"Study of Speed Variation in Mixed Traffic Using Statistical Distributions"

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Abstract

In mixed traffic flow conditions, traffic stream speed is an essential parameter that reflects the combined movement of various types of vehicles, including cars, two-wheelers, autorickshaws, and heavy-duty vehicles. It acts as a key indicator for analysing roadway performance, evaluating the level of service, and measuring congestion severity. Additionally, these vehicles exhibit significant differences in both their static and dynamic characteristics. Because of this heterogeneity, traffic does not behave uniformly. Large vehicles, such as buses and trucks, interact with smaller, faster vehicles, including two-wheelers and cars, resulting in frequent variations in speed. On the other hand, non-motorised vehicles further complicate the situation by influencing vehicular movement patterns in mixed traffic. In this study, traffic flow is investigated by accounting for vehicle speeds and analysing their statistical distribution.

Keywords: *Cumulative frequency, mixed traffic, speed, statistics.*

1. Introduction:

Traffic stream speed has long been recognised as one of the most fundamental factors in studying traffic flow, as it directly affects travel time, level of service, fuel use, safety, and the overall efficiency of the road facility. A higher average speed generally means less traffic and shorter travel times. Conversely, a lower average speed generally indicates increased traffic, higher travel expenses, and a greater risk of accidents. Therefore, a thorough study of speed is necessary for planning transportation, designing roads, and developing effective traffic management strategies.

Under homogeneous traffic, common in developed nations, vehicles are similar in type and performance. Cars, buses, and trucks tend to follow well-defined lane discipline, and speed analysis often reveals predictable, consistent trends. Models based on fundamental traffic flow theory, such as the speed–flow and speed–density relationships, are effectively applied in these scenarios. This situation allows researchers to assume uniform vehicle dimensions, similar acceleration and deceleration characteristics, and relatively stable driver behaviour, thereby simplifying traffic analysis.

On the other hand, in developing countries, a mixed traffic situation creates a more complex problem. The roadway accommodates a variety of vehicles, including two-wheelers, auto-rickshaws, buses, bicycles, and carts drawn by animals. These vehicles exhibit substantial differences in both static (dimensions, form, mass) and dynamic (acceleration, deceleration, manoeuvrability) characteristics. Moreover, the absence of lane discipline and varied driving behaviours results in frequent speed variations. Faster vehicles frequently manoeuvre through the spaces left by slower ones. This difference makes speed analysis in mixed traffic considerably challenging.

The primary aim of this study is to conduct a detailed analysis of traffic stream speed data collected from a selected roadway section operating under mixed traffic flow conditions. The roadway is shared by a wide variety of vehicles with different static and dynamic characteristics in such situations. This heterogeneity makes speed behaviour more complex and less predictable compared to homogeneous traffic, thereby requiring a comprehensive examination of speed patterns. This heterogeneity makes speed behaviour more complex and less predictable than in homogeneous traffic, thereby requiring a detailed examination of speed patterns. The objective is to evaluate the observed speed data. This involves calculating key statistical measures such as the average speed, which represents the overall central tendency of the traffic stream; the median speed, which gives the middle value of the distribution; and selected percentile speeds (such as the 15^{th}, 50^{th}, 85^{th}, and 95^{th} percentiles) that help exhibit the variability within the data.

2. Literature Review:

Greenshields (1935) pioneered the fundamental relationship among speed, flow, and density, which served as the basis for modern traffic flow theory. His successful efforts introduced the concept that traffic parameters are interdependent and can be mathematically modelled to describe traffic stream behaviour. Especially, he proposed a linear relationship between speed and density, from which the speed–flow–density relationship could be derived [1]. Al-Ghamdi (2002**)** et.al. emphasised that mixed traffic conditions cannot be fully represented by models developed for homogeneous traffic [2]. The Indian Roads Congress (IRC-106) provided an essential guideline on Indian urban roads, which performed a significant role in understanding traffic flow and its fundamental characteristics [3]. HCM (2010) outlined methodologies for analysing roadway capacity, level of service (LOS), and performance measures, thus offering traffic engineers a systematic approach to evaluate how roads function under varying demand and congestion levels [4]. Many researchers and authors have examined studies related to speed for specific traffic conditions [5],[6],[7].

This work builds on such foundations by analysing actual mixed-traffic speed data and applying speed distribution models.

3. Methodology:

Data Collection

Traffic speed data were collected using video-graphic survey methods at a mid-block section of the C.G. Road urban road segment in Ahmedabad. The individual speeds of vehicles (km/h) were calculated using the general time–distance method. The dataset comprises a diverse range of vehicles, including two-wheelers, cars, autorickshaws, Heavy Motor Vehicles (such as buses and trucks), and Light Commercial Motor Vehicles.

Speed Measures

The following speed measures were considered:

Mean Speed: Reflects the central tendency of the traffic stream.

