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A Review on Travel Time Reliability on Urban Roads

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Abstract - *The increase in number of vehicles per capita leads to uncertainties in travel time and there is growing worry over traffic management on urban roads. It is getting difficult to manage traffic as traffic influencing events, travel demand and physical feature highly vary travel time. This leads to the problems like congestion and travel time delay. Therefore, there is a need to consider the performance of urban corridors and an effort has been made to examine Travel time reliability. The term travel time reliability referred as "dependability or consistency of travel time as measured from various times of the day". It was found that growth in traffic volume, growth in population and delay are major problems for congestion. Methods like planning time, planning time index and buffer index are most commonly estimated which provides valuable information about the reliability of urban corridors. The travel time reliability can efficiently be utilized as a method in performance evaluation of traffic stream. The impact of a few other significant traffic characteristics, such as waiting delay and congestion delay, have also been reflected. Here this paper reviews and examined various existing reliability matrices and congestion matrices. The study then address procedure for calculating the travel time reliability measures.*

Key Words: Travel time reliability, Congestion, Buffer index, Planning time index, travel time index.

1. INTRODUCTION

Transportation is the strength of any developing country, and road transport is most common mode of transit. The usage of road transportation increases the number of vehicles on the road. India's vehicle population has exploded with an average growth rate of 9.91% during 2009-2019. Due to these vast increase in number of vehicles cities of our country becoming congested and which causing delays in travel time also causing increase in air pollution and noise pollution. In Fig-1 we can see Delhi has highest number of registered motor vehicles, afterward Faridabad, Bengaluru, Chennai and Ahmedabad. These five cities accounted for about 40.61% and 41.49% respectively of the total registered vehicles in respect of the reported Million Plus Cities in 2018 & 2019 [1]. For the purpose of evaluating metropolitan networks and corridors for traffic management and control, travel time has emerged as a critical performance standard. Travel time reliability is one of the criteria used to assess the quality of traffic service on an urban road. Numerous disciplines, including electronic systems, electrical systems, transportation systems, etc., have researched reliability [2]. As a foundation for the creation of a robust and sustainable transportation system, this review paper intends to elaborate on the state of the art in strategies to reduce traffic congestion on the roads.

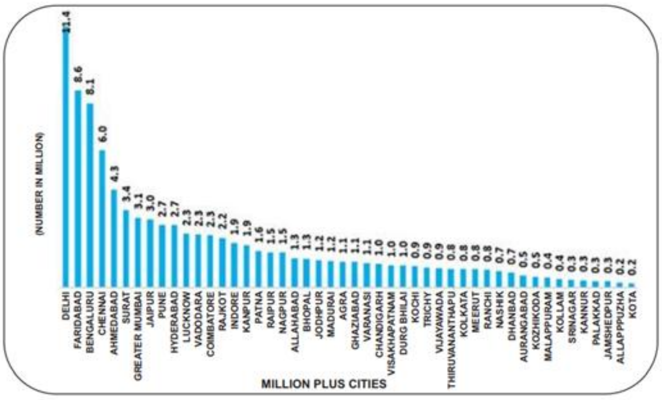

Fig -1: Total Registered Motor Vehicles in million Plus Cities as on 31st March,2019 (in million)

1.2 Travel time reliability

The travel time reliability is an important feature of transportation system performance. Travelers and transportation professionals value reliability for a variety of reasons like many transportation system users, whether they are vehicle drivers, transit riders, or others, find it important for on-time performance of the entire transportation system [2]. FHWA defines that the travel time, a fundamental measure in transportation, can be defined as the time taken to traverse a route between any two points of interest. High variation in reliability indicates reduction in the performance of roadway due to traffic influencing events and presence of physical features. These are the reasons travel time for similar trip at different times of a day or over the day become inconsistent. Researchers devised a number of measures to capture these anomalies [3]. Travel time reliability measures the performance of an urban arterial. In a broader sense reliability is an attribute of mobility and congestion. The buffer time measure like planning time (95% Travel time), planning time index, buffer time index was introduced as performance indicator. And the congestion measure volume, speed and congestion frequency graphs these helps to view the variability in traffic condition and find the unreliable period of day [4]. The buffer time indicates the unexpected delays and planning time considers both unexpected delay and typical delay. Sharmili Banik observes that all buffer time measures were able to depict the field condition to a great extent day. Planning time differs by only 0.87% between the sections whereas planning time index differs by almost 40%. This shows that even though the 95% percentile travel times are almost equal, section is more unreliable at this period. Overall, these measures connect to the way decisions made by the travers. Measures like buffer time index has to be cautiously used because of the unstable indication of changes in reliability over time [4]. However, buffer time index has to be cautiously used because of the unstable indication of changes in reliability as it can move in a direction opposite to the mean and percentile-based measures [5]. Saptarshi sen finds that the higher the value of planning time index indicates unreliable mode of transport, as a commuter has to include this extra time while planning their journey time. Once the travel time increases which forces the passengers to shifts their mode from public to private [6]. Aathira K Das finds that to build the priority foundation of improvement for the road on a short-term and long-term basis, one can calculate the Travel speed Indices values for peak and off-peak conditions and identify the congestion patches along the route for every kilometer of length [7]. Pagidimarry Gopi used a License Plate matching technique for measuring the travel time reliability in study corridor in a study in Delhi city. they identify the requirement of travel time reliability measurement for traffic management of urban corridor in India [2]. Reliability is so important for transportation system users; transportation planners and decision-makers should consider travel time reliability a key performance measure.

