A Review on Distribution Models Using for Different Traffic Condition

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Abstract - *Vehicle headway distribution models are frequently employed in traffic engineering domains because they succinctly convey the stochastic nature of traffic flows while reflecting the inherent uncertainty in drivers' car following maneuvers. In this study, we examined traffic flow studies that have been conducted in earlier research. The objective of the paper is to give a broad understanding of distribution models for various passenger car unit (PCU) that ranges in varied traffic conditions of roadways. It is beneficial to learn more about how headway distribution develops in various traffic situations. Begin by highlighting the key concerns raised in this study regarding headway variability, traffic congestion on the road, transportation planning, operations, and level of service. Some critics claim that the data for road capacity are used to calculate time headway. Based on the research, we examine various methods for connecting macroscopic models of vehicle headway distribution with microscopic models of driver behavior. We have covered the factors that contribute to headway variability, effects, and alternative distribution for measuring headway. We also discuss proactive and reactive methods for reducing headway variability in theory and practice.*

Key Words: **Headway, Traffic headway, Distribution model, capacity**

1. INTRODUCTION

Headway data can be used to determine traffic flow stability. Traffic flow study is one of the fundamental keys that help traffic engineers to understand traffic conditions and design a better way to regulate flow **[1].** But it is difficult to analyse traffic congestion with different lanes in width and dissimilar characteristics because traffic volume fluctuates at each location **[2].** The roadway's traffic state is mixed because it contains vehicles of varied physical dimensions and other dynamic characteristics, such as two-wheelers, three-wheelers, and so on. Because of these qualities, the vehicle does not maintain lane discipline and occupies any lateral position throughout the entire width of the route, resulting in mixed traffic conditions **[3].** It is necessary to conduct a headway distribution model to make a better understanding of traffic operations.

The driver's behaviour is described by headway. The time difference between two succeeding vehicles with the same reference point is referred to as headway. It is usually calculated using the common attributes of the cars. As a result, it is critical in traffic engineering applications **[4].** That varies according to traffic conditions; the greater the flow of traffic, the less the headway. In traffic flow analysis, defining the headway distribution function is critical. It can be utilized in traffic flow modelling and analysis **[5].** It is necessary to define a headway distribution pattern, which translates to density and flow, the two main traffic flow metrics **[6].** The definition and measurement of these parameters under mixed traffic conditions with a lack of lane discipline is a challenging task. Headway can be analysed as time headway or space headway **[5].**

Time headway is the time interval between succeeding cars in a traffic flow, commonly measured in seconds **[7].** The driver's projection of time headway is typically based on the unanticipated delay of the vehicle driving ahead in the same direction, which influences safety, level of service, driver behaviour, and the capacity of a Transportation system **[8].** Time headway is an important statistic in traffic flow theory because it contains a lot of information about driver behaviour and acts as a bridge that connects drivers' vehicular activity to traffic flow **[9].** Traffic managers can smooth the traffic flow and alleviate traffic congestion by analysing time headway from traffic rate **[10].** For example, using time headway distribution, the traffic flow rate can be anticipated based on the traffic rate between cars. According to probability theory, the advent of headway distribution models has simplified the description of uncertainty in traffic flow and influences the opportunity for passing, merging, and crossing, as well as governing the system's capacity **[9].**

The same points of two consecutive vehicles following each other are characterized as space headway **[11].** Its values are critical for identifying traffic engineering issues and forecasting congestion **[10].** It is often measured as the time lapse between the first vehicle's front bumper crossing the designated location and the second vehicle's front bumper crossing the same point **[12].** Specifically, the physical distance between the leading vehicle's front bumper and the following vehicle's front bumper. it indicates the level of service, congestion, and the relationship to traffic density **[3].** These are essential microscopic traffic flow parameters that influence congestion and serve as a direct measure of density **[9].**

The main types of traffic models are microscopic, and macroscopic models consider the aggregate behaviour of traffic flow, and microscopic models consider the interaction of individual vehicles **[11].** In fig .1, the time-space diagram highlighting each vehicle's route in both time and space, there are two vehicles, dx denotes the short length of the route. The speeds and headways are easily visible.

