ENHANCING URBAN ROAD NETWORK EFFICIENCY IN KERALA, INDIA: A COMPREHENSIVE ANALYSIS OF TRAFFIC CONGESTION AND LEVEL OF SERVICE

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Abstract - *In recent years, the growing problem of traffic congestion and the decreasing level of service in metropolitan areas has drawn increasing attention due to its adverse impact on urban economies and the environment. This paper presents the findings of a detailed traffic study conducted in one of the busiest towns in the state of Kerala, India, namely Tirur which serves as a critical transportation link between two prominent cities Kozhikode and Ernakulam. The study focuses on understanding the Level of Service (LOS) on urban roads in Indian conditions, with a specific emphasis on the factors contributing to congestion and reduced service levels.*

The research employs a comprehensive and multifaceted methodology, encompassing critical factors such as speed, travel time, traffic interruptions, and restrictions. This approach is designed to offer a nuanced and thorough examination of the intricate nature of urban traffic congestion. To achieve a comprehensive understanding, data was collected on various parameters used to define LOS during different days and times, enabling the identification of congested areas and the underlying causes of inconvenience for commuters.

This paper also proposes a range of improvement measures and remedies to address the identified issues, contributing to more efficient road networks and improved travel experiences for citizens and visitors. The application of Geographic Information Systems (GIS) facilitates the visualization and analysis of spatial data, enabling a data-driven approach to urban transportation management.

The study encompasses a comprehensive analysis of a 13 km stretch between Rajiv Gandhi Stadium to Nariparambu Junction, dividing it into seven locations, to evaluate LOS, travel time reliability, and regression analysis. It was observed that road width was a key determinant of LOS, with different segments exhibiting varying levels of service. Travel time reliability was assessed using multiple indices, emphasizing the importance of proactive trip planning. The regression model highlighted the impact of road length and vehicle speed on travel time, with implications for travel time reduction.

The findings and recommendations presented in this paper serve as a valuable resource for policymakers, urban planners, and transportation authorities seeking to enhance the efficiency and sustainability of urban road networks in Indian metropolitan areas. This research contributes to the broader discourse on urban transportation, providing insights and solutions that can be adapted to similar urban contexts.

***Key Words*: Urban transportation, Level of Service, Travel Time Reliability, Geographic Information System, Moving Observer Car method, Regression Analysis.**

1. INTRODUCTION

The essence of human mobility is woven into the fabric of our existence. Since time immemorial, individuals have journeyed, whether in pursuit of sustenance or leisure. Fundamental to this enduring need is the efficient transportation of raw materials to manufacturing hubs and finished goods to consumers. Indeed, transportation fulfills these elemental human requirements. Moreover, it has played an indispensable role in the evolution of human civilization. As we reflect on the historical trajectory of human settlements, it becomes evident that the proximity of transportation facilities has had a profound impact on the development of these communities.

The quality of transportation infrastructure is intricately linked to the standard of living, forming a nexus that shapes societies and economies. Consequently, our expectations for transportation facilities are lofty. We demand that they be not only analytically grounded and economically viable but also socially accepted, environmentally conscious, practical, and sustainable. In essence, the solutions to transportation challenges should embody attributes such as safety, speed, comfort, convenience, affordability, and eco-friendliness.

At the heart of this complex web of considerations lies the field of traffic engineering, a discipline dedicated to the analysis of traffic behaviour and the design of facilities that enable the smooth, safe, and cost-effective operation of traffic. Much like the flow of water, traffic exhibits a multitude of parameters that define its characteristics. The study of traffic stream parameters offers valuable insights into the nature of traffic flow, enabling experts to identify variations in traffic patterns and behaviours. Consequently, a comprehensive understanding of traffic behaviour necessitates a profound grasp of these parameters and their interrelationships.

Capacity and Level of Service are two fundamental concepts in traffic engineering. Capacity analysis seeks to quantify the volume of traffic that a specific transportation facility can effectively accommodate, offering a quantitative measurement. In contrast, Level of Service provides a qualitative assessment of the current traffic conditions in a given facility, shedding light on how well it is performing. Both these metrics are dynamic, and influenced by a range of factors including facility type, traffic volume, and prevailing road conditions.

Unlike many other fields of study, traffic engineering relies heavily on real-world data, gathered from the field, which cannot be precisely replicated within the controlled environment of a laboratory. Speed data are obtained through measurements taken at specific points or over short sections, while traffic flow data is collected from designated points along the transportation network.

