4. Study Area

Karnali Highway (NH58) is one of the eighty national highways of Nepal. This highway is the backbone of Karnali province joining major districts within the province to the India border through Banke of Lumbini Province. Surkhet is the capital city of the province with dense settlements. Hence the section of highway in between Airport Chowk to Mangalgadhi section was considered for the study, where we observed dense settlement as shown in Figure 2.

Figure 2. Study Area considered for the research

The considered road section being the national highway, it has a right of way equivalent to 50m. It is a lane-divided highway with a median to separate opposing vehicles. Despite being within urban areas, it lacks pedestrian walking facilities but is provided with zebra crossing at regular intervals. The basic road characteristics are summarized in Table 1.

Table 1. Geometrical Features of the road under consideration

S.N	Description	Dimension
1	Lane width (m)	3.5m
2	Number of lanes in one direction	2
3	Total width of the carriageway in one direction	7m
4	Median width	3m
5	Cross Slope	2.5%
6	Control Access to the center lane	Yes, Access

5. Methods

5.1. Data collection

The primary data for this study is the spot speed of various categories of vehicles. Spot Speed is the average speed of vehicles passing a point. Among various methods, the manual method of data collection was adopted with noting the time taken by category of vehicles to cross certain length of road. The urban area of Nepal has heterogeneous traffic, so the speed data needs to be collected for different categories of transportation means. It is recommended to collect speed samples in the same proportion of volume. A recent study by Luitel et. al. has provided the three-day traffic volume composition along the same corridor (Refer Table 2).

Table 2. Traffic Volume Scenario

Direction	Truck	Bus	Car/4WD	2- Wheelers	Utility Vehicles	3-Wheelers	Others
East - West	338	207	407	5957	390	3024	204
West - East	285	214	502	6053	367	3066	208
Total	623	421	909	12010	757	6090	412
Proportion	2.94%	1.98%	4.28%	56.59%	3.57%	28.70%	1.94%

(Luitel et.al, 2024)

Analyzing further it shows more than 50% of the vehicles are two-wheelers and being urban areas, almost 29% is three-wheelers used as public transportation. The minimum sample for each category of vehicles is taken as

a minimum of 10%. Speed data were collected during the period when headways is greater than 5 seconds as per accepted practice in various papers (Figueroa & Tarko, 2005; Tarko, 2009).

5.2. Data Analysis

The collected speed data is used for various descriptive analyses through frequency distribution and cumulative frequency distribution curves, which are further used to find out various speed percentiles. Usually (15th and 85th) percentiles are carried out to find out the minimum and reasonable speed limits on the road system (Roshandeh et al., 2009). Bar charts and graphs are made on the Excel sheets to carry out the further requirements for speed percentiles. Time mean speed and space mean speed are analyzed and their relationship is to be analyzed. The speed data collected were analyzed for above mention average speed along with variance and standard deviation. The relationship between two mean speeds is expressed as per equation (1) and (2).

$$Time\ mean\ speed\ (V_t) = Space\ Mean\ Speed\ (V_s) + \frac{S^2}{V_S} \quad \text{(Equation 1)}$$

$$\text{Where, S=Standard deviation for the distribution} = \sqrt{\frac{\sum fi(vi-v)^2}{\sum fi-1}} \quad \text{(Equation 2)}$$

As all the vehicles do not travel at the same speed, there is a spread or dispersion of spread about the mean. The standard deviation is a statistical measure of this spread.

Modal speed is the most preferred speed at which the maximum proportion of vehicles travel which can be obtained by plotting the frequency distribution curve. Speed percentile is the tool used to determine effective and adequate speed limits. 98th Percentile Speed: It is the speed below which 98 % of all the vehicle travel, is used as a design speed in geometric design.

- **85th Percentile Speed**: It is the speed below which 85th % of all vehicles travel, is used for determining the speed limits for Traffic regulation and is used as the posted speed limit
- **50th percentile Speed**: It is the average speed or median speed in which 50% of the vehicle tends to flow at the average speed for that class of vehicles along the road section. It is also called median speed.
- **15th Percentile Speed**: It is the speed below which is 15% of all the vehicles travel, and is used to determine the lower limit on major highway facilities.

6. Speed Assessment

The vehicles were categorized as buses, trucks, four-wheelers (Car), Two-wheelers (motorcycle/scooter), three-wheelers (tempo), and utility vehicles based on the classified volume category. The various types of speeds for each type of vehicle are obtained based on frequency distribution and cumulative frequency distribution curve (Refer Figure 3-13).