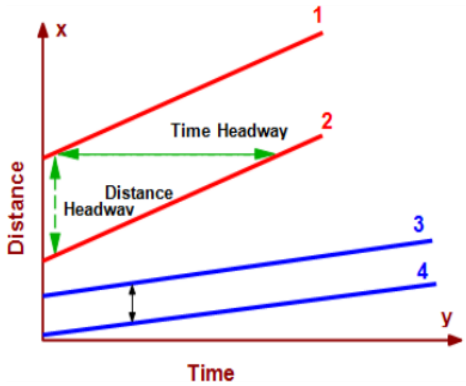

Fig.1 Time-space diagram showing headways

1.1 Macroscopic Indicators

Macroscopic Indicators characterize the flow of traffic as a unit (system), to obtain an operational picture of the whole system. Example: Volume, speed, density. Volume, velocity, and density are macroscopic measures in which traffic in a given time interval is represented by a single value of each that forms the flow of traffic as a whole **[13].** Macroscopic modelling collects the entire traffic stream on a road section, in terms of the traffic flow characteristics like flow, density, and mean speeds indicators **[6].** The fundamentals of traffic congestions as a minimum headway between the following vehicle and the vehicle traveling ahead to define Free Flow all the larger values are preferred if traffic conditions permit **[13]** as a single variable traffic rate is insufficient to determine traffic state since a certain value of flow to distinct density and speed value in two completely different flow States congested and un-congested **[9].** Headway translates to density and flow which are two macroscopic traffic flow parameters that can be used in the Modelling and analysis of traffic flow studies **[5].** However, it has been demonstrated that density may not properly indicate congestion because congestion is not likely to increase proportionally to the increase in density **[6], [9].** Modelling of headway is important due to the fact that headway and its distribution can affect different flow parameters including capacity, level of service, and safety **[6].**

1.2 Microscopic Indicators

Microscopic Indicators characterize the behavior of each vehicle in the traffic flow that affects each other. Example headway, spacing, occupancy, gap, and clearance **[13].** Time headway is one of the most important parameters in traffic flow theory because it indicates the unpredictability of the driver's behaviour and explains the problematic property of traffic flow which cannot be noticed by microscopic parameters **[14].** Time headway is a bridge that links to macroscopic traffic flow and microscopic traffic flow since the fundamental diagram un-expressly depends on the time headway it has also been proven that the time headway is speed-dependent when traffic flow is congested **[9].**

1.3 Road Capacity Determination Using Headway

The ability of a road to pass vehicles per unit of time under typical road and traffic conditions is referred to as its capacity. Statistics numbers can be used to calculate road capacity **[10].** Lane width, lateral flexibility, road alignment, surface condition, and road shoulder are all elements that influence road capacity **[3].** The capacity of the road determines traffic flow. In order to calculate the passenger car unit (pcu) can be defined by the formula (Highway Capacity Manual, 2010).

C = Co. FCW. FCSP. FCSF. FCCS……………..(1.1)

Where:

C = Road capacity (pcu/hour)

Co = Basic capacity (pcu/hour)

FCW = Adjustment factor for road width

FCSP = Adjustment factor for traffic separation

FCSF = Adjustment factor for side friction

FCCS = Adjustment factor for city size

Using headway data, traffic volumes and road capacity are estimated to assess the number of vehicles. Traffic volumes and road capacity are evaluated using headway data to examine the number of vehicles. Traffic volume includes elements such as traffic composition, traffic interruption, and lane distribution. Traffic volume and time headway are two types of traffic statistics needed to determine road capacity **[6].** Additionally, some data such as traffic density and average traffic speed, for example, traffic speed data can be used to analyse traffic situations. The average speed drops as traffic density increases. In this case, time headway can be used to determine a more dependable capacity **[15].**

hm: hp / n ………………………………………....(1.2)

Q: n/T = 1/hm ……………………………………..(1.3)

where:

hp = Time Headway of a vehicle (p) to a vehicle in front (second/vehicle)

hm = Average Time Headway (second/veh)

Q = Road Capacity (vehicle/second)

n = Total Number of Vehicles Passing a Certain Point of Observation during the period of T.

In equation 1.1, road capacity is expressed as a function of basic capacity. The passenger car equivalent is utilized to calculate this basic road capacity value. When the vehicle equivalent is used to calculate the fundamental road capacity, this result will undoubtedly differ. by Applying equations 1.2, and 1.3 the road capacity can be calculated using time headway values **[15].**