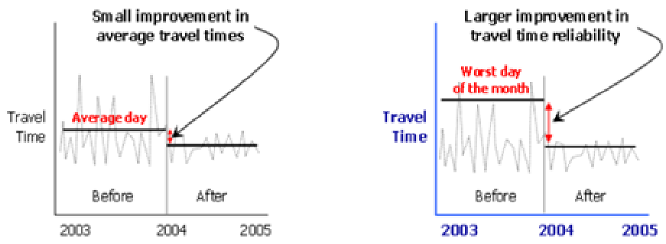

Fig-2: Reliability measures capture the benefits of traffic management

In Fig-2 two-line charts, each depicting daily travel time over two-year period, with first year representing travel time before a traffic management improvement and the second year representing travel times before traffic management improvement. In first chart, the improvement in average travel times is shown, and this improvement in average travel time is quite small. In second chart, the improvement in travel time reliability is shown (based on the worst day of the month), and this reliability improvement is much better than the improvement in average travel time. [3]

1.3 Measurement of Travel Time Reliability on urban roads

The measurement of travel time reliability is an emerging practice, yet a few measurements appear to have technical worth and are understandable to non-technical audience. The majority of these indicators compare days with a long delay to days with a short delay. The four recommended measures are outlined below: 90th or 95th percentile travel time, buffer Index, planning time index, and the frequency with which congestion surpasses some predicted threshold. [3], [8]

95th percentile travel time: It is the 95th percentile travel time of the measured travel time of the route it indicates how bad delay will be on heaviest travel days. This is measured in seconds or minutes which can be easily understood by commuters. Users familiar with the route (such as commuters) can see how bad traffic is during those few bad days and plan their trips accordingly. This measure has the disadvantage of not being easily compared across trips, as most trips will have different lengths. It is also difficult to combine route or trip travel times into a subarea or citywide average. Several reliability indices are presented below that enable comparisons or combinations of routes or trips with different lengths.

Buffer index (BI): Buffer index represents the extra time that most travelers add to their average travel time when planning trips to ensure on-time arrival. This time is added to account for unexpected delay. It is expressed in percentage. Buffer time index is signified as follows:

Buffer time = 95th percentile travel time for a trip – average travel time

Or

$$BI = \frac{95th\ percentile\ travel\ time - average\ travel\ time}{average\ travel\ time}$$

Planning time index (PTI): Planning time represents the total travel time that should be planned when an adequate buffer time is included. It is the ratio of 95th percentile travel time to free flow travel time.

To end, the delay brought on by riding public transportation also serves to demonstrate reliability. The dependability decreases as the delay increases. Planning time index Is signified as follows:

$$PTI = \frac{95th\ percentile\ travel\ time}{free\ flow\ travel\ time}$$

These metrics which are discussed above are straight forward to comprehend, and they are simple to calculate. Fig

3 shows the relationship between the travel time index, the buffer index, and the planning time index. The travel time index represents the average additional time required during peak times as compared to times of light traffic. The buffer index represents the additional time that is necessary above the average peak travel time, whereas the planning time index represents the total travel time that is necessary.[3]

