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ASSESSING MEASURES OF HIGHWAY TRAFFIC FLOW WITH TRAVEL TIME RELIABILITY BASED ON TRAVEL TIME INDEX. In-depth literature reviewed.

BY

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Abstract:
Viewing cities in this contemporary era, travel time efficiency and operational performance as well as the service quality of transport connectivity posed a strong effect on transportation networks. However, severe and unanticipated delays disrupted deliveries, program and activity schedules, operations, and other logistics. The travel time index was used to identify the determinants of the buffer time index (BTI) and planning time index (PTI) as a technique for measuring travel time consistency. This study aimed to examine highway travel time reliability measures based on BTI and PTI using a highway capacity manual (HCM) as an integral part of this work. The study focuses on the following objectives. Firstly, to identify the measures of highway travel time reliability. Secondly, to assess the effectiveness of travel time reliability measures. The researchers developed a bibliometric analysis to identify the intensity of the two variables used based on the literature. The study further provides an explanatory framework for travel time reliability through wide and broader learning under diverse works of literature. The study shows that BTI was more consistent and proven more effective in measuring TTI compared to PTI with minimum percentile. The study's findings will be useful to transportation planners, academics, and traffic engineers in their decision-making process to improve TTR.

Keywords: *Highway traffic flow, Travel time, Reliability, Buffer time index, Planning time index.*

1. Introduction

Travel time can be inconsistence depending on the factors either positive or negative downstream of hold-up associated with long travel time, route length, location of the route on the city's plan, period of the day or season of the year, passenger turnover, intensity of passenger's capacity usage, corridor or road situations, number of stops, routes, and driver's knowledge. Travellers may encounter substantial performance fluctuations as a result of their expectation or concern of inconsistent travel time dependability, which might impact the concentration of the roadway.

Trip makers may view the reliability of arrival times frequently as the most essential component of total journey time. Seeing towns and regions in this contemporary era, travel time efficiency, operational performance, the service quality of transport connectivity, and travel time dependability posed a strong effect on the co-partners in transportation systems comprises of trip makers, service deliverers, transportation planners, highway engineers, and administrators. Reliability denotes an idea of recurrence, though it is open to explanation. It is the likelihood that a trip will be concluded within a specified time frame when travellers have an infinitely long memory; and are upset about travel(Chen et al., 2019).

Travellers pay attention to reliability for two reasons: commuters face timing requirements and the consequences of arriving early or late, and travellers are inherently uncomfortable with unreliability due to pressure (Ghader et al., 2019). Active Traffic Management and integrated corridor management (ICM) are two ways of traffic management strategies that integrate variable speed limits (VSL), queue warning (QW), and ramp metering (RM) though, ICM aimed to make the best use of existing infrastructure assets such as freeways and arterials (Chung et al., 2020). Probe Vehicle Data is one of the most important data sources for evaluating

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non-highway roads because they are typically underserved by unit sensors (Steinmaßl et al., 2021).

The impact of congestion level and travel time reliability on truck drivers' path optimisation behaviour can be assessed using extensive non - homogenous traffic data combined with geospatial information (Kong et al., 2018). Car ownership has generated an enormous concentration of automobiles on the road network in modern cities (Hameed et al., 2019; Tsuboi, 2021). The presence of heavy and sluggish vehicles in the traffic stream reduces traffic capacity significantly on the flow of moving passenger automobiles (Macioszek, 2019). Road infrastructure, unregulated road conditions, informal activities, off-street parking, and insufficient public transportation were the significant reasons for traffic congestion on the Abuja-Kugbo-Nyaya axis (Chidera, 2020).

This study aimed at assessing measures of corridor highway traffic with travel time reliability for disaggregate traffic flow and travel time index using buffer time index (BTI), and planning time index (PTI) to establish congestion travel time reliability threshold. In the events of congestion, reliability is measured by buffer time index and standard deviations from foreseeable traffic flow connected with a given traffic situation. The study will foresee travel time reliability as a dependent variable for calculating the buffer time index (BTI) and planning time index (PTI) by the Highway capacity manual

Research Background

Drivers face delays, annoyance, and financial losses as a result of traffic congestion, and also smog (Afrin & Yodo, 2020). Traffic congestion refers to the pressure caused by vehicles inflicted on each other as a result of vehicular flow (A. et al., 2020)(Kumar Singh et al., 2020). Traffic congestion has placed a good sized and ongoing stress on productivity, vehicle accidents, immoderate emissions, and ecological pollution, all of which can be triggered via way of means of traffic congestion (Yang et al., 2019). It is true that much time is wasted in densely populated cities due to heavy road congestion and relatively low labour productivity (Chidera,2020)(Nwankwo et al., 2019). Highway traffic is a situation where city road capacity could no longer take in the volume of traffic at a given time (D.N et al., 2019).

