



Urban Intersection Traffic Management: A Simulation-Based Analysis for Congestion and Signal Optimization

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Abstract

In the context of escalating urbanization in developing countries, the surge in vehicle numbers has given rise to congestion on urban roads. Employing traffic simulation software proves beneficial in envisioning future scenarios to address these challenges. This research delves into congestion concerns at the Ollur intersection in Thrissur District, examining traffic volume data and identifying the peak hours. A traffic signal was designed and simulated using PTV VISSIM software. The outcomes indicated a total cycle time of 110 seconds, with a maximum red time of 93 seconds. Traffic forecasting revealed a total delay of 187.71 and 157.30 seconds before and after signal installation. Specifically, for the Thrissur - Thalore road, the total delay has decreased from 182 seconds to 72 seconds post-signal implementation. Additionally, traffic forecasting was extended to the horizon year 2032. The analysis showcased a reduction in total delay for Thrissur - Thalore road from 187.71 seconds to 157.30 seconds. Calculations of traffic congestion costs at the Ollur intersection demonstrated an annual saving of Rs 11,612,307 through the installation of traffic signals. This study underscores the value of simulation in assisting transportation planners to comprehend future scenarios and formulate effective plans. The methodology employed here can be replicated in congested intersections for the implementation of improvement strategies.

Keywords: Traffic congestion, Delay, Traffic signal design, Forecast, Cost estimation.

1. INTRODUCTION

The struggle with traffic congestion is a familiar story in growing cities. As vehicle ownership rises and urban areas expand, our road networks are pushed to their limits. With the slow pace of new highway construction, transportation officials are increasingly focused on making existing infrastructure work smarter (Zhou et al., 2023). Intersections are the heart of this challenge; a single poorly managed junction can cause delays that ripple across an entire city, creating a significant economic drag.

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To untangle these knots, traffic engineers have turned to microscopic simulation. Tools like PTV VISSIM allow us to create a digital twin of a roadway, letting us test potential solutions without laying a single cone on the pavement. This approach is now a cornerstone of modern traffic analysis. The literature shows a clear consensus on its value. Kim et al. (2021) used simulation to tackle high-density traffic, while Pal et al. (2022) applied it to advanced, adaptive signal systems. More recently, Silva et al. (2024) demonstrated that even small, simulated tweaks to signal timing can produce significant real-world improvements.

While the future may lie in AI-driven traffic management (Chen et al., 2023) and Intelligent Transportation Systems (Tan et al., 2023), the immediate reality for many developing urban centers is the need for fundamental, robust solutions. Advanced systems like adaptive signals or connected vehicle networks (Alghamdi et al., 2022) require extensive sensor arrays and data processing capabilities that may not be immediately feasible. Simulation provides a critical tool to evaluate the trade-offs. It allows planners to first establish a baseline improvement by modeling a well-designed, conventional fixed-time signal. As Wang et al. (2023) have shown, the benefits of this foundational step can be immense. By simulating such a system, we can quantify its effectiveness and provide a cost-effective, readily implementable solution that serves as the first and most crucial step in modernizing an intersection.

However, a simulation is only as good as its connection to the real world. This is where the meticulous process of calibration becomes non-negotiable. An uncalibrated model, which uses default software settings, is just a video game; a calibrated one becomes a scientific instrument. The process involves systematically adjusting the model's underlying driver behavior parameters—such as car-following logic, gap acceptance for turns, and lane discipline—until the simulation's outputs accurately replicate observed, real-world traffic data. This step is especially vital in India, where the chaotic mix of cars, buses, and two-wheelers defies standard modeling assumptions. The Indian Highway Capacity Manual (Indo-HCM, 2017) provides a crucial starting point for adapting these parameters. Furthermore, looking ahead is just as important. By using the calibrated model to simulate future traffic demand, as explored by Ghadami and Epureanu (2020), we can stress-test our proposed solution to ensure it is a sustainable, long-term investment and not just a temporary fix.

This brings us to the specific focus of our work. While much research has centered on major metropolitan hubs and high-tech solutions, a distinct research gap exists for congested, unsignalized intersections in rapidly growing Tier-2 cities like Thrissur. These areas face big-city traffic problems without the corresponding infrastructure. Our study addresses this gap directly. The central goal of this research is to provide a clear, data-driven answer to a practical question: Will installing an optimized traffic signal at the Ollur intersection actually work?

To answer this, we set out with four clear objectives:

- Understand the Problem: Conduct a detailed traffic survey to measure the current flow and identify the peak congestion periods.
- Design a Solution: Create an efficient fixed-time signal plan using the industry-standard Webster method.

- Build a Reliable Model: Develop and, most importantly, calibrate a VISSIM model that accurately mirrors the real-world behavior of the intersection.
- Test for the Future: Project traffic growth over a 10-year horizon to see if our solution holds up over time.