2. LITERATURE REVIEW

There have been several researchers who suggested several theoretical models for describing headways some experiences in urban traffic indicate that hyper-Lang distribution is best to describe the headway characteristics under mixed traffic Conditions **[16]** whereas negative exponential distribution exhibits its compatibility over a wide range of traffic flow levels if the traffic consists of a substantial percentage of smaller vehicles such as motorized two-wheelers **[1].** different headway distribution models in the passing and middle lanes in urban highways under heavy traffic conditions and concluded that lognormal and gamma models are suitable in passing and middle lanes respectively **[10]** calibrate and examine the performance of various headway mixed models. The goodness-of-fit was checked by the K-S test and the test result showed that the double displaced negative exponential distribution model provided the best fit to the urban freeway headway data and shifted lognormal distribution fits the general intention lane headways very well. Besides, several other mixed models have been developed and tested over the years in predicting headway distributions; they are respectively combined normal distribution and shifted negative exponential distribution, combined negative exponential distribution, and shifted negative exponential distribution **[17]** the distribution of headway using a nonparametric method along with the Gaussian kernel over a parametric for the freeway. The nonparametric method with Gaussian kernel exhibited more suitability than the parametric method having a log-normal distribution to analyze the individual vehicle headway distribution for freeways **[18]** the log-normal distribution model is a better choice when fitting headway data when the traffic is in free flow status; while the log-logistic distribution model is more suitable in fitting headway data when the traffic is in congestion status **[19].** Researchers have found that the discharge headway for vehicles standing in subsequent positions in a queue follows a lognormal distribution even if the headway of the first vehicle in a particular queue follows a normal distribution **[14]** There have been several reports concerning the development of headway models including Log-logistic distribution, Gamma distribution, Beta distribution, Gaussian kernels distribution, person 5, and person 6 distribution, etc **[19], [14], [18], [20].**

Several researchers focused on obtaining more accurate distribution models by combining both macroscopic traffic flow information and microscopic traffic flow information. Wang considered that it is better to use both macroscopic and microscopic traffic flow theory in practice **[9].**

In an attempt to analyze time headway distribution at the microscopic level of the six different continuous distribution models namely: Lognormal, beta, gamma, Weibull, exponential, and Log-logistic were selected to find an accurate model for time headway distribution the goodness of fit was checked by K-S test also visualized by PDF and CDF plot. The test result showed that the gamma and beta distribution were fitted with all the positions of traffic **[14].**

Panichpapiboon investigated and characterized the time-headway distributions of vehicles traveling on an urban expressway in Bangkok, Thailand, and concluded that GEV distribution is most effective in modeling time headway. whereas the exponential distribution was found to be the least effective distribution **[1].** The beta distribution is giving the best fit in most of the cases whereas Burr appears to be suitable for representing time headway distribution for all density ranges on two-lane bi-directional roads under mixed traffic conditions. further, they found Log-person, Type 3, Inverse Gaussian, and Log-logistic to represent the speed and time headway distribution on a two-lane two-way highway (NH-31) at different density ranges **[3].** However, analyzed the time headway and vehicle speed on urban roads and investigated the relationship between them. Based on the studies, as a conclusion achieved the high correlation between time headway and vehicle speed shows that the models can be used to describe the desired time headways at various vehicle speeds on Tanke - Unilorin, and other urban roads **[21].** There have been several single distribution models of the time headway have been proposed for free flow, such as Person 5, Weibull, Gamma-GQM, Johanson-SU, etc **[7], [22]–[24].**

Based upon the reviewed literature, a number of the existing literature has focused on finding out the best-fit distribution of space headway under various traffic flow conditions **[11]** The log-normal distribution and log-logistic distribution are suitable for high-flow traffic rates. Based on their observations the capacity space headway follows a normal distribution, while the observed space headway follows a log-normal distribution **[24]** However, zhang determined that the log-normal distribution is fit to observe the space headway **[18].** the space headway data should be positive and the Log normal distribution found the best fit of available data for evaluating the space headway that provides a reasonable approach to understanding the operational benefits for safety and traffic concerns **[4].**

3. MODELS OF HEADWAY DISTRIBUTION

3.1 Normal distribution

Appropriate for describing the relationship between time headway and traffic volume. That is well-fitted in heavy traffic flow and deviates for headway distribution for each vehicle position in congestion. The vehicle range is 800-1200 veh/hr. As the normal distribution, the appropriate headway distribution significantly observed headway value for each vehicle position **[15].**

3.2 Exponential distribution

Appropriate for describing time intervals between random events. Inter-arrival time of vehicles in low volume conditions. Whereas inappropriate condition when traffic becomes congested. The vehicle range is less than 400 veh/hr **[8].**

3.3 Erlang distribution

Appropriate to describe high traffic flow state. Whereas less suitable in the condition when traffic flow is low or medium. Well reflects traffic conditions when the congested state starts at 1200 up **[7].**

