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Evaluation of Capacity and Delay Modeling at Signalized Intersection under Mixed Traffic Flow Conditions in Hyderabad City

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Abstract:

Traffic delays on the road can evaluate the road performance based on the signalized interaction. In such circumstances, signalized intersection plays a vital role in managing the traffic flow. The concept of quality of services is involved in measuring the operational conditions based on the traffic stream and the range of the traffic volume. Delays experienced in the signalized areas are associated with the signalized intersection and the controlled traffic signals and conflicted movement can affect the entire operations. The regression model has been used to make decisions regarding road congestion based on several types of intersections. Therefore, the regression analysis method is used to gather information regarding the signaling intersection and manage the traffic flow of the road. The critical points of the urban road can easily analysed to make decisions regarding the mixed traffic conditions and decrease the road traffic.

Keywords: Traffic delay, signalized intersection, road congestion, traffic flow, queue length

1. Introduction Background

Traffic delay is a significant index that can estimate the entire performance of a signalized intersection. Signalized intersections can be considered critical points for exploring the urban road network and evaluating its performance based on the city road network system. An effective capacity of signalized intersections is relevant as the intersections can control the city's road traffic. Urban traffic congestion is a serious issue in India and relevant policies are required to be implemented to improve urban planning decisions (Arti *et al*. 2022). However, their performance is effectively impacted by the mixed traffic conditions and multiple vehicle types such as buses, cars, rickshaws, and bikes in India affect the traffic flow.

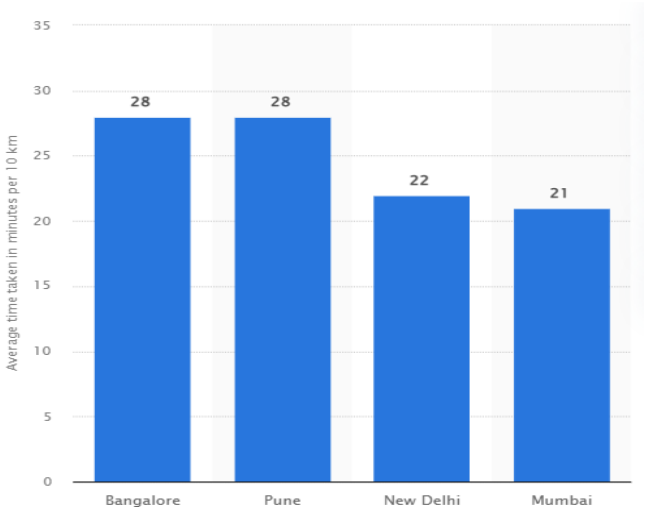

Fig 1: Showing the average time taken per 10 km

(Source: Sun, 2024)

The above figure has been used to explore the traffic congestion in India and it has been noticed that 21 minutes per 10 km was required to manage the average travel time in traffic. The highest average travel time is 28 minutes per 10 km in Bangalore and Pune (Sun, 2024). Therefore, the signalized intersection can control the traffic flow in India, and a valuable

understanding of the road network system can decrease long queues, as well as traffic congestion.

Objectives

- To evaluate the capacity of signalized intersections under mixed traffic flow conditions
- To explore the influence of factors that involve in contributing to delays and affect the level of services
- To analyse the delay modeling at signalized intersections under heterogeneous traffic conditions
- To propose relevant recommendations for managing the traffic flow in Hyderabad

2. Literature Review

Analysing the capacity of signalized intersections

The capacity of signalized intersections can be evaluated regarding the number of vehicles that can pass through at the time of the green signal. In such circumstances, vehicle types, signal timings, and lane width are involved in affecting the capacity of signalized intersections. A highway Capacity Manual (HCM) can deliver the appropriate concept of the traffic flow and provide the relevant computational procedures for exploring the performance of highway facilities (Makki *et al*. 2020). HCM provides a relevant data chart based on the average travel speed in Km per hour and the manual can easily improve the level of services for signalized intersections. The capacity of signalized intersections is required to be modified based on the driver's behaviour and vehicle size.