Median Speed (50th Percentile): A reliable measure less influenced by skewed or extreme values.

85th Percentile Speed (V85): Commonly utilised for determining design speeds and suggesting speed limits.

95th Percentile Speed (V95): Represents the maximum traffic speed.

Standard Deviation & Coefficient of Variation: Measures speed dispersion.

4. Results and Discussion:

The statistical analysis of the traffic stream data reveals significant variation in vehicle speeds under mixed traffic conditions. The Median speed of the stream was 31.75 km/h, which is considerably lower than the free-flow speeds of the individual vehicle categories. This reduction in average speed highlights the influence of congestion, lane sharing, and vehicle heterogeneity, which are typically observed on urban roads.

Descriptive Statistics of Observed Speeds

The basic descriptive statistics of the traffic stream are presented in **Table 1**. These parameters indicate a high degree of variability in the observed speeds, as reflected by the standard deviation and coefficient of variation.

Table 1: Statistical Summary of Observed Traffic Speeds	
Parameter	**Value**
Number of Observations (n)	120
Median Speed (km/h)	31.75
Mode Speed (km/h)	34.4
Standard Deviation, sample (km/h)	9.92
Coefficient of Variation (%)	32.75
Minimum Speed (km/h)	9.5
Maximum Speed (km/h)	51.1

Observed Speed Distribution

The histogram of vehicle speeds (Figure 1) shows that most vehicles travel between 20 km/h and 40 km/h, with the highest frequency around 30 km/h. This indicates that the majority of traffic moves at a moderate speed under the observed conditions.