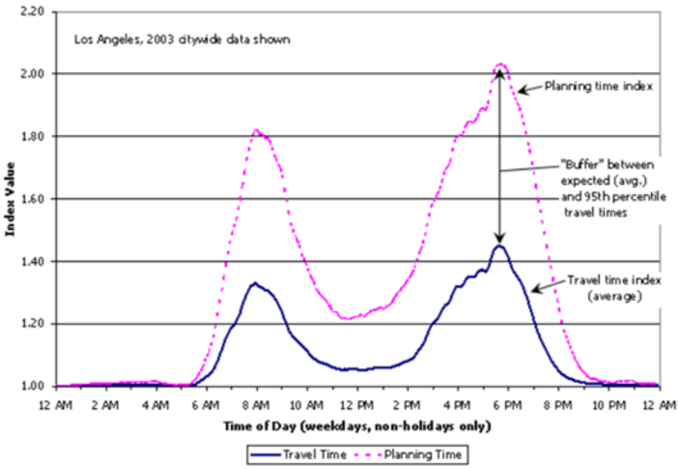

Fig-3: Reliability measures are related to average congestion Measures

Lastly, the reliability is also indicated with the help of the delay caused by travelling in public buses. The more the delay, the less is the reliability. The different types of delay focussed in this present study are as follows:[9]

I. Signal Delay: The vehicle stopping within a distance of 100 m from the 'stop' line under the influence of signal which incurs the delay in the travel time is termed as signal delay.

II. Bus Stop Delay: These delays are attributed to boarding and alighting of individual passengers at specified bus stops only.

III. Waiting Delay: This includes any extra delay occurred due to unnecessary halt at empty stoppages.

IV. Congestion Delay: Any delay caused by the congestion created due to the huge volume of traffic during the peak hours

1.4 Main causes of congestion

Urban or metropolitan regions may have congestion for a number of causes, including high demand, signals, incidents, work zones, weather-related factors, or special events. Road traffic congestion may typically be split into two types, based on a variety of primary reasons.[9]

1.4.1 Recurring congestion- In the majority of large cities, traffic is congested every day during peak hours. According to FHWA, around half of the congestion that traffic users encounter is recurrent. The following are typical causes of recurring congestion:

I. Bottleneck and Capacity: Bottleneck are the primary source of congestion. When more lanes are converging on a road, bridge, or tunnel than these facilities can accommodate during peak flow times, bottlenecks develop. It may also happen if a road's capacity is exceeded by demand. Any road's capacity tells you how much traffic it can support at its peak. Capacity may be affected by quantity and breadth of lanes, the distance required to merge at interchanges, and the orientation of the road.

II. Lack of infrastructure: One of the main causes of congestion, particularly in densely populated places, is a lack of infrastructure. The number of automobiles likewise rises along with the population growth rate. Congestion arises when the available infrastructure cannot accommodate the growing number of cars.

III. Variation in traffic flow: Because daily traffic demands vary day to day results in higher volume in some day than other. A delay could happen if these variable demands exceed the set capacity.

IV. Poorly timed signals or traffic controller designs, such as stop signs, speed bumps, or train crossings, can obstruct a regular traffic flow, causing congestion and travel time variations.

1.4.2 Nonrecurring congestion- non-recurring congestions typically happened as a result of unexpected circumstances, such as traffic accidents, construction zones, bad weather, or other unique situations. Nonrecurring congestion can cause fresh congestion to start up during off-peak times and can also lengthen the time it takes for recurring congestion to clear. Examples of typical non-recurring congestion include [9], [10]

I. Vehicle accidents, breakdowns, and debris in the lanes of travel are the most frequent types of traffic events. These incidents interfere with the regular flow of traffic, typically by obstructing the lanes, which further reduces capacity.

II. Work zones: Work zones are areas where there are construction projects taking place that will physically alter the surroundings of the route. These modifications result in changes to the number or width of travel lanes, lane "shifts," lane diversions, the elimination or decrease of shoulders, and momentary closures of the road.

III. Weather: Variations in the outside environment or the weather can have an impact on traffic flow and driver behavior. These could alter the way roads are built, as well as traffic control devices like signals and railroad crossings. About 28% of all highway crashes and 19% of all fatalities are caused by weather-related road conditions. Additionally, extreme wind gusts, torrential rain, or snow can have an impact on both vehicle speed and volume.

IV. Other exceptional events: These events call for modifications in traffic flow that often deviate from the typical flow pattern. These occasions could be concerts, sporting games (game days), or other social gatherings. During special occasions, a sudden increase in traffic demand might overload the infrastructure and cause congestion.