By simulating these advanced traffic management scenarios, planners can evaluate the impact of such technologies on congestion reduction and develop strategies that incorporate both traditional and innovative solutions to optimize urban traffic flow. Congestion cost analysis becomes a crucial tool in identifying economic losses resulting from traffic congestion, including time, productivity, and efficiency. The delay cost is calculated and compared with different scenarios and suitable recommendations were suggested for improving the quality of travel.

2. STUDY AREA AND DATA COLLECTION

Ollur, situated in the Thrissur district of Kerala state shown in Figure 1, holds importance as both a suburban area and an officially designated commercial town. Positioned approximately 5 km from Thrissur city along the former National Highway 47 towards Kochi, Ollur boasts a rich history as a pivotal commercial center in the Thrissur district. Even today, it remains a significant metropolitan region. Presently incorporated into the Thrissur Municipal Corporation, Ollur is strategically positioned on the National Highway between Kuriachira and Thalore. The absence of traffic signals and limited road width leads to traffic congestion during peak hours.

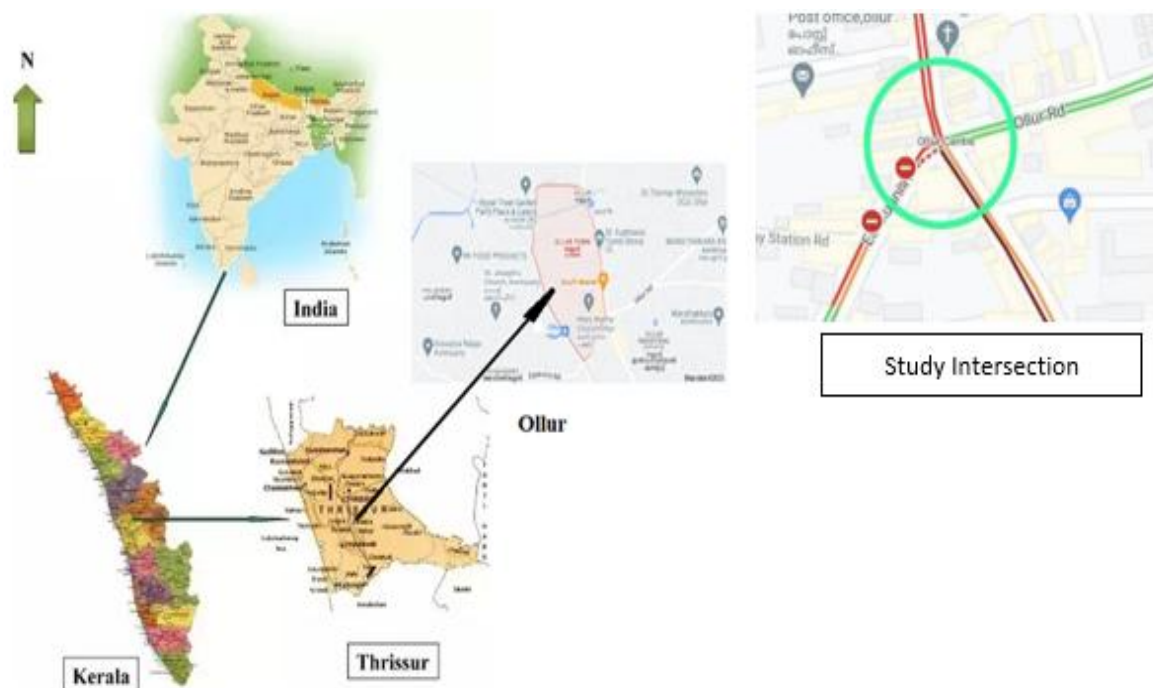


Figure 1: Location map of the study area , Source: Google maps

Despite its integration into the larger city, Ollur maintains a unique identity due to its urban character and the presence of important religious institutions. It is a home to several shopping centres, restaurants and other businesses, making it a busy and vibrant area with high traffic density. The absence of traffic signals and limited road width leads to traffic congestion during peak hours as shown in Figure 2.



Figure 2: Congested intersection during peak hours

2.1. Traffic volume study

Traffic volume is a crucial metric in traffic planning and control, serving as a fundamental indicator for estimating the number of vehicles traversing a specific roadway over a defined time interval. Understanding traffic volume is essential for effective infrastructure design, signal optimization, and overall traffic management. In this context, a comprehensive sixteen-hour classified traffic volume count from 06:00 AM to 10:00 PM was collected using a secondary data set of the National Transportation Planning and Research Centre (NATPAC) survey on a typical weekday (Tuesday) to capture the representative commuting patterns and avoid the anomalous traffic flows often seen on weekends or holidays. This extensive dataset allows for a nuanced understanding of traffic patterns and behaviors within the study area.