In this context, this paper delves into the intricate realm of traffic engineering, where the principles of transportation are brought to life through the exploration of traffic flow parameters, capacity analysis, and Level of Service. By deciphering these fundamental concepts, we aim to provide a comprehensive understanding of the dynamic world of transportation and its pivotal role in shaping the communities and societies we inhabit.

2. STUDY APPROACH

2.1 Objectives

•To determine traffic flow patterns on weekdays and weekends for morning and evening peak hours for the selected stretch of roads.

•To determine the travel time reliability indices using the obtained data.

•To evaluate the Level of Service of the taken stretch.

•Regression analysis using regression models.

•To propose the traffic improvement measures for the selected road stretch.

•To digitalize the area of study using QGIS Software.

2.2 Level of Service (LOS)

The concept of Level of Service (LOS) is fundamental in the field of traffic engineering, providing a standardized measure to assess the quality of service on a particular traffic facility to its flow rate. LOS, as introduced by the Highway Capacity Manual (HCM), is a valuable tool for evaluating the user experience and operational characteristics of a transportation infrastructure. It's an essential framework for understanding the relationship between traffic volume and the quality of service provided.

The HCM system classifies LOS using a letter-based notation, with six distinct levels: A, B, C, D, E, and F. Each letter corresponds to a range of operating conditions on a specific type of facility, where A represents the highest quality of service and F indicates the poorest quality. These designations are based on Measures of Effectiveness (MoE) related to that facility.

Typical MoE encompasses various factors such as speed, travel time, traffic density, and delay. These measures offer insight into the performance of the transportation system and provide a basis for determining the appropriate LOS designation. For instance, LOS A typically indicates minimal delays, fast travel times, and a high level of service quality, while LOS F suggests significant congestion, extended travel times, and suboptimal service quality.

It's important to note that each LOS level is associated with a specific service volume or service flow rate. This figure represents the maximum number of vehicles, passengers, or other relevant entities that the facility can effectively accommodate under given conditions while maintaining the designated LOS. This quantitative aspect adds precision to the assessment of traffic facilities, allowing for informed decision-making in transportation planning, design, and management.be used. Other font types may be used if needed for special purposes.

2.3 Travel Time Reliability

Reliability in the context of transportation is a crucial measure that directly affects a driver's ability to accurately predict and plan for their travel time. Essentially, it's a reflection of the consistency and predictability of travel conditions on a roadway. The more unexpected or irregular events that occur on a road, the less reliable it becomes for commuters.

When it comes to traffic congestion, it's important to distinguish between two main types: recurrent congestion and non-recurrent congestion. Non-recurrent congestion, which stems from incidents like accidents, roadwork, or adverse weather conditions, has a more pronounced impact on the reliability of a roadway compared to concurrent congestion, which results from everyday traffic volume fluctuations.

Travel-time reliability is the yardstick used to gauge the level of consistency in travel conditions over a significant period. This reliability is measured by analyzing the distribution of travel times that occur during this extended period. In essence, it quantifies how dependable and consistent travel conditions are for drivers. For example, if a road consistently experiences delays during peak hours or due to frequent incidents, it's considered less reliable compared to a road where travel times are more consistent.

Reliability is a pivotal component of roadway performance, and it significantly influences motorists' perceptions of how well a roadway is functioning. When motorists can reasonably anticipate their travel times, they generally have a more positive experience with the road network. This is particularly crucial in urban planning and traffic management, as it affects commuters' overall satisfaction and willingness to use certain routes.

The concept of reliability can be quantified using various metrics. These may include the average travel rate or speed standard deviation, which measures the consistency of speeds, and the delay standard deviation, which assesses the consistency of delays. By considering these measures, transportation planners and engineers can make informed decisions to enhance the reliability of road networks and improve the overall quality of the commuting experience for drivers.