1.5 Congestion measures

Congestion measures are used to evaluate transportation network performance and identify issue regions. They can define how well the system achieves its stated aims and objectives, as well as explain differences in user experiences. Delay, risk of delay, mean speed, journey time, and vehicle hours travelled are some of the factors that indicate how long users are stuck in traffic. other measurements, such as the volume-to-capacity ratio, which is commonly stated as a level of service, show how well the system is performing at a given place [11]. As part of an overall performance program the FHWA [5] encourages agencies to consider travel time experienced by users as a source for congestion measurement in addition to other measures. they also claim that present congestion measurements are insufficient for evaluating the true impact of congestion on the transportations system from the perspective of users, and that they are unable to adequately measure the impacts of congestion mitigation techniques (Bureau of transportation statistics). Numerous congestion measures have been devised taking into account various performance parameters in order to assess the level of congestion. Congestion measures are (i) speed, (ii) travel time, (iii) delay, (iv) level of service and (v) congestion index. Table-1 illustrate these categories. Improving traffic management and control requires measuring the level of congestion [9].

Table - 1: congestion measures in different categories

Speed	**Travel Time**	**Delay**	**Level of service**	**Speed**	**Federal**
Average speed	Travel rate	Delay rate Delay ratio	Volume to capacity ratio (V/C)	Congestion index	Travel time index Planning time index

Improving traffic management and control requires measuring the level of congestion. The real conditions of traffic on the roads have a significant impact on the subsequent decision-making processes towards a sustainable transport system. In order to create a transportation system that is resilient and sustainable, the assessment method used to determine the severity of the congestion should be feasible for decision-makers to use.

1.6 Systematic Approach used to determine Reliability measures

In the study of travel time reliability and congestion firstly we need to choose appropriate measure under Indian Traffic condition for selected study corridor. Data collection is main part of any study so it is important to find methods for gathering data and create a timeline plan for doing so. Data collection mainly includes Traffic Volume, Travel Time, Average Speed etc. Data can be collected by Intelligent Transport System (ITS), GPS and surveys. Three different types of surveys—the speed and delay study, traffic volume count survey, and vehicle license plate survey have been conducted to assess the operational effectiveness of the chosen urban corridor. Numerous performance measurements were recorded, and developments in traffic data gathering technology produced enormous amounts of data in both real-time and historical settings. Then we can Calculate reliability measures - 95th or other percentile travel time, Buffer index – Evaluation of buffer index for each road and effect of non-motorized vehicle on buffer index is studied, Planning time index - study is done on the impact of non-motorized vehicles on the planning time index and the evaluation of the planning time index for each road. The time model is influenced by different parameters. One of the most important variables is speed. Distance is another main variable for determination of travel time, meanwhile increase in length of segment will obviously increase the travel time. Model has been developed using software like SPSS, VISSIM, Excel etc. for statical analysis, micro simulation, Regression analysis linear or multiple. At last development of travel time reliability models using parameters affecting congestion is done and then validated the model in selected study corridor using appropriate tests t-test, ANOVA test, chi-square test etc. but in SPSS software's has been limited up to maximum 1500 cases and 50 variables and when limit exceeds you have to create new file.

2. LITERATURE REVIEW

This section cover literature related to Travel time reliability measures of transportation and congestion delay and how reliability parameters can be adopted for computing travel time delay for urban corridors. The detailed literature has been discussed below.

(Sharmili Banik, et al. 2021), have done a case study of Chennai city for better understanding and representation of applicability of travel time reliability measures. For this purpose, data has been collected for one month period using GPS fitted on buses that are operated in study corridor. Author compared various statical range measures like Buffer time, Tardy trip, Probabilistic and Congestion measures. From the measure and finding they observed that many of the measures give different reliability indications.[4]

(Ahmed Hassan Mohamed, et al. 2021), in this paper author focuses on the elements that influence travel time reliability of bus transport. Travel Time was used as the dependent variable, while elements discovered during data collections that appeared to affect bus travel time dependability were used as independent variables to determine factors affecting travel time reliability. ANOVA was used to analyze the difference among groups. This was followed by more in-depth examination utilizing the SPSS statical software. Travel Time is strongly affected by the number of bus stoppings, length of the route. The reliability of all routes during the weekday is low because of delays in departure. The number of signalized intersections along the route affects reliability. Meanwhile, more passengers boarding and paying cash increased the travel time reliability of buses.[12]