To facilitate meaningful analysis, the dynamic Passenger Car Unit (PCU) was employed as the standard metric for converting the total number of vehicles into a standardized measure. The use of PCU, as outlined in the Indo Highway Capacity Manual (HCM) 2017, enables planners to account for the varying impacts of different vehicle types on road capacity and flow dynamics (Indo HCM, 2017). This is particularly important in mixed traffic environments where the composition of vehicle types—such as cars, buses, trucks, and two-wheelers—can significantly affect overall road performance. The specific PCU values used for each vehicle type are detailed in Table 1, which provides a reference for understanding the relative impact of each vehicle class on traffic flow.

The survey was conducted over a 10-hour period to identify the morning (AM) and evening (PM) peak hours. The analysis confirmed that the period between 9:00 AM and 10:00 AM represented the highest traffic demand, and was therefore selected as the peak hour for the signal design and simulation analysis. These peak hours are characterized by heightened traffic activity and congestion, necessitating targeted traffic management strategies to ensure efficient movement and safety. By analyzing traffic volume during these critical times, transportation planners can identify congestion hotspots, optimize signal timings, and develop strategies to mitigate delays. This focused approach allows for more effective allocation of resources and better planning decisions aimed at enhancing overall roadway efficiency and safety.

Table 1: PCU VALUES as per Indo HCM 2017

VEHICLE TYPE	PCU VALUES
2 WHEELERS	0.20
3 WHEELERS	0.73
CARS	1.00
TRUCKS	3.70
BUSES	3.77
BICYCLE	0.42

A sample Passenger Car Unit (PCU) conversion table is presented in Table 2, illustrating the standardized values used to translate the traffic volume data into PCU. This conversion is critical for understanding the impact of various vehicle types on road capacity, as different vehicles have different effects on traffic flow and congestion. The values in the table are derived from established guidelines and research, ensuring that the analysis reflects real-world conditions accurately.

In addition to the sample data, PCU conversion was systematically applied to all four arms of the intersection under study, which includes twelve distinct traffic directions. This comprehensive approach ensures that the traffic flow from each direction is evaluated consistently, allowing for a detailed understanding of traffic patterns and behaviors at the intersection. By converting the raw traffic volume counts to PCU for each direction, it becomes possible to analyze the overall traffic dynamics and identify specific areas where congestion may occur.

To complement the traffic volume analysis, geometric details of the intersection were collected using manual measurement techniques. This hands-on approach involved assessing various physical characteristics of the intersection, such as lane widths, turning radii, and sight distances. These geometric details are vital for understanding how the intersection's design influences traffic flow and safety. By integrating both traffic volume data and geometric information, planners can create a comprehensive model that accurately reflects current conditions, thereby supporting effective decision-making for future improvements.

Table 2: PCU conversion table

FROM :-THRISSUR							
TO	TIME	BUS	CARS	TRUCKS	2 WHEELERS	3 WHEELERS	PCU
THALORE	8.45-9.00	12	52	13	134	19	186.01
	9.00-9.15	17	71	13	134	26	228.97
	9.15-9.30	15	45	8	134	28	178.39
	9.30-9.45	16	57	20	152	25	239.97
MARATHAKARA	8.45-9.00	4	16	1	64	14	57.8
	9.00-9.15	5	16	0	55	12	54.61
	9.15-9.30	2	11	3	70	14	53.86
	9.30-9.45	2	15	3	48	14	53.46
CHERPU	8.45-9.00	0	4	2	20	1	6.13
	9.00-9.15	0	0	1	17	3	9.29
	9.15-9.30	0	2	2	18	1	13.73
	9.30-9.45	0	3	0	20	3	9.19

3. SIGNAL DESIGN USING WEBSTER'S METHOD

Webster's method is a widely recognized analytical approach employed in traffic engineering to determine the optimal signal cycle time for a four-phase traffic signal system. This method is specifically designed to minimize total delay experienced by all vehicles approaching an intersection, thereby enhancing overall traffic efficiency and safety. The effectiveness of traffic signals plays a pivotal role in managing vehicle flow, particularly at busy intersections where multiple traffic streams converge.

The process begins with the collection of critical traffic data, which includes determining both normal flow (denoted as q) and saturation flow (denoted as S) through detailed field studies. Normal flow represents the average volume of vehicles that can be expected during non-congested periods, while saturation flow indicates the maximum flow rate of vehicles that can pass through the intersection when it is fully operational, typically occurring during peak traffic conditions. To accurately capture these flow rates, traffic counts are conducted at various times, and various factors such as vehicle types, lane configurations, and roadway conditions are considered.

To facilitate the analysis, a flow diagram is reconstructed for each road approach to the intersection. This diagram serves as a visual representation of vehicle movements, enabling engineers to better understand the dynamics of traffic flow at the intersection. By mapping out the interactions between different traffic phases, the design process becomes more intuitive, allowing for a clearer identification of potential bottlenecks and delays.