A town is a place where people live, where knowledge and innovations, and recreation activities accommodate travel time (Ayo-odifiri et al., 2021). (Nnamani et al., 2020). Highway traffic is an everyday occurrence in major and medium-sized cities across the world (Wang et al., 2020). Highway traffic causes overcrowding and occurs when a large number of cars flood the road, disrupts the smooth movement (Ali et al., 2018). Road traffic crash is one of the factors for travel time reliability and death in Nigeria (Kenneth, 2021).

Research Justification

Urban areas as a knowledge-based centre connected with transport, create an avenue for numerous activities, community, services, goods, information communication technology engagement, and business opportunities can be attack through travel delay. Studying the current state of travel time reliability data and availability of data requires a rigorous understanding of the variable measures, requiring means by which appropriate build a finding that will contribute to travel time reliability.

2.0.Literature Review

Travel delay is typically connected with an excess of vehicles on a part of the corridor highway at one time, resulting in speeds that are significantly slower than normal or "free flow" rates (Federal Highway Administration, 2016). This could imply a halt or stop-and-go situation. The authors assess the reliability of metropolitan highway travel time using the Buffer Time (BT) and Planning Indices (PTI) (Susilawati et al., 2010). With the enactment of Moving Ahead for Progress in the 21st century (MAP), state and metropolitan transportation agencies must adopt performance-based planning travel time reliability incorporating safety, infrastructure condition, congestion minimisation, sustainability, freight movement, and economic viability, and minimised project delivery delays (Chen et al., 2019)(Aiyegbajeje, 2019)(Nnamani et al., 2020). Olorunnimbe et al., (2022) emphasised mostly on dilapidated traffic flow networks. Reliability measures and models (mostly means, median distribution, standard deviation, buffer time index, planning time index, misery index, coefficient of variance; normal and lognormal distribution, Burr distribution, and Weibull distribution can be use travel time studies (FHWA, 2019)(Mathew et al., 2020)(Zou et al., 2020) (Pulugurtha & Koilada, 2021),(Jain & Pulugurtha, 2022).

The diverse performance of urban travel, and provides a critical assessment of the development of the proposed technology-based solution (Moriarty, 2022). (Rivera-Royero et al., 2022) examine the classification of road network performance as a foundation for mapping the various boundaries and the relationship between the road network performance (RNP) concept. (Siddiqui & Ko, 2020) uniqueness of roadway systems provides a metric on the dependability of travel time and the features of the roadway system based on the variability of travel time. The used of binary logistic regression model, and ANOVA objectively identify collinearity between the TTI and PTI ratio; compare the level of traffic delays at various traffic points (Kong et al., 2018)(Shahrour & Xie, 2021).

Kong et al., (2018) investigate the impact of two analytical determinants, congestion rates, and travel time reliability on route choices where motorists have varying awareness levels of real-time and historical traffic situations on available roads. However, some travellers are less tolerant of unforeseen delays (Federal Highway Administration, 2016). Travellers' route choice behaviour, and various types of extra knowledge of mean-variance, relative gap-based, and penalty-based types to model traveller route choice behaviour in terms of travel time consistency (Zhu et al., 2021). The utilised of neural network (NN), support vector regression (SVR), linear, polynomial, and radial basis function (RBF) kernel functions, K-nearest neighbours (KNN), and decision tree (DT) to evaluate TTR (Afandizadeh Zargari et al., 2021).

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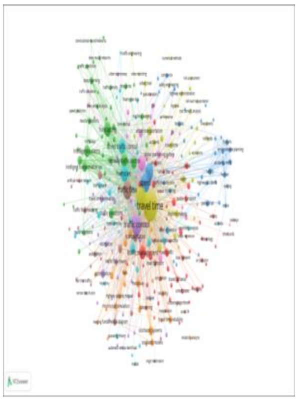	Analysis -Total number of clustered = 8 -Total number of co-occurrence Layout Parameters -Random = 1 -Max, Iteration = 1000 -Initial Stepsize = 1.000 -Stepsize Reduction = 0.75 -Stepsize Convergence = 0.001 Random Seed = 0
Figure 1 Authors Generated Bibliometric Analysis	