2.4 90th Or 95th Percentile Travel Times

It estimates how bad delays will be on specific routes during the heaviest traffic days. The one or two bad days each month mark the 95th or 90th percentile, respectively. 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 is reported in minutes.[17]

2.5 Buffer Index

The buffer index represents the extra time (or time cushion) that travellers must add to their average travel time when planning trips to ensure on-time arrival. [17]

Buffer index= (95% travel time-avg travel time)/avg travel time

2.6 Planning Time Index

The planning time index represents how much total time a traveller should allow to ensure on-time arrival. The planning time index shows the total necessary travel time.[17]

Planning time index= 95% travel time/free flow travel time

2.7 Congestion Index

The Roadway Congestion Index (RCI) is a measure of vehicle travel density on major roadways in an urban area. [17]

Congestion index= (Avg. travel time-Free flow travel time)/Free flow travel time

2.8 Speed Ratio

Speed ratio = Actual mean speed of trip/mean free flow speed

3. METHODS OF DATA COLLECTION

3.1 Moving observer car method

The moving car or moving observer method of traffic stream measurement has been developed to provide simultaneous measurement of traffic stream variables. It has the advantage of obtaining the complete state with just three observers and a vehicle. Determination of any of the two parameters of the traffic flow will provide the third one by the equation $q = u.k$. [17]

3.2 Methodology

1. Preliminary Surveys:

•Perform preliminary surveys to collect essential information about the road segment, including the number of lanes, road length, road width, and other relevant characteristics.

2. Field Traffic Surveys:

• Execute field traffic surveys to collect data on vehicular volume and vehicular speed within specific road sections in the city.

• Utilize the Moving Observer Car method as the data collection approach for accurate and real-time traffic data.

3.Data Analysis:

•Analyze the collected data to estimate the Level of Service (LOS) for the selected road segment.

•Calculate and assess various travel time reliability indices to provide a comprehensive view of the reliability of travel conditions.

4. Cause of Congestion Identification:

•Investigate and identify the root causes of congestion on the selected road stretch, utilizing the data and analysis findings as a basis for this assessment.

•Propose targeted improvement measures to address these identified causes and alleviate traffic congestion.

5. Geospatial Mapping with QGIS:

• Employ QGIS (Quantum GIS) software to digitally map and analyze the study area.

• Generate geospatial representations to visualize and understand the road network, traffic flow patterns, and congestion-prone areas in the region.

This refined methodology emphasizes the use of field surveys and data analysis to assess traffic conditions, determine the Level of Service, identify congestion causes, and propose specific improvements. Additionally, it highlights the use of geospatial tools like QGIS for a comprehensive understanding of the study area.

4. STUDY AREA

Tirur, a vibrant town and municipality located in the Malappuram district of the Indian state of Kerala, spans an area of approximately 62.34 square kilometres. Positioned as one of the primary business centres in the Malappuram district, Tirur holds a strategic location, situated 26 kilometres west of Malappuram and 52.5 kilometres south of Kozhikode. This town is an integral part of the Shoranur–Mangalore section of the Mangalore–Chennai railway line. Notably, Tirur is a significant regional trading hub, particularly renowned for its trade in fish and betel leaf. The town's average elevation stands at 2 meters above sea level.

For transportation, the nearest airport is the Calicut International Airport, conveniently located approximately 35 kilometres away, ensuring connectivity with domestic and international destinations.

Tirur also holds historical and cultural significance, serving as a coastal city that has been a pivotal commercial and business hub within the coastal area of Kerala. The town's rich cultural fabric is highlighted by its numerous places of worship and a calendar filled with cultural events.

The specific stretch selected for the reliability study serves as a crucial link on the route connecting Kozhikode and Ernakulam. This route offers significant advantages, including shorter travel distances and reduced travel times between these two key cities. The primary objective of the study is to assess the Level of Service (LOS) and Travel Time Reliability of the busiest segment within the Tirur urban region, contributing to a deeper understanding of the transportation dynamics in this thriving locale.

•The selected stretch from Rajiv Gandhi Stadium to Nariparambu Junction is a 13 km stretch comprising several important junctions, places of worship, educational institutions etc. Seven locations (Stadium, Thazhepalam, Poongotukulam, B.P Angadi, Alathiyur, Chamvravattom, Nariparambu Bridge Junction)

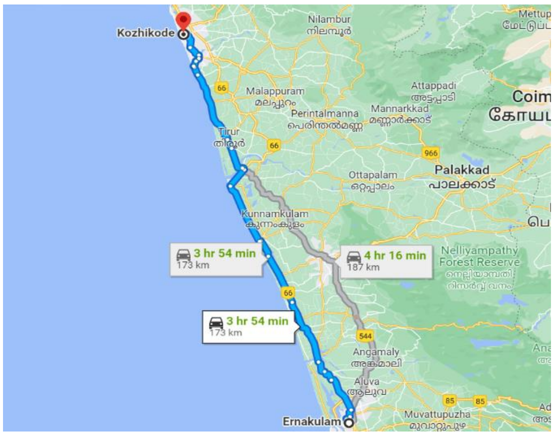

Fig-1: The easiest identified route between Kozhikode and Ernakulam from Google Maps.