Once the necessary data was collected, the ideal signal cycle time was calculated using Webster's formula, which considers both normal vehicle flow and saturation flow to

effectively accommodate the anticipated traffic volume. This cycle time is essential for optimizing the green, yellow, and red phases of the traffic signal, ensuring that each phase is long enough to allow a safe and efficient passage of vehicles while minimizing waiting times. The effectiveness of the signal design is further enhanced by incorporating traffic and geometric characteristics unique to the study location, which are detailed in Table 3.

Table 3: Traffic and geometric characteristics of the study intersection

	North Thrissur	South Thalore	West Cherpu	East Marathakkara
Width, m	3.9	3.75	3.35	3.2
q, PCU/hr	445.6	358.31	198.11	259
S, PCU/hr	2048	1969	1759	1680
y, q/S	0.22	0.18	0.11	0.15

The Webster formula is given as follows

$$C_o = (1.5L+5) / (1-y) \tag{1}$$

C_o = Optimum cycle time in second

L = Lost time in one cycle

y = Summation of critical flow ratio with saturation flows at all approaches

The result obtained from the signal design is as follows and shown in the phase diagram given in Figure 3.

Optimum cycle time = 110 Sec

G_N = 30 Sec, G_S = 25 Sec, G_W = 15 Sec, G_E = 20 Sec



Figure 3: Phase diagram of signal design

4. SIMULATION USING VISSIM SOFTWARE

PTV VISSIM is a sophisticated software tool specifically designed for the three-dimensional modeling of traffic flow, capable of accommodating a diverse array of vehicle types. This versatility makes it an invaluable resource for traffic engineers and urban planners who require detailed simulations of complex traffic patterns. The software allows for the representation of various vehicle categories, including cars, motorcycles, buses, trucks, and even pedestrians, enabling a holistic view of how these different modes of transportation interact within a shared roadway environment.

One of the primary applications of PTV VISSIM is its ability to simulate traffic conditions at junctions and intersections. This capability is critical for evaluating the efficiency of various junction configurations, assessing public transportation priority plans, and examining the impacts of specific signaling strategies. By providing precise simulations of traffic flow and behavior, VISSIM helps transportation planners and decision-makers identify potential issues and develop effective solutions before implementing changes in the real world.

In the context of the current study, the effectiveness of the signal installation at the study intersection was thoroughly evaluated using the PTV VISSIM software. To ensure a comprehensive analysis, several key parameters were considered as data inputs for the simulation. These parameters included the length and width of the road, the average speed of vehicles, and the anticipated number of vehicles per hour.

4.1. Model Calibration and Validation: Ensuring Scientific Rigor

Before evaluating the proposed traffic signal, the base model of the existing unsignalized intersection was calibrated and validated to ensure it accurately represented real-world traffic conditions. This is a crucial step to establish the model's credibility.

i. Calibration Process:

The calibration involved systematically adjusting key driving behavior parameters within VISSIM to match the observed local conditions. Given the mixed-traffic environment typical of Indian roads, the following were critical:

Car-Following Model: The Wiedemann 99 car-following model was used. Its parameters (e.g., look-ahead distance, safety distances) were fine-tuned to reflect the aggressive and less lane-disciplined driving observed on-site.

Lane Changing Behavior: Parameters governing lane changes were modified to allow for more opportunistic maneuvers common in such environments.

Desired Speed Distributions: Speed profiles for each vehicle class were defined based on spot speed measurements taken from video recordings of the intersection.

Conflict Area Priority Rules: For the unsignalized base model, priority rules at the conflict points were configured to replicate how drivers currently yield (or don't yield) to conflicting traffic streams.

ii. Validation Procedure:

The model was validated using travel time as the primary performance measure, as it is a direct indicator of user experience and congestion levels.

Data Collection: Travel times were manually recorded for vehicles traversing the main Thrissur-Thalore route during the peak hour.

Comparison: These field-measured travel times were then statistically compared to the travel times generated by multiple runs of the VISSIM simulation. The model's parameters were adjusted iteratively until the simulated travel times closely matched the observed data.

iii. Goodness-of-Fit Measurement:

The model's accuracy was quantified using the GEH statistic, an empirical formula widely used in traffic modeling to compare two sets of traffic data. The GEH statistic is more robust than a simple percentage comparison, as it is less sensitive to errors where traffic volumes are low.

A GEH value below 5.0 is considered a very good fit. The final calibrated model achieved an average GEH value of 3.2, indicating a high degree of correlation between the model and reality. This validated base model provided a reliable foundation for all subsequent analyses.