Concept of Travel Time Reliability

Travel Time Reliability Theory and Models Applications

Travel time reliability measures as gained a widespread attention in transportation planning and engineering for couple of years. It one of the main performance measures adopted by group of both private, and public agencies in developed countries (Texas Transportation Institute & Cambridge Systems, 2006). Travel time can be categorised in to performance-driven and reliability measures and traveller's response to reliability. Lomax et al. were among the old scholars who studied travel time reliability measures that demonstrate a practical performance (Schrank et al., 2021). Taylor & Susilawati, (2012) recommended 90th and 95th percentile travel time, buffer index, as well as frequency of congestion for travel time reliability measures. Generalised Extreme Value (GEV) theory to measure extremely lengthen travel time, and evaluate the possible dominant factors (Zhang et al., 2019). According to Afandizadeh Zargari et al., (2021) analysing coefficient, root mean square error (RMAE), and model stability using statistical measures of error in terms of maximum, standard deviation, and mean; KNN is the best method for calculating TTR.

Speed prediction can be examined where travel time detection is used to separate speed limits and volume data to establish a transportation travel time reliability threshold (Pennetti et al., 2020). Measuring reliability could be used to determine the stability value for a specific mode choice problem and to establish the relationship between travel time and reliability (Mishra et al., 2018a) . Log-linear model is more appropriate for route travelers-kilometers non-homogenous relationship and correlation under direct linear technique (Dike et al., 2018). Burr distribution was specified to as an approach to travel time reliability modelling to investigate real day-to-day travel time bus route over six months in Klang Valley Malaysia (Khoo et al., 2021).

2.1. Travel Time Reliability Measures

2.2 Comparative View of Travel Time Reliability Measures

Yao et al., (2020) examines the consequences of rainwater variability and differences in traffic congestion bottlenecks area. The study adopted index calculation and clustered method through floating car data (FCD) and Open Street Map data (OSM). The method to quantify travel time reliability metrics can be grouped into variation metrics, probabilistic measures, and percentile index (Kidando, Moses, Ozguven, et al., 2019)(Kidando, Moses, Sando, et al., 2019)

The percentile index recognises percentile such as the 10^{th},50^{th} 90^{th}, and 95^{th} percentile of travel time distribution to analyse different measures such as buffer time index, planning time index, travel time index, and skew statistics (Engelson & Fosgerau, 2016)(Taylor, 2017)(Zhu et al., 2021). The measure of comparing mean travel time somehow tends to ignore information specifically for majorly skewed travel time distributions related to the change flow situation including congestion onset and congestion and congestion dissipation (Kidando, Moses, Sando, et al., 2019). Travel time reliability is influenced by numerous which include traffic incidents, traffic volume, vehicle heterogeneity, land use features, and traffic management systems (Kidando, Moses, Ozguven, et al., 2019).

Kidando, Moses, Sando, et al., (2019) employed probability-based logic to identify the constituents of travel time reliability and prediction methods. Reliability is regarded as a performance metric because trip planners value reliability and consider it to be their preferred option(Mishra et al., 2018b). The researcher concluded that index calculation and clustering (ICC) is more reliable. (Wang et al., 2020). (Kathuria et al., 2020) examines various public transport reliability measures including factors accounting for variability in the journey time.

Banke-Thomas et al., (2021) investigated retroactive examination of antenatal women under obstetric situation over a year at the public hospitality. The researchers review clinical data retrieved from demographic travel data, also exported google map at a given time of th day. The author further used multivariable logistic regression to determine the relative important variation of time, and location(Banke-Thomas et al., 2021). (Oluwole, 2017)investigated the main reasons influences access to public transport facilities using factor analysis and regression technique and revealed that reliability of Bus schedule on road is high, therefore, Bus fare is the root causes of public transport. Optimisation model parameters can be transfer to independent basin to assess production of discharge water (Ogbu et al., 2022).

Schroten et al., (2020) investigate the influence of Smart Mobility and the new technologies that underpin it on transportation infrastructure and society more realistic outcomes. Traffic congestion using traffic assignment, can reduces total travel time on network dependability of road users from the same source and destination with traversal time (Angelelli et al., 2020). Big Data is a technological system that was developed to deal with the expansion of knowledge and increased the rate of user of mobile and internet data accessibility (Ratna et al., 2020). The study presented an

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empirical research for determining passenger car equivalent factors for big trucks on a turbo roundabout in Poland (Macioszek, 2019). The researchers proposed a data analysis technique for traffic regarding the production noises summation that creates a criterion for chaotic identification (Wang et al., 2020).