(M.M. Harsha, et al. 2021), here travel time variability is investigated by utilizing travel time distribution that accounts various temporal and spatial aggregation.travel time distribution is evaluated with regard to temporal aggregations (peak period, off-peak period) and spatial aggregations (route level and segment level) using Automatic Vehicle Location data from four transit routes in Mysore City, Karnataka, India. The findings of route and segment level study show that the generalized extreme value distribution has the highest accuracy and robustness values. The distribution has been shown to be superior in characterizing public transit trip time variability.[13]

(C. P. Muneera, et. al. 2020), here in this paper author takes travel time index for measurement of reliability for urban roads. Statistical measures of travel time index of each road are calculated for reliability estimation. Author developed a model for travel time index with traffic flow rate to predict the travel time reliability. This paper also focuses on proposing level of service criteria using travel time reliability measure. The results obtained will be useful for traffic management and planning.[14]

(Saptarshi Sen, et al. 2019), did the study to determine the travel time reliability of various public transportation modes along a specific route in the Kolkata city. The state government bus, private bus and minibus in-vehicle journey time reliability were estimated and then results is compared to metro railway. According to the findings, the journey time reliability of all bus kinds ranges from 45 to 65 percent of the metro railway's reliability. The parameters such as Buffer time, Buffer Index, planning time and Planning time index, were also estimated, providing useful information on the bus reliability. Other significant traffic parameters, such as congestion delay and waiting time delay, have also been explored in relation to reliability. According to delay measurement, Results shows buses experience a high signal and congestion delay during peak hours.[6]

(Anish Kumar Bharti, et. al. 2018), author illustrates how travel time reliability can be used to quantify the level of service (LOS) for urban arterial and inter-urban highway corridors on Indian roadways. Automatic vehicle license plate number data were gathered using the TrafficMonitoring system to estimate travel times. They fully use video-base system to analyze which is set in entry and exit of the section. According to the findings of the trip time analysis, the urban uninterrupted and intercity highway routes' respective PTI thresholds for LOS B were 1.37 and 1.01 respectively. This suggests that the urban uninterrupted study route has a 1.37-times longer travel time than the free flow corridor. [15]

(Pagidimarry Gopi, et. al. 2014), author did research to assess the travel time reliability measures of an unbroken urban arterial corridor in the Delhi Road network during peak and non-peak hours. Various existing travel time reliability indices are studied and examined in order to do this. The benefit of travel time reliability is that it can be utilized as a new evaluation technique in performance evaluation and as travel time related information to system users. Planning time index, Planning Time, and Buffer Time Index are among the reliability measurements investigated. The findings show that dependability measures are better in assessing the effectiveness of urban arterial corridors.[2]

(Ravi Sekhar, et. al. 2013), the author aims to study the reliability of travel time under the influence of various demand and supply side components in the transportation system. For one week, data on traffic volume, speed, and travel time were collected in order to assess travel time reliability on study corridor and calculated relevant reliability metrics. A microscopic traffic simulation model was constructed using VISSIM software to investigate the influence of various demand and supply side variables on trip time reliability. The created simulation model was successfully tested with observed data, and the study revealed that time increases by 5.3 and 6 times for scenarios of a 50% increase in demand and a lane closure for around 30 minutes, respectively.[16]

(Srinivas S. Pulugurtha, et. al. 2010), here author design and demonstrate how a methodology for estimating journey time and fluctuations, travel delay index owing to crashes and their severity, congestion score, and network connection reliability works. The computations take into account traffic volume, link capacity, travel speed, collisions and their severity, and the projected time it takes for normal traffic conditions to return after a crash. Because travel demand and crash occurrence vary depending on the time of day, temporal changes in travel time and crashes for each link are also investigated. Sensitivity analysis is also used to test and evaluate the reliability of links based on weight fluctuations to integrate recurrent and nonrecurring congestion components.[17]

(Tanzina Afrin, et al. 2020), here author reviews current road traffic congestion measures like speed, travel time, delay, level of service, congestion indices, federal approach. These congestion measure compared using a real-time traffic tracker dataset. The analysis of congestion was performed daily and weekly. The weekly research revealed a little variation in peak congestion periods from day to day. The data analysis reveals the pros and downsides of each measure. This paper reviews current road traffic congestion measurements and offers helpful suggestions for the construction of a long-term and robust traffic management system.[9]