Exploring the importance of factors that contribute to delays

Control delay at signalized intersections is an effective key performance metric and the attribute can manage long queues, road design, and signal timing. Signalized intersections on highways can control the safety procedure, as well as manage the road facility, capacity of the vehicles, and road efficiency. Lateral clearance, lane width, surface condition, commercial vehicles, and road geometries are the effective factors of transport that can decrease the capacity of the roadway and affect the level of services. Lateral clearance is a vital factor in decreasing road congestion and managing the traffic flows on the road (Matcha *et al*. 2020). Therefore, effective factors are required to be followed in improving the road design and managing the operational activities of the traffic flow.

Evaluating the delay modeling under mixed traffic conditions

Delay modeling is an effective parameter that is required to evaluate the performance based on the signalized intersections. Complex road network systems and the many vehicles on the road can affect the level of services. Traffic density and congestion on roads can cause poor conditions of the roads (Albalate and Fageda, 2021). The estimation of intersection delay is directed towards the simply stopped delay or estimating the total delay in travel.

Application of emerging techniques to manage the traffic flow

The application of emerging techniques can manage the traffic flow and improve the road condition. In this case, effective intersection software such as SIDRA can be implemented to manage the range of traffic, as well as control the road conditions. SIDRA is a relevant software that can make decisions regarding lane-by-lane analysis and improve traffic performance (Hafizyar *et al*. 2021). SIDRA has the ability to analyse the queues and manage the road network performance by measuring delay, stop rate, and travel time. Additionally, CCTV cameras can be required to be integrated to manage real-time traffic management and control the traffic flow.

3. Research Methodology Study area

The traffic flow on the road has been analyzed based on Hyderabad city and the area of the city is 217 Sq Km., as well as the altitude of the city is 536 meters (Hyderabad, 2024). The road congestion of Hyderabad can be evaluated based on the traffic density and the vehicle population on the road can make decisions regarding the road condition. In 2022, the vehicle population of Telangana crossed 1.5 crores, and the vehicle population affected the traffic flow (Romeo, 2023). Congested traffic conditions can affect operational activities and decrease the control of traffic flow. In Hyderabad city, maximum traffic congestion is observed on Thursdays and Fridays with major peak times at 10 am and 7 pm (Kumar and Kaur, 2024). Hence, Hyderabad traffic police can easily determine seven congestion hotspots to control the traffic flow on the road.

Description of selected study intersection

The signalized intersection can analyze the level of services in Hyderabad city and several intersections are involved in gathering information. The type and name of signalized intersections in the city are shown in the table

Table 1: Name and type of signalized intersection in the city

No.	Intersection Name	Type of intersection
1	Nampally T-junction	3 -legged intersection
2	MJ Market stretch	3- legged intersection
3	Mehdipatnam – Nanal Nagar	4 -legged intersection
4	Masab Tank – Virinchi Hospital	4- legged intersection

Data collection method

Survey analysis method has been conducted to make decisions regarding the traffic volume of Hyderabad city. The number of vehicles and pedestrian numbers are involved in creating road congestion and affecting the traffic flow of the city. Hence, a survey has been conducted from 8:00 am to 5:00 pm at 15-minute intervals and the survey can explore the fluctuation of the traffic volume.

Data analysis method

SIDRA intersection software tool can be used to explore the level of service, performance analysis, and network capacity. The software tool can easily explore traffic performance like queue length, number of stops, and delay. Moreover, the SPSS software tool has been implemented to make decisions regarding traffic delays and manage traffic flow at the roadway intersections.

Ethical consideration

Ethical consideration of the research can increase the data validity by managing the data integrity. Data confidentiality, anonymity, and effective copyright guidelines have been followed to improve the transparency of the research.

4. Result and discussion

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.996[a]	.992	.989	1.07839

a. Predictors: (Constant), Queue Length, Pedestrian, Traffic Flow

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	911.922	3	303.974	261.387	.000[b]
	Residual	6.978	6	1.163		
	Total	918.900	9			

a. Dependent Variable: Delay

b. Predictors: (Constant), queue length, pedestrian, traffic flow

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	25.258	4.520		5.588	.001
	Traffic flow	.047	.003	.794	13.546	.000
	Pedestrian	.011	.004	.172	3.157	.020
	Queue Length	.251	.058	.231	4.363	.005

a. Dependent Variable: Delay

Fig 2: Analysing the output of regression model

Delay has been used as the dependent variable and queue length, traffic flow, and pedestrian have been selected as the predictors. In the regression model, the R-square value of the regression model is 0.992 and the value indicates the well-fitted model to predict the traffic flow. The above regression model explores Nampally T-junction based on the survey responses. In such circumstances, the p-value of the regression model is less than 0.05 and it indicates the traffic delay depends on the traffic flow, pedestrian, and queue length.