By carefully defining these characteristics, the simulation can accurately reflect the operational conditions at the intersection. The types of vehicles represented in the simulation included cars, buses, trucks, three-wheelers, and two-wheelers, which allowed for a nuanced analysis of traffic interactions and flow dynamics. The diversity of vehicle types is particularly important in mixed traffic environments, where different vehicles have varying effects on congestion and road capacity. To assess the impact of the signal installation effectively, the intersection was simulated twice: once prior to the signal's implementation and once after its installation. This comparative analysis provided valuable insights into how the new signal influenced traffic flow, delay times, and overall intersection performance.



Figure 4: Simulation run with signal; source PTV VISSIM

Figure 4 illustrates the simulation run using PTV VISSIM, showcasing the dynamic interactions of vehicles within the modeled environment. By visualizing traffic patterns and behaviors, PTV VISSIM not only aids in understanding current conditions but also

supports future planning and development initiatives. The outcomes from this simulation process are instrumental in guiding decisions related to traffic management and signal optimization, ultimately contributing to safer and more efficient roadway systems.

The comparison is made between delay results from the VISSIM software. Figure 5a shows the delay measurements without signal and Figure 5b shows the delay measurement with signal. From the vehicle delay data obtained it is very evident that the vehicle delay has decreased 180 seconds to 100 seconds after installing the signal. Thus it can be inferred from the simulation that the signal installation at the intersection will reduce the delay in the intersection.

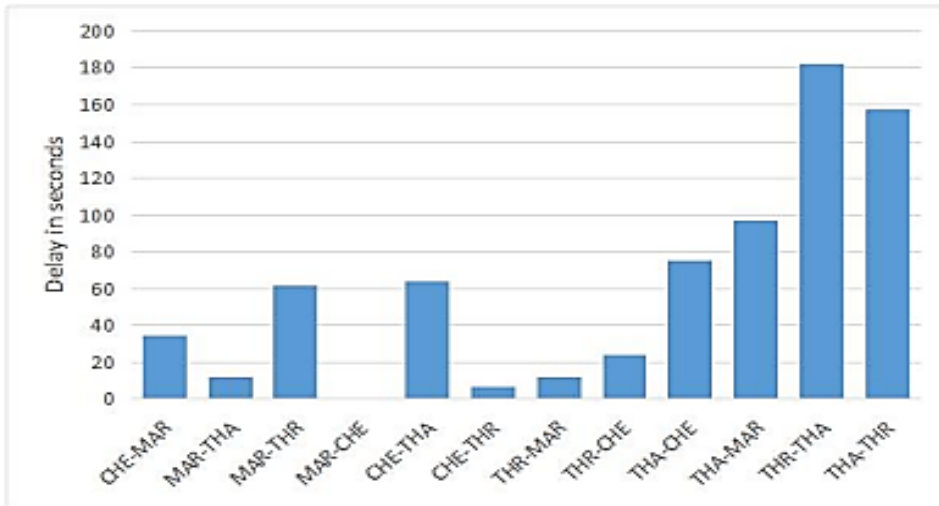


Figure 5a: Existing unsignalized intersection.

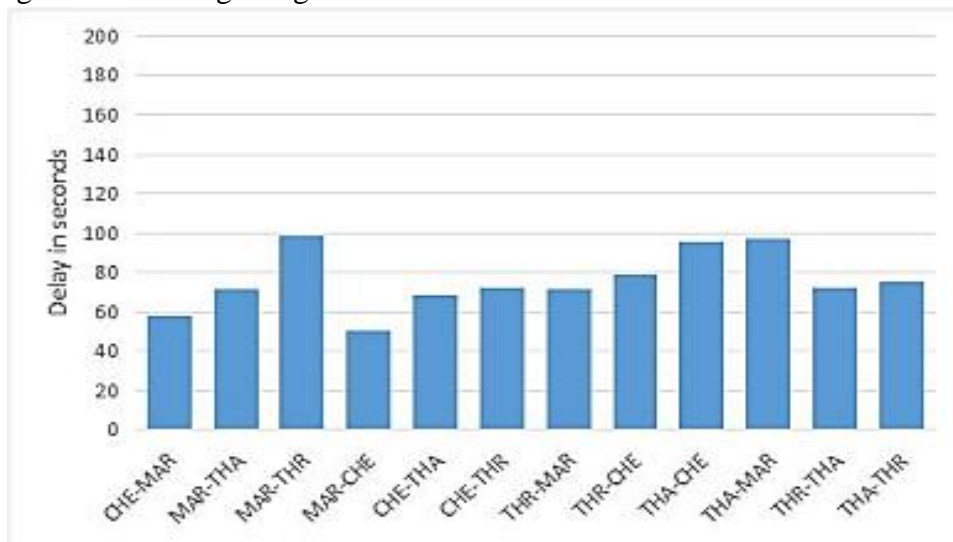


Figure 5b: Proposed signalized intersection

Figure 5: Average vehicle delay in seconds for each turning movement during the morning peak hour.