A. Transport Means (Car)

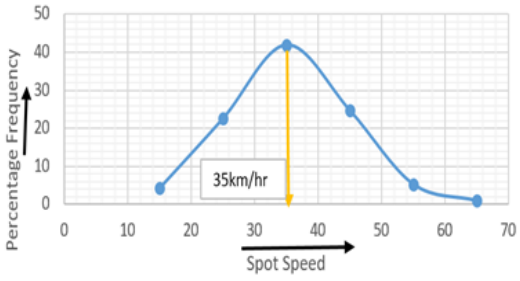

Figure 3. Frequency Distribution curve for Car

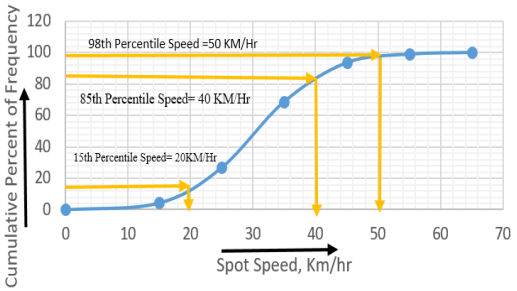

Figure 4. Cumulative Frequency Distribution curve for Car

Transport Means (Bus)

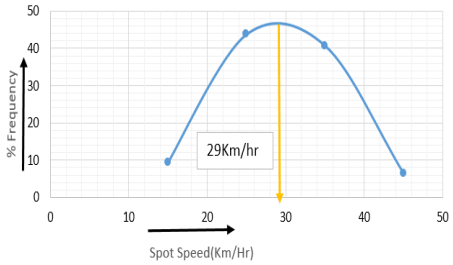

Figure 5. Frequency curve for Bus

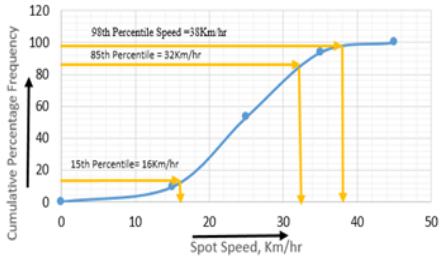

Figure 6. Cumulative Frequency curve for Bus

B. Goods Transport Means (Utility Vehicles)

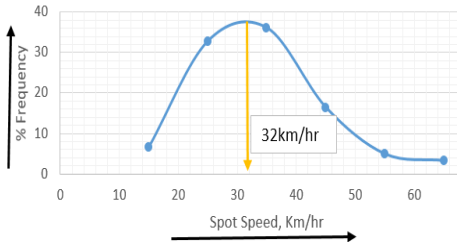

Figure 7. Frequency curve for Utility Vehicles

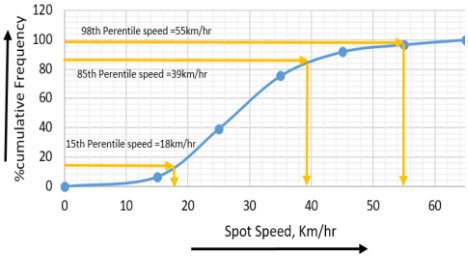

Figure 8. Cumulative Frequency curve for Utility Vehicles

C. Transport Means(3-Wheeler)

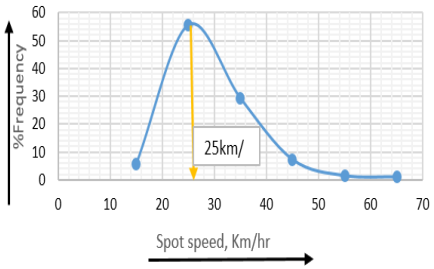

Figure 9. Frequency curve for 3-Wheeler

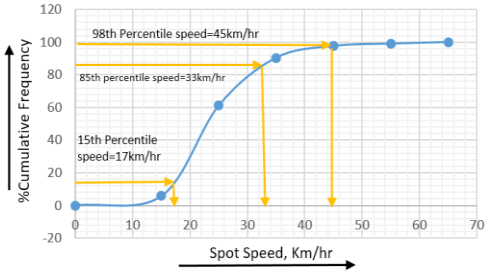

Figure 10. Cumulative Frequency curve for 3-Wheeler

D. Transport Means (2-Wheeler)

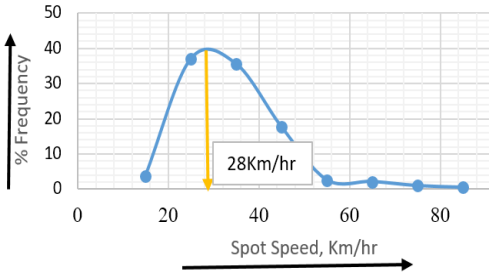

Figure 11. Frequency curve for 2-Wheeler

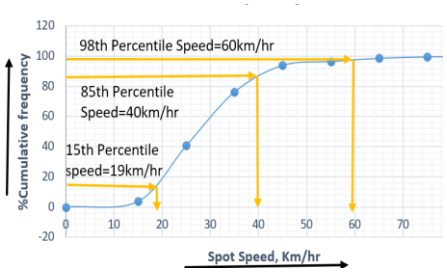

Figure 12. Cumulative Frequency curve for 2-Wheeler

E. Transport Means (Truck)

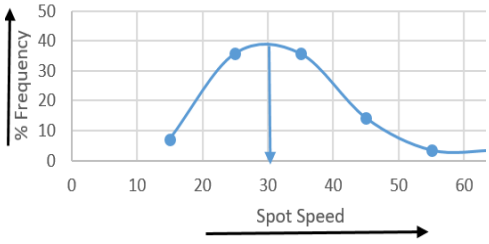

Figure 13. Cumulative frequency curve for Truck

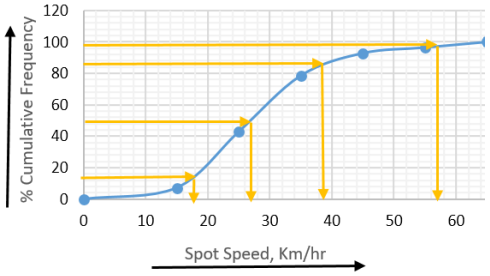

Figure 14. Frequency curve for Truck

The summary of all percentile speed, modal speed, maximum speed and minimum speed of all categories of vehicles is summarized as below in Table 3.

Table 3. Comparison of different means regarding the speed percentiles, modal speed

Parameter (Km/hr.)	Car	Bus	Utility vehicles	2-Wheeler	3-Wheeler	Truck
Maximum Speed V_{85}	40	32	39	40	33	38
Minimum Speed V_{15}	20	16	18	19	17	18
Design Speed V_{98}	50	39	55	60	45	56
Median Speed V_{50}	31	31	28	27	24	28
Modal Speed (km/hr.)	35	29	35	28	29	30
Max Speed (Individual)	65.9	49.6	69.3	81	54.3	60.4
Min Speed (Individual)	17.2	15.4	16.7	14	14.9	16.8

The maximum speed of cars, utility vehicles, and trucks was in the range of 60-70kmph, and the two-wheeler had a maximum speed of 81kmph and maximum range. Car and 2-Wheeler due to personalized in nature is having higher speed. The minimum range of speed was observed for buses and three-wheelers. Three-wheeler due to its engine characteristics and stability is among the means of transport with low running speed. Based on the frequency distribution curve, modal speeds are 35 Km/hr., 29 km/hr., 35km/hr., 28km/hr. and 29km/hr. respectively for cars, buses, goods delivery Van, two-wheeler, and three-wheeler (Auto). This shows the modal speed is in the range of 30kmph, which may be due to the fact the people are aware of urban posted limit. The large difference between V_{85} and Maximum Speed, which shows only few vehicles that runs above the speed limit. Truck and utilities vehicles, interestingly have higher speed in all speed percentiles. This may be due to more stability of vehicles. Also, the above comparison shows that 15% of all of the vehicles are moving below the minimum posted limit of 20kmph.