LINK	ROAD NAME	LENGTH(m)	SPEED REDUCTION MEASURES	
			HUMP	ZEBRA
1	Stadium-Thazhepalam	400	0	2
2	Thazhepalam-Poongottukulam	500	0	3
3	Poongottukulam-BP Angadi	2700	1(5),1(5)	10
4	BP Angadi - Alathiyoor	3400	1(5)	14
5	Alahyoor-Chamravattom	5000	1(5)	18
6	Chamravattom-Nariparambu	1500	0	1

Table -1: Selected Stretches and its Specifications

5. DATA ANALYSIS

m_a –opposing traffic count of vehicles met when test vehicle moving against traffic flow

m_o – No. of vehicles overtaking the observer

m_p – No. of vehicles overtaken by the observer

So, $m_w = m_o - m_p$

Flow (Q) = $m_a+m_wt_a+t_w$

Where t_w - journey time in the direction of flow

t_a - journey time against the direction of flow

Space mean speed (Vs) = $lt_w - m_wQ$

l – travel distance

The primary business centres in the Malappuram district, Tirur holds a strategic location, situated 26 kilometres west of Malappuram and 52.5 kilometres south of Kozhikode. This town is an integral part of the Shoranur–Mangalore section of the Mangalore–Chennai railway line. Notably, Tirur is a significant regional trading hub, particularly renowned for its trade in fish and betel leaf. The town's average elevation stands at 2 meters above sea level.

6. TRAVEL TIME RELIABILITY

Travel Time min	Speed km/hr
21	36
21	36
24	32
22	32
27	25
28	25
25	30
25	30
25	29
24	29
29	25
31	22
32	22
32	22
36	20
36	20
33	22
25	29
20	36
21	36
24	29
24	29
21	36
21	36
Avg=26.125	Avg=28.67

Table-2: Travel time and speed for 13 km study stretch

• Travel Time Index= Avg. travel time/free flow travel time[17]

= (26.125/18)
=1.45

• Speed ratio = Actual mean speed of trip/mean free flow speed [17]

= (28.67/43.33)
= 0.662

•Planning Time Index= 95% travel time/free flow travel time [17]

= (35.4/18)
=1.967

•Planning time = Planning Time Index x Free flow travel time[17]

= 1.967 x 18
= 35.41 minutes

That is, for an 18-minute trip in light traffic, the total time that should be planned for the trip is 35.41 minutes.

•Congestion Index= (Avg. travel time-free flow travel time)/free flow travel time [17]

= (26.125-18)/18
=0.45

•Buffer Index= (95% travel time-avg travel time)/avg travel time [17]

= (35.4-26.125)/26.125
= 0.355 = 35.5%

•Buffer time = Buffer Index x Avg. travel time [17]

= 0.355 x 26.125
= 9.3 minutes

Therefore, the traveller should allow 35.4 minutes for the trip to ensure on-time arrival 95 per cent of the time.

7. LEVEL OF SERVICE

LOCATION	Average speed V(km/hr)	Free Flow Speed V_f(km/hr)	LOS
Stadium to Thazhepalam	21.15	24	B
Thazhepalam to Poongottukulam	24.39	30	B
Poongottukulam to BP Angadi	30.81	40.5	B

BP Angadi to Alathyoor	30.55	51	C
Alathiyoor to Chamravattom	38.54	42.85	B
Chamravattom to Nariparambu	39.49	45	A

Table-3: Average speed, Free flow speed, and LOS of various links

The comprehensive study of the 13 km stretch from Rajiv Gandhi Stadium to Nariparambu Junction revealed valuable insights into its transportation dynamics. The stretch was divided into seven locations, and the Level of Service (LOS), travel time reliability, and regression analysis were carried out.

8. REGRESSION ANALYSIS

A regression model expresses a 'dependent' variable as a function of one or more 'independent' variables, generally in the form:

- Y= Constant+ B1X1 + B2X2+………. + BnXn

The line that expresses the relationship between the y variable, is called the dependent variable. Regression with a single dependent variable y whose value is dependent upon the independent variable x is expressed as

LINK	TIME (hr)	SPEED (km/hr)	WIDTH(m)	LENGTH(m)
STA-THA	0.016	21.15	8.3	400
THA-POO	0.0225	24.39	8.3	500
POO-BP	0.0915	30.81	7.4	2700
BP-ALA	0.106	30.55	6.6	3400
ALA-CHA	0.134	38.54	6.95	5000
CHA-NAR	0.405	39.49	7.15	1500

Table-4: Data for regression analysis on various links

Y= Constant+ B1X1 + B2X2+………. + BnXn

Travel time = (0.301149076) + (0.021478615*Speed) + (-0.08875259*Width) + (-7.68E-05*Length)

The predicted time when speed is 40km/hr, width 7.5m and length 5000 m is 7 minutes.