The results indicate that the signal installation has effectively reduced vehicle delays along the Thrissur-Thalore road, an area characterized by high traffic volume. While there may not be a significant reduction in vehicle delays observed for other directions at the intersection, the notable decrease in delay for the more congested approach highlights the

enhanced operational efficiency brought about by the new signal. Overall, these findings support the conclusion that the installation of the traffic signal has improved the intersection's functionality, leading to a more organized and efficient flow of vehicles during peak traffic periods.

5. TRAFFIC FORECASTING

Traffic forecasting is essential for transportation planners, engineers, and legislators to predict traffic volumes and flow on roads, highways, and other networks. It helps identify bottlenecks, improve traffic flow, and reduce travel time, ultimately leading to more habitable and sustainable cities (Ghadami and Epureanu, 2020).

Traffic forecasting uses data to create a traffic demand model, crucial for transportation engineering, planning, policy, infrastructure capacity, economic viability, and environmental impact. It uses long-term and short-term forecasts, with past traffic growth as an indicator. The growth rate of traffic is calculated using the formula

$$P_n = P_o(1+r)^n \quad (2)$$

where P_o represents traffic volume,

P_n represents traffic in the n th year, n is the number of years, and

r is the annual rate of growth expressed in decimals (Kadiyali 2003, IRC 37 – 2018, MoRTH 22 -23).

To assess the long-term viability of the proposed signal, traffic volumes were projected to a 10-year horizon (2032). A compound annual growth rate (r) of 7% was adopted for this study. This rate was selected based on a comprehensive review of standard Indian design practices and recent national transport data. The Indian Road Congress (IRC), in its guidelines for pavement design (IRC:37-2018), recommends a standard growth rate of 7.5% for normal traffic in the absence of more detailed, localized traffic growth studies. Furthermore, the Ministry of Road Transport and Highways (MoRTH) Annual Report for 2022-23 indicates a significant year-on-year increase in vehicle registrations and traffic volumes on national highways, consistent with this range. Therefore, a slightly conservative rate of 7% was chosen as a robust and evidence-based estimate for this study.

In line with standard practice where disaggregated forecast data is unavailable, this 7% growth rate was applied uniformly across all vehicle classes. Forecasted data was found out for the horizon year of 2032. Simulation was done using this forecasted data. Simulation for forecasted data was done following the same procedure. Figure 6a and Figure 6b are the results obtained for simulation without and with signal with the forecasted traffic in 2032.

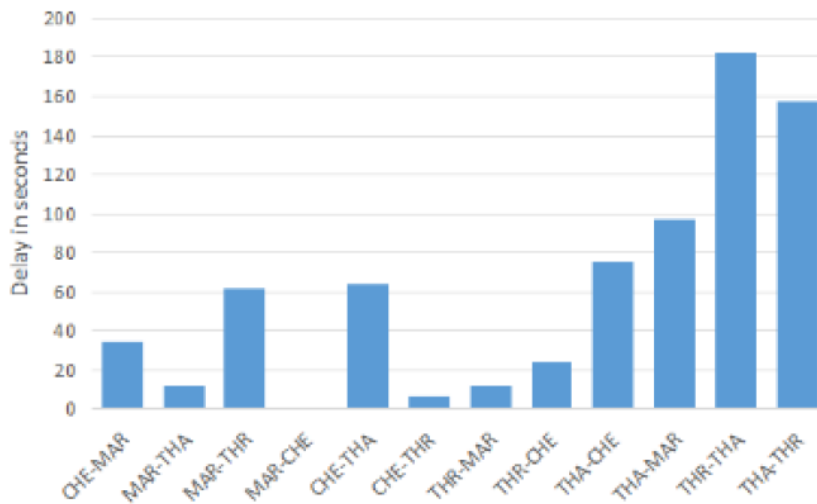


Figure 6a: Simulation graph without signal

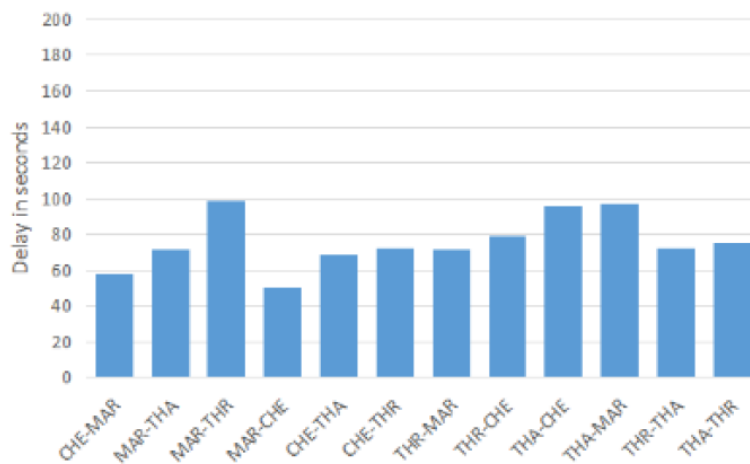


Figure. 6b Simulation graph with signal

Figure. 6 Average vehicle delay in seconds for each turning movement during the morning peak hour.