The data was further analysed for time mean speed and space mean speed for all categories of vehicles are presented in Table 4.

Table 4. Comparison between time mean speed and space mean speed

Particular	Car	Bus	Utility Vehicles	2-Wheeler	3-Wheeler	Truck
Time Mean Speed (km/hr.)	35.71	29.37	34.02	34.28	29	34.36
Space Mean Speed (km/hr.)	33.18	27.23	30.46	31.40	27.50	30.19
Standard Deviation	9.80	7.59	11.21	9.47	8.43	11.23

6.1. Posted Speed Limit and the Compliance.

This highway section has unique characteristics. Within the small section of this road, a three-speed limit is witnessed. The speed limit of 20kmph, 30kmph, and 40kmph is witnessed in the study area (Refer Figure 15). Previously the road only witnessed a 20kmph speed limit, but later federal government installed a speed limit of 40kmph, and the local government in support of the Traffic Police installed a speed limit of 30kmph in line

with the UN Love 30 slogan. There is no proper education or awareness of the posted speed limit among the various vehicle users which seems to be the reason behind the non-obeyance of the speed limit sign.

Figure 15. Posted speed limit sign observed along the road section.

Based on the volume proportion of the same route as described in section 5.1 and calculated various types of speed, the combined average speed is calculated and summarized in Table 5.

Table 5. Assessment of Speed with Posted Limit

Combined Average Speed (km/hr.) based on		
Time Mean Speed	Space Mean Speed	Maximum Speed
32.6	29.3	37.7

This shows that people are obeying the speed limit of 40kmph, which is also specified in the Motor Vehicle and Transport Management Act 2049 but with the introduction of a new speed limit sign, it needs to be properly backed by traffic awareness and adequate enforcement measures. Analyzing separately cars, two-wheelers and utility vehicles move at higher speeds. The speed limit of 20kmph was not properly enforced and hence was not obeyed and only the speed limit of 40kmph is obeyed as the roads are also wider to invite higher speed.

7. Conclusion and Recommendation

The average speed of vehicular traffic on the highway was within the upper posted speed limit of 40kmph. Similarly, buses and tempo are the ones with a small range of speeds and moving at comparatively lower speeds. Analyzing the proportion of different types of vehicles, the speed range gives an average speed of around

30kmph and a maximum speed range of 38kmph. This speed is also linked with the proportion of vehicles and is recommended to analyze the average speed at different traffic volume conditions.

Acknowledgement

The authors would like to gratitude to all the students (Graduate School of Engineering, Civil Engineering) who supported in the speed data collection phase.

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