(Ashwini Thakare, et. al. 2020), in this paper author envisioned a possible approach to reduce delay. The geographical spread (Origin & Destination) pattern for Nagpur is being developed for the study. Vehicular tracking system is used for identifying possible delays. The study used questionnaires, GIS, observation techniques. The results will quantify the elements that causes delays in travel along a certain route. Depending on problem solutions will helps in reducing congestion and queue length, results in lesser fuel consumption and also less cost of transportation.[14]

(Satya Ranjan Samal, et. al. 2020), author aims to investigate and assess the possibility of using a modeling technique to predict congestion indices under heterogeneous traffic condition. Video graphic data, traffic volume and travel time was measured in peak hours congestion indices are evaluated. Author mainly focusses on congestion in terms of travel time reliability measurements to determine the operational effectiveness of urban road network. From result it is found that travel time and congestion indices varied according to vehicular composition.[8]

(Roshani Dhapudkar, et. al. 2018), in this author looked into traffic parameters including speed, flow and density, as well as the relationship between them. The videographic data were captured from traffic stream and analyzed it to look at key traffic metrics including speed, flow and density. It is found that traditional traffic stream equations are insufficient for these heterogeneous traffic flows. As a result, well need to devise a new equation to account for the Indian scenarios heterogeneous traffic. They discovered the traffic stream parameters after a thorough investigation. They obtain a standard relationship between the parameters of the traffic stream.[18]

(Sourabh Jain, et. al. 2017), did their research to better understand congestion on urban arterial and sub arterial having heterogeneous traffic condition. The predicted travel time for a journey is calculated using sectional traffic characteristics (flow and speed) at the origin and destination points of road segments, as well as other highway and segment traffic variables such as diversion routes. Using a congestion index, predicted journey time is combined with free flow time to determine the state of congestion on the segments. This type of advancement could aid with the comprehension of traffic.[19]

(Aathira K Das, et. al. 2016), did research to make a concerted effort to address traffic congestion measurement using V-Box trip speed profiles. Despite the fact that there are variety of traffic congestion measures, there is still a need for a simple and effective manner of presenting traffic congestion on enroute segments. M-TCM traffic congestion model, which is multi-linear regression, is used to calculate the congestion condition along a route. Traffic congestion Index, the model's output, serves as the foundation traffic quality performance, allowing traffic engineers to take the necessary actions to minimize Traffic Congestion Index values by implementing appropriate traffic engineering solutions.[7]

3. DISCUSSIONS

The current study focused on Travel time reliability and congestion measures for urban roads under heterogeneous traffic condition. Additionally, the FHWA Report 2006's reliability measures like buffer time, buffer time index, planning time index and planning time were applied here. Travel time reliability and congestion measurement criteria can be adopted based on speed base or travel time base matrices. For a road length, daily and weekly analyses of congestion were conducted in peak and off-peak hours of the day. In India, travel time reliability is not usually considered to evaluate transportation planning or corridor performance evaluation. This compressive review focus on demonstrating the value of travel time reliability and its significance for Indian urban roads.

4. CONCLUSIONS

This study identified the requirement of travel time reliability measurements for measuring performance of urban roads in traditional measures. The following Conclusions can be obtained from the literature:

1. The statistical indicator of travel time reliability, the travel time index exhibits a positive exponential rise with traffic flow rate. This analysis forecasts how much travel time passengers would need to arrive on time at various traffic flow rates on urban singles in heterogeneous traffic conditions.

2. It is observed that many of the measures give different reliability indications. This may be due to the fact that some measures use non-robust characteristics of the travel time distribution.

3. It was noted that there is good agreement between standard deviation, percent variation, width, buffer time, planning time, misery index, and frequency of congestion with reference to the dependability condition. These measurements do match quite nicely with one another.
4. On-time arrival and Unreliability Index do not agree well with the other measurements or each other. It simply displays a linear connection, If the measurements are connected nonlinearly, this will not indicate that.
5. The study of travel time reliability will be helpful for road planning and traffic parameters management to reduce traffic jam density and increase flow of road.
6. This will be helpful for identifying various factors responsible for delays.
7. After studying Travel Time Reliability measure, we can easily find maximum delay and flow delay.
8. It will be beneficial for finding the congestion patches along the route for every km of length to develop the priority basis of improvement for the route.
9. This study predicts allocations of travel time for the users for on-time performance at different traffic flow rate on urban roads under heterogeneous traffic condition.

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