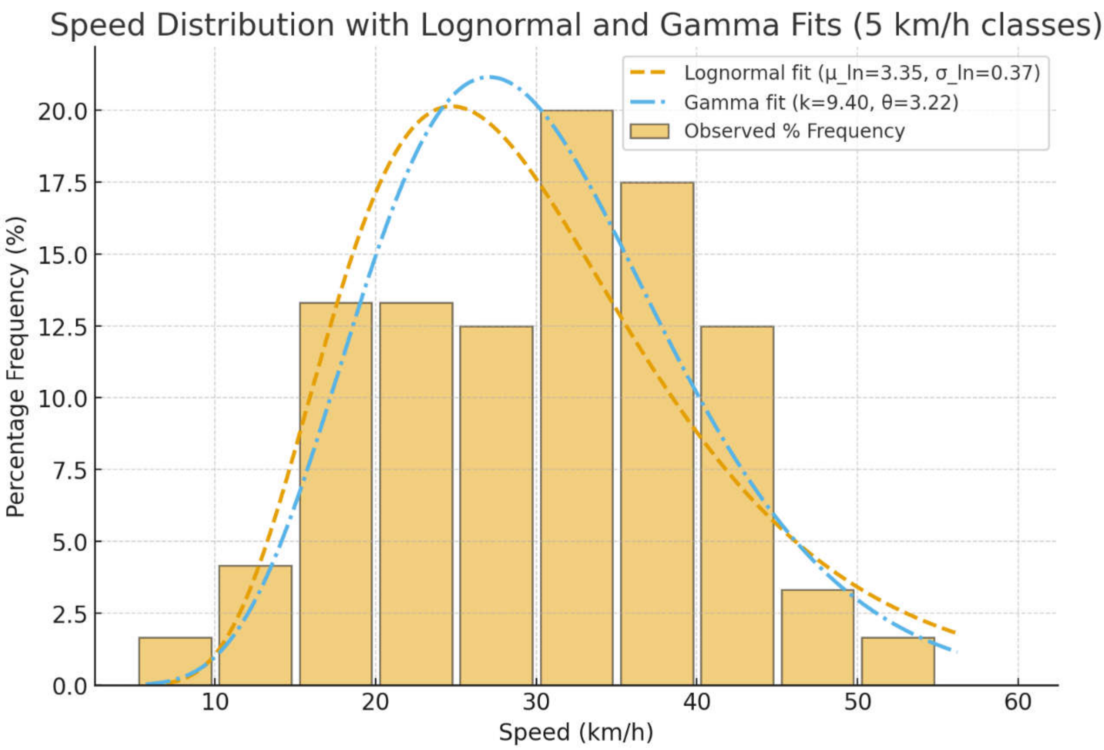

Figure 1: Histogram of Observed Speed Distribution

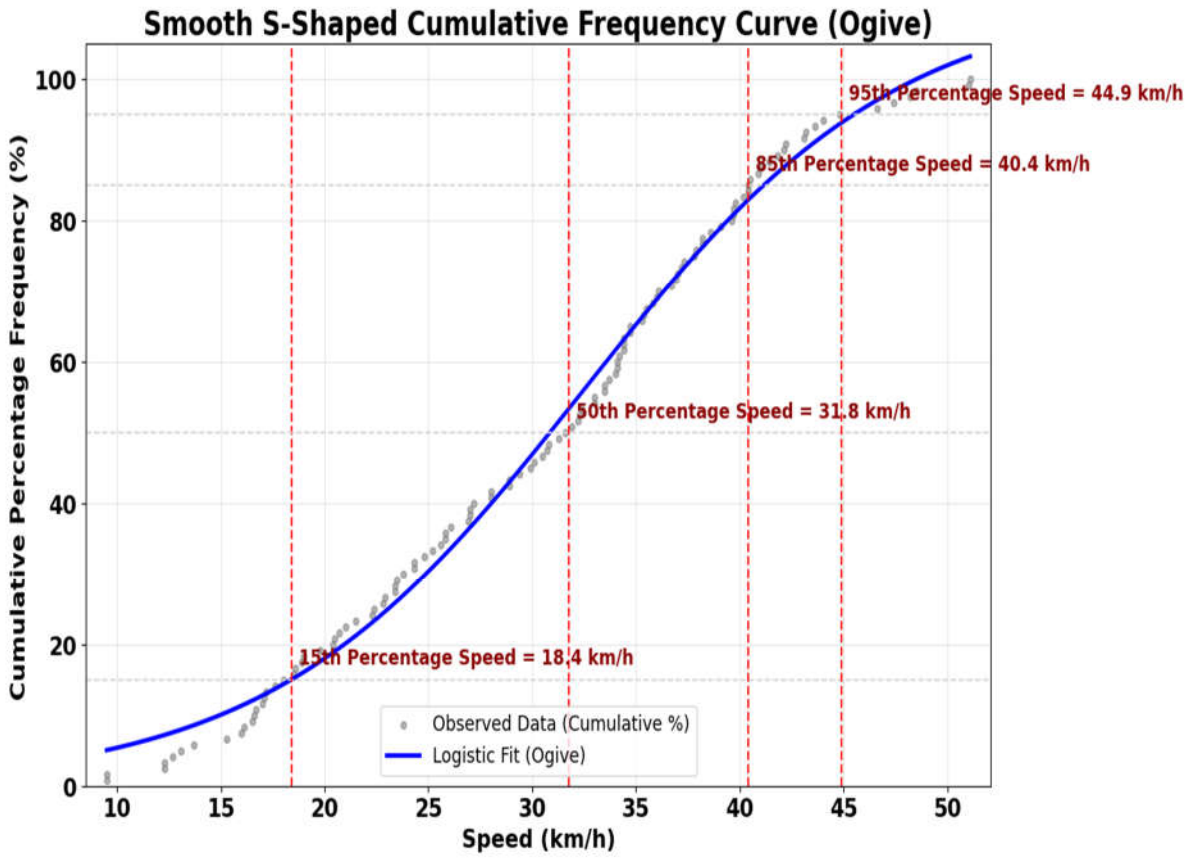

Figure 2: Cumulative Percentage Frequency versus Speed (km/h))

Lognormal Fit and Gamma Fit:
To further evaluate the speed distribution, two probabilistic models—Lognormal and Gamma—were fitted to the observed data (Figure 1).

Lognormal Fit ($\mu\_ln = 3.35$, $\sigma\_ln = 0.37$): Slightly overestimates in the 20–25 km/h range but provides a good match for the tail region.

Gamma Fit ($k = 9.40$, $\theta = 3.22$): Captures the peak around 30 km/h more closely but slightly underestimates in the tail region (above 45 km/h).

Since both models closely resemble the observed distribution, either can be used for traffic simulation or congestion modelling. The choice depends on the specific application: Gamma for better peak accuracy, or Lognormal for better tail representation.

The cumulative percentage frequency versus speed curve (ogive) shown in Figure 2 exhibits the characteristic S-shaped pattern, illustrating the percentile distribution of vehicle speeds. The curve indicates that the 15th percentile speed is 18.4 km/h, the 50th percentile (median) speed is 31.8 km/h, the 85th percentile speed is 40.4 km/h, and the 95th percentile speed is 44.9 km/h. This representation provides a clear understanding of how speeds are distributed across different percentiles in the observed traffic stream.

5. Conclusion:

This study analysed traffic stream data under mixed traffic conditions and revealed significant variability in vehicle speeds. The Median speed of 32.6 km/h was considerably lower than free-flow speeds, reflecting congestion, lane sharing, and heterogeneity. Descriptive statistics indicated high variability, with most vehicles travelling between 20 and 40 km/h, with a peak near 30 km/h. Both the Lognormal and Gamma models fitted the distribution well, with the Gamma model capturing the peak and the Lognormal model representing the tail. The ogive provided key percentile speeds which can serve as an input parameter for Level of Service assessment. The findings emphasize that a distribution-based approach effectively represents the inherent variability of mixed traffic conditions.

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