3.4 Gamma distribution

Appropriate in describing low and medium traffic flow conditions. As well as inappropriate in a high-traffic state and reflects a decent fit for a range of flow on arterials around 600-1200 veh/hr **[10].**

3.5 lognormal distribution

Appropriate for describing lower traffic flow circumstances. Which is not suitable in peak hours traffic, the vehicle range is less than 400-600 veh/hr **[20].**

3.6 Inverse Gaussian

Appropriate for describing mixed traffic conditions. Maintain higher time headway at low flow conditions. The vehicle range is less than 400-600 veh/hr **[1], [14].**

3.7 GEV (Generalized Extreme Value)

GEV distribution is more flexible than the log-normal distribution and inappropriate in high-traffic flow. Appropriate with 800-1000 veh/hr **[1].**

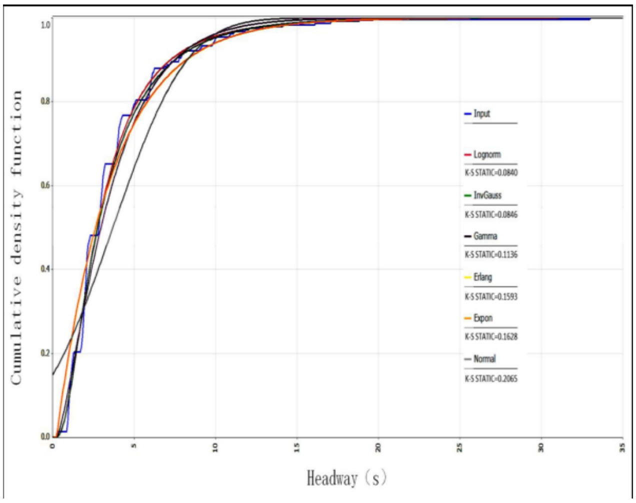

Fig.2 Example of the fitted distribution

As per the previous study Fig.2, the fitted distribution model is as follows: The lognormal distribution (3.670, 3.206) with K-S static is 0.0840, the inverse Gaussian distribution (3.881, 5.975) with K-S static is 0.0846, the gamma distribution (1.501, 2.322) with K-S static is 0.1136, the exponential distribution (3.462) with K-S static is 0.1628, the normal distribution (3.692, 3.557) with K-S static is 0.2065, and the Erlang distribution (The lognormal pattern is the best fit since the K-S static of 0.0840 is the smallest of them all and smaller than the critical value (0.0876) with a level of significance a = 0.05 **[25].**

4. CLASSIFICATION OF TRAFFIC FLOW

Generally, boundaries of traffic flow can be divided into three states; namely low, medium, and high flow conditions. According to previous studies, the major features of each of the flow states are imparted below the distribution.

4.1 Low-volume flow

Headway follows a random process as there is no interaction between the arrival of two vehicles. The arrival of one vehicle is independent of the arrival of another vehicle. The minimum headway is controlled by safety measures with range of low volume is less than 400 veh/hr. In this condition of flow the exponential distribution can be used to model such flow. The exponential distribution has the worst performance it can fit fewer than 30% of the empirical distributions. The exponential distribution only performs well during periods when the traffic is extremely light **[8], [20].**

4.2 Intermediate flow

Some vehicles travel independently and some vehicles interact with other vehicles. Intermediate flow is more difficult to analyze, however, has more application in the field with a volume between 400-800 veh/hr. The Pearson Type III distribution and Gaussian distribution as well as the lognormal distribution are also able to model this type of flow since the lognormal distribution can fit around 80% of the empirical distributions **[18], [10].**

4.3 High-volume flow

The flow is very high and is near the capacity. There is very high interaction between the vehicle which were characterized by near-constant headway and the mean and variance of the headway were very low with a volume between 800-1200 vec/hr. The normal distribution and Erlang distribution model can be used in high-volume traffic as well as GEV distribution is found appropriate model as the GEV distribution can cover the broadest range of traffic, and more than 90% of the empirical distribution can be described by the GEV distribution **[1], [7].**