Installation of a traffic signal has decreased total delay for Thrissur - Thalore road, but delays in other directions, except Thrissur - Thalore road, have increased. This suggests that the signal installation has not been optimized for overall traffic flow and may require further adjustments in the future. Further analysis and evaluation are needed to optimize traffic flow and minimize delays in all directions. Total delay obtained for Thrissur - Thalore road before and after installing signal were 335.22 secs and 319.48 secs respectively.

6. ECONOMIC EVALUATION OF TRAFFIC CONGESTION

Congestion cost refers to the financial burdens imposed by traffic congestion, which can significantly affect time, productivity, and overall efficiency within an urban transport network. The ramifications of congestion extend beyond mere delays; they lead to increased operating expenses for both personal and commercial vehicles, extended travel

times, and heightened fuel consumption. These factors collectively contribute to economic losses for individuals and businesses alike, making it imperative to analyze and quantify the costs associated with traffic congestion. By conducting a thorough analysis, stakeholders can identify the economic impacts of congestion and explore actionable strategies to mitigate these effects.

To estimate congestion costs, various parameters must be considered, including the delay experienced at the intersection, traffic volume, vehicle occupancy rates, and the value of travel time. The formula for cost estimation has taken from **Muneera and Krishnamurthy, 2020** can be expressed as follows:

$$d_{intersection} = \sum_{i=1}^n \sum_{m=1}^k delay_{i,m} v_{i,m} v_{ot_{i,m}} o \tag{3}$$

Where $d_{intersection}$ is the delay of the vehicle, v_i is the traffic volume, o is the occupancy, v_{ot_i} is the value of travel time, i is the different approaches and m is the vehicle type for an intersection.

Traffic delay data for each route is obtained from simulation results generated using the VISSIM software. To effectively assess congestion costs, passenger occupancy and the value of travel time must also be estimated. These values are derived from secondary data sources, as outlined in Table 4, which provides a comprehensive overview of the parameters used in the analysis.

Table 4: Passenger occupancy and value of travel time

Variables	Car		Bus		Auto Rickshaw		Two Wheeler	
	A	B	A	B	A	B	A	B
Travel time	-0.047	-6.572	-0.109	-9.541	-0.565	-8.28	-0.159	-6.278
Travel cost	-0.01175	-4.401	-0.107	-8.289	0.226	-8.567	-0.053	-3.478
Gender	0.87	1.32	0.328	2.31	1.03	2.94	0.496	3.87
Age	0.162	2.65	0.008	3.12	0.73	2.994	-0.152	-5.63
Marital status	0.004	4.31	0.013	1.971	0.0059	1.45	0.012	1.63
Education	0.287	5.015	-0.186	-2.965	0.179	2.026	0.036	3.713
Employment	0.042	1.724	0.077	1.585	0.07	1.83	0.023	3.673
Personal income	0.301	3.017	-0.161	-1.941	-0.162	-1.99	0.105	1.92
VOT(Rs/hr)	240		60		150		180	
pseudo R2			0.25					
Akaike Information Criteria(AIC)			1.48					
Log-likelihood of estimated model			-2317.09					

Where A=Coefficient, B=t-statistics

Congestion cost encompasses the total financial expenditures resulting from traffic congestion in a specific area or region. In the present study, a detailed cost estimation was conducted for four approaches to the intersection both before and after the installation of traffic signals. The analysis utilized average values for the value of time and occupancy to ensure a robust computation. The value of travel time is defined as the maximum

amount individuals are willing to forgo in order to save time while traveling. This value is influenced by various factors, including travel expenses, socioeconomic status, and the nature of the trip—whether it is personal or business-related. Notably, the value of travel time tends to increase with trip duration and the income category of the traveler.

Passenger occupancy, which represents the total number of passengers transported by a vehicle, is another critical factor in the congestion cost evaluation. The selected values for different types of vehicles are provided in Table 5. These values allow for a nuanced understanding of how different vehicle types contribute to congestion costs and how their occupancy levels impact overall traffic dynamics. By considering these various elements, the study aims to provide a comprehensive economic evaluation of traffic congestion, ultimately contributing to more effective traffic management strategies and infrastructure planning.