9. RESULT

In the study of the Tirur urban region's traffic dynamics, the stretch between BP Angadi and Alathyoor stands out as having the worst Level of Service (LOS), characterized as LOS C. This segment extends over a distance of 3,400 meters and maintains an average width of 6.6 meters throughout its length. Notably, among the 13-kilometre stretch from Stadium to Naripparambu, this particular section records the narrowest road width, accentuating the challenges it poses to traffic flow.

Level-of-Service (LOS) is a fundamental concept used to assess the quality of traffic service in relation to the flow rate of a specific transportation facility. It is denoted by a letter representing a range of operating conditions in that particular type of facility. LOS C, in this case, signifies a zone of stable flow, yet it marks the commencement of the range of flow where the operation of individual users begins to be significantly impacted by interactions with other vehicles in the traffic stream.

At LOS C, factors such as speed selection are influenced by the presence of other vehicles, and maneuvering within the traffic stream requires heightened vigilance from users. This level of service also marks a noticeable decline in the general level of comfort and convenience experienced by commuters. Therefore, LOS C reflects a scenario where traffic conditions, while not in a state of severe congestion, have reached a point where traffic interactions affect the overall quality of the journey and necessitate more careful navigation.

10. CONCLUSION

The comprehensive study of the 13 km stretch from Rajiv Gandhi Stadium to Nariparambu Junction revealed valuable insights into its transportation dynamics. The stretch was divided into seven locations, and the Level of Service (LOS), travel time reliability, and regression analysis were carried out.

Regarding LOS based on average travel speed, four sub-stretches (Stadium to Thazhepalam, Thazhepalam to Poongotukulam, Poongotukulam to BP Angadi, and Alathyoor to Chamravattom) exhibited a LOS of B. Notably, the section between BP Angadi and Alathyoor recorded the worst LOS, marked as LOS C, while the segment from Chamravattom to Naripparambu displayed the best LOS, designated as LOS A. It was evident from our studies that road width was the key factor influencing the LOS.

The travel time reliability assessment included six reliability indices, highlighting the need for proactive trip planning. For instance, for an 18-minute trip in light traffic, planning for 35.41 minutes was recommended to ensure on-time arrival 95 percent of the time.

In the regression model developed, the road length exhibited a positive effect on travel time, as increased length impacted travel time and overtaking opportunities. On the other hand, vehicle speed had a negative influence, making it a significant determinant of travel time. Higher speeds translated to reduced travel times for vehicles.

This study underscores the importance of road width, travel time reliability, and vehicle speed in determining the Level of Service and overall traffic conditions on this critical stretch. The findings provide a foundation for informed decisions and potential improvements to enhance the quality of transportation services and alleviate congestion in the region.

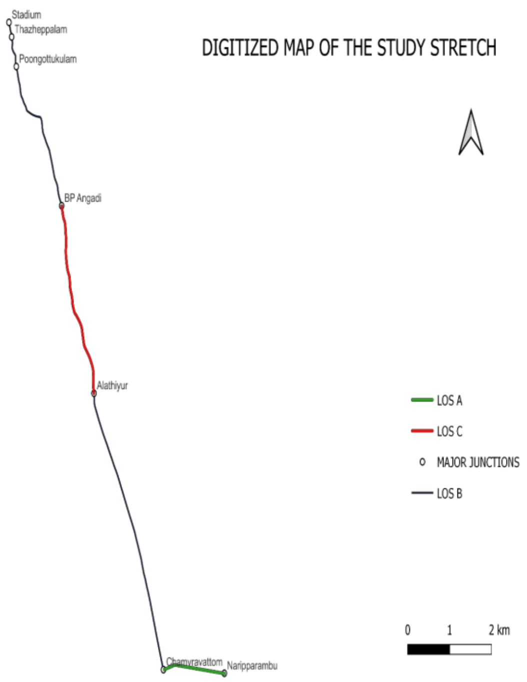

Fig-2: Digitized map of the study stretch.

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