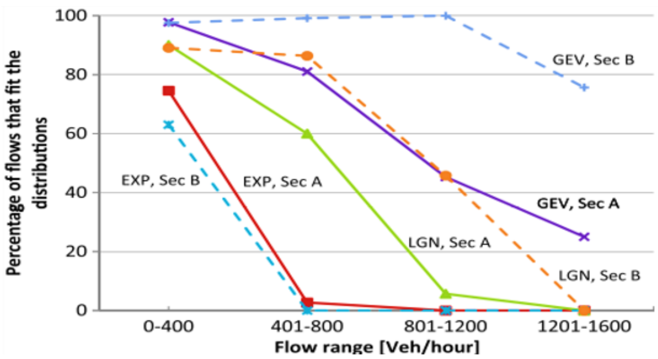

Fig.3 Percentage of flows that each type of fitted distribution

Fig.3 Illustrates the percentage of the flow that each type of distribution can fit for each class of traffic volume. This graphic shows the outcomes of Section A and Section B. Section A. findings are represented with solid lines, whereas Section B. results are plotted with dotted lines. Fig.3 clearly shows that the exponential distribution can only simulate low-volume flows. The lognormal distribution, on the other hand, performs the exponential distribution. It can simulate low- and medium-volume flows. The GEV distribution, on the other hand, can model flow over a wide range of volumes. In reality, the percentages of flows that can be predicted by the GEV distribution in practically all traffic classes are close to 100% in Section B. Furthermore, in the case of very high-volume traffic, the GEV distribution can model a large number of flows, whereas the other two types of distributions cannot **[1].**

5. DISCUSSION

The study attempted to provide a broad understanding of distribution models for various passenger car unit (PCU) that ranges in various traffic conditions of roadways, in order to learn more about how headway distribution develops in various traffic situations, that occur consisting of various types of vehicle movements that are based on the correction factor of a Passenger Car Unit (PCU) vehicle. Headway is an essential traffic metric that can be used to predict traffic congestion. Because it is difficult to gather headway data due to a lack of lane discipline, each type of distribution is examined to determine how well it can predict traffic flow at various levels of traffic volume. Some of the distributions used to model the statical distribution that can effectively model headway include the Normal distribution, exponential distribution, Erlang distribution, Gamma distribution, and Log-normal distribution. The goodness of fit of these models is determined using the K-S test. The K-S statistic reported is alpha, where alpha is the reject level for the hypothesis. K-S should be a high value (Max =1.0) when the fit is good and a low value (Min = 0.0) when the fit is not good. When the K-S value goes below 0.05, you will be informed that the Lack of fit is significant, the best-fitted distribution as per k-s values for different distributions are observed in review studies such as the K-S value for lognormal distribution is 0.1083, for Normal distribution value is 0.1398, for Gamma distribution, the value of K-S is 0.1175, For Erlang distribution, the K-S value is 0.3419 and for Inverse Gaussian the k-s value is 0.4042, For exponential distribution, the K-S value is 3.462, And for GEV distribution the value of the K-S test is 0.1076.0**[3], [26].**

6. CONCLUSIONS

In this paper, we present a literature review with intended to describe a simple, realistic distribution model to characterize the traffic flow.

1. Traffic flow is highly flexible in uniform conditions, depending on the capacity of the roadways, different types of vehicles, driver behavior, and pedestrian characteristics, as well. The proportion of freely moving vehicles is low in heavy traffic.

2. Some analysts have segregated data related to vehicle headway into several traffic flow categories, which is regarded as an appropriate distribution for analyzing traffic conditions.

3. Headway models were developed based on the findings of background reading. where a significant proportion of researchers have determined that improving distribution is the most valuable strategy to improve traffic variability. This will be beneficial in the future to headway control strategies and to increase headway regularity for further use.

4. The distribution headway has a significant impact on flow and capacity. A more exact estimation of distribution headways could reduce intersection delays.

5. A deviation from the conventional model and accordingly, the lognormal distribution fits for headway under lower traffic pressure circumstances, while the log-logistic distribution model is better for fitting headway data of peak hour, in higher traffic pressure **[19].**

6. It was discovered that the limitation of flow level ratio conditions is shorter headway, which can be considered as mixed traffic. In mixed traffic situations with varying flow scopes up to a low level of volume-to-capacity ratio of 0.3, Erlang and exponential models were found adequate, while exponential and gamma models were found appropriate in moderate and heavy flow **[8].**

7. These models can also be employed for automatic control of traffic flow to reduce travel time.

8. This will lead to better control of traffic behavior to mitigate congestion and improve public safety.

9. This paper, by systematically and comprehensively reviewing presents the headway distribution models, as well as some closely related microscopic and macroscopic traffic flow models.

Based on previous studies all intended to describe a headway distribution to determine Road capacity for traffic and variables. In summary, headway distribution models fill the gap between macroscopic and microscopic models and combine their advantages.

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