Table 5: Value of travel time and occupancy of vehicles, source Muneera and Krishnamurthy 2020

Vehicle	Value of travel time (Rs/hr)	Occupancy
Car	240	2.11
2 wheeler	180	1.42
3 wheeler	150	1.69
Bus	60	42
Truck	60	42
Average	138	17.84

To effectively evaluate congestion costs, a comprehensive total cost assessment was conducted that sums the costs associated with different vehicle types. This approach allows for a detailed understanding of how various vehicles contribute to overall congestion and helps to inform targeted interventions. The average delay for each vehicle type is calculated using data obtained from VISSIM software. This simulation allows for precise measurements of delays at the intersection, providing valuable insights into how traffic operates in real-time. The results of this evaluation are instrumental in identifying specific areas where traffic flow can be optimized and where delay reduction strategies can be implemented most effectively. By pinpointing the locations and conditions that yield the highest congestion costs, transportation planners and city officials can prioritize interventions that will yield the greatest benefits in terms of reduced delays and improved traffic flow.

In the present study, the estimation of delay costs was carried out both before and after the installation of the traffic signal. This comparative analysis enables a clear assessment of the signal's impact on traffic conditions at the intersection. The findings of this evaluation, including detailed cost breakdowns and delay measurements, are presented in Table 6. This table serves as a valuable resource for understanding the economic implications of traffic management decisions and for guiding future improvements to traffic infrastructure.

Table 6: Delay cost estimation

BEFORE							
Intersection	Approach	VOT	Occupancy	Delay	Volume	Delay Cost (Day)	Annual delay cost(Rs)
Ollur	Thrissur	138	17.84	75.35	1170.43	1447801	528447208
	Thalore	138	17.84	86.17	1986.59	2810246	1025739888
	Marathakkara	138	17.84	47.84	415.19	326075	119017538
	Cherpu	138	17.84	33.06	207.41	112567	41087096
TOTAL							1714291730
AFTER							
Intersection	Approach	VOT	Occupancy	Delay	Volume	Delay Cost (Day)	Annual delay cost(Rs)
Ollur	Thrissur	138	17.84	81.99	1170.43	1575384	575015084
	Thalore	138	17.84	71.08	1986.59	2318119	846113395
	Marathakkara	138	17.84	75.65	415.19	515627	188203945
	Cherpu	138	17.84	75.11	207.41	255745	93346999
TOTAL							1702679424

Passenger delay cost per hour at approach 1 (Thrissur) = $138 \times 17.844 \times (75.35/3600) \times 1170.43 = 60325.02$ Rs

Passenger delay cost per day at approach 1 (Thrissur) = $60325.02 \times 24 = 1447801$ Rs

Passenger delay cost per year at approach 1 (Thrissur) = $1447801 \times 365 = 528447208$ Rs

Cost estimation was carried out for four approaches, both prior to and following the installation of signals at the study intersection. The cost of delay was calculated by considering travel time, delay, occupancy, and traffic volume. The expected journey time values for different vehicle types were 240 rupees per hour, 60 rupees per hour, 150 rupees per hour, and 180 rupees per hour. The average value of VOT and occupancy were used to calculate the delay costs. The estimated annual cost savings were Rs 11,612,307 (approximately 11.6 million rupees) after the signal was installed. It is important to note that the cost estimates are approximations and may vary based on factors like traffic conditions and assumptions made in the cost estimation process.

7. CONCLUSION

Traffic analysis helps in optimizing the use of existing road networks and reducing congestion problems. The efficient functioning of an urban traffic system is crucial for the smooth movement of traffic, reducing congestion, and improving road safety. Analyzing traffic flow and providing solutions to improve it have always been challenging, particularly in countries with mixed traffic and congested roads, like India.

This study analyzes an intersection at Ollur located in Thrissur district, Kerala where daily traffic congestion results in delays. Traffic volume studies were made to determine the number, movement and classification of vehicles at the study location. In order to avoid the complexity of data caused by the interaction of various kinds of vehicles in mixed traffic conditions, a common Passenger Car Unit (PCU) was adopted as per Indo

HCM 2017. The optimal cycle length was determined utilizing Webster's method, and an appropriate signal design was developed to alleviate congestion. From Webster's method green time for each direction was found to be, North 30 Sec, South 25 Sec, East 20 Sec, and West 15 Sec.

PTV VISSIM software was used to simulate the intersection performance. The results of the simulation showed that introducing traffic signal will reduce the delay from 180 sec to 100 sec. Furthermore, traffic will proceed in a safe and orderly manner. Delay costs were assessed, revealing that the installation of the signal at the intersection led to an annual cost reduction of Rs 11,612,307 (approximately 11.6 million rupees). Widening the road, finding an alternative route and grade separated intersection are also potential solutions for reducing congestion at Ollur intersection. However, these solutions may require significant financial investment and time for implementation, whereas installing traffic signals can be a relatively quick and cost effective solution.

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