Table Reliability Performance Measures

Reliability Performance metrics	Definition	Unit
Planning Time Index	90^{th} percentile travel time index (90^{th} percentile travel time divided by the free flow travel time)	None
Buffer Index	The difference between the 95^{th} travel time and the average travel time, normalised by the median travel time	Percentile
Failure/On-Time Measures	Percentile of trips with travel times less than 1.1 multiply by median travel time or 1.25 *median travel time. Percent of trips with space mean speed less than 50 mph; 45 mph; 30 mph	Percentile
8^{th} Percentile Travel Time Index	80^{th} percentile travel time divided by the free flow travel time	None
Skew Statistic	(90^{th} percentile travel time – the median) divided by (the median – the 10^{th} percentile travel time)	None
Misery Index	The average of the highest 5% of travel time divided by the free flow travel time	None

Source: (Kittelson & Vandehey, 2014)(Chen et al., 2019).

Analysis of BTI

Buffer Time Index (BTI) measure factor that affects the extra travel time that travellers need to reserve beyond the median travel time.

$$BTI = \frac{T_{95} - T_{50}}{T_{50}} = \frac{T_{95}}{T_{50}} - 1$$

Table Error! No text of specified style in document.**.1 Travel Time Reliability Index**

S/NO.	Reliability Index	Definition	Relevance
1	PTI	$\frac{90^{th}/95^{th}\ Percentile}{FFT}$	Personal trip & urban trip
2	BTI	$\frac{95^{th}\ Percentile - T_{avg}}{FFT}$	Commercial trip, logistic service, carriers
3	TTI	$\frac{T_{avg}}{FFT}$	Used as a congestion measure
4	Misery Index	$\frac{5\%\ worst\ Tavg}{FFT}$	Used as an instrument to estimate bad trips
5	λ Skew	$\frac{5\%\ worst\ Tavg.}{FFT}$	Operator Side Index
6	λ variance	$\frac{TT90 - TT10}{TT50}$	Operator Side Index
7	P (T_{ave} + ATTV)	Percentile when TT is ATT above T_{ave}	User Side Index
8	P (T_{ave} - DTTR)	Percentile when TT is ATT above T_{ave}	User Side Index
9	TT80 – TT20	-	Range of average TT
10	TT70 – TT30	-	Range of average TT

Source: Adapted from (Jose & Ram, 2020)

Uncertainty of Variable Reliabilities.

In sufficiency of timely or relevant variable reliability data affect most of the reliability analysis especially, where the reasons for the analysis is reliably predicted. Reliability is a mechanism for making decisions correlated to choosing one out of a number of best design alternatives or investigate variables which mutually requires reliability upgrade or improvement. Comparing alternative models, variations in system reliability tendency that is more of concern. The uncertainty correspond to the differences are in whole, much lower compare to the absolute reliability values.

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(Lomax et al., 2003)(Li et al., 2019). Identify four (4) types of reliability measures:

(a). **Statistical range measure:** Using standard deviation

STD = $\sqrt{\frac{1}{(N-1} \sum_{ij}(TTi - M)^2}$

Or the covariance coefficient

Cov = $\frac{STD}{M}$,

Where M is the mean travel time.

(b) **Buffer time measures**: The additional percentage of time a traveller should reserve when considering travel time variability, i.e., BI =, where TT_i is I percentile quantile of travel time.

(c). **Tard trip measure**: The difference between the average travel time of a tardy trip and the average travel time, i.e., Misery Index (MI) $\frac{(M \mid TT_I > TT_{90} - M)}{M}$

d) **Probability measure**: The likelihood of travel time exceeding a certain threshold, such as a time media: PR (α) = P (TT_i – α TT_{50})

e). **Skewness and variability:** The skewness and width of the distribution are represented by

ƛ skew = TT_{90} - TT_{50} $\frac{TT_{90} - TT_{50}}{TT_{50} - TT_{10}}$ ƛ and – $\frac{TT_{90} - TT_{10}}{TT_{50}}$

3.0.Conclusion

The challenges of travel time reliability globally, are seen as undeterminable factor accomplish with highway traffic though, much is been done in some developed countries of the world to improve transportation systems and travel time variability. The situation in Nigeria is different because such measures are not being implemented effectively. Much research has been conducted in African country like Ghana, and other countries around the world to measure travel time variability. The situation in Nigeria is different because such measures are not being efficiently handled. The literature shows that previous researchers deviate from TTR measure to improve travel time dependability. The geographical location proven little difference measures of TTR in different angle, direction, and perspectives. The literature also notes that traffic congestion and travel time reliability cannot be distinguishable. The study will assist future researchers on relative measures are more fitted to estimate, assess, evaluate, and quantify the effectiveness of travel time

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