Delay= 25.258+0.047*traffic flow+0.011*pedestrain+0.251* queue length

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.995[a]	.990	.985	.63447

a. Predictors: (Constant), Traffic flow, Queue length, Pedestrian

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	233.685	3	77.895	193.504	.000[b]
	Residual	2.415	6	.403		
	Total	236.100	9			

a. Dependent Variable: Delay

b. Predictors: (Constant), Traffic flow, Queue length, Pedestrian

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-20.437	5.254		-3.890	.008
	Queue Length	1.143	.069	1.005	16.585	.000
	Pedestrian	-.007	.003	-.236	-2.877	.028
	Traffic Flow	.013	.003	.302	4.701	.003

a. Dependent Variable: Delay

Fig 3: Regression analysis for MJ Market Stretch

The above output demonstrates the outcomes of the regression model and statistical analysis can make decisions regarding the MJ Market Stretch. The R-square value of the model is 0.990 and the p-value is 0.00. Therefore, the traffic delay depends on queue length, traffic flow, and pedestrians based on the MJ Market Stretch intersection.

Delay= -20.437+1.143*queue length-0.007*pedestrain+0.013* traffic flow

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.878[a]	.771	.752	5.660

a. Predictors: (Constant), Traffic Flow, Queue Length, Pedestrians

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3889.603	3	1296.534	40.468	.000[b]
	Residual	1153.372	36	32.038		
	Total	5042.975	39			

a. Dependent Variable: Delay

b. Predictors: (Constant), Traffic Flow, Queue Length, Pedestrians

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	30.882	3.438		8.982	.000
	Pedestrian	.060	.015	.357	3.990	.000
	Queue Length	.229	.070	.294	3.287	.002
	Traffic Volume	-.105	.013	-.684	-7.865	.000

a. Dependent Variable: Delay

Fig 4: Regression analysis for Mehdipatnam – Nanal Nagar

Traffic flow, queue length, and pedestrians are the main factors in analyzing the traffic delay in the road congestion area. The r-squared value of the regression model is 0.771 and the value defines the well-fitted of the analytical model. In this case, it has been observed that the traffic volume creates a negative impact on the traffic delay.

Delay= 30.882+0.060*pedestrain+0.229* queue length-0.105* traffic flow

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.873[a]	.762	.743	4.877

a. Predictors: (Constant), Traffic Flow, Queue Length, Pedestrian

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2748.732	3	916.244	38.523	.000[b]
	Residual	856.243	36	23.785		
	Total	3604.975	39			

a. Dependent Variable: Delay

b. Predictors: (Constant), Traffic Flow, Queue Length, Pedestrian

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	30.201	2.666		11.327	.000
	Pedestrian	-.098	.017	-.497	-5.729	.000
	Queue Length	.337	.056	.518	5.982	.000
	Traffic Flow	-.073	.017	-.363	-4.199	.000

a. Dependent Variable: Delay

Fig 5: Regression analysis for Masab Tank – Virinchi Hospital intersection

The r-square value of the prediction model is 0.762 and the value explored the traffic delay based on pedestrian, queue length, and traffic flow. The traffic flow and pedestrians can create a negative impact on the traffic delay.

Delay= 30.201-0.098*pedestrain+0.337* queue length-0.073* traffic flow

5. Conclusions and Recommendations Conclusions

It can be concluded that traffic flow and road congestion can be managed by the signalized intersection. Road design, lane width, road efficiency, and the surface condition of the road can be managed to improve the level of services. SPSS software tool has been used to analyze the road performance based on the congestion area. The performance of roads can be analyzed based on the type of intersection to manage the traffic flow. Regression analysis methods have been used to explore the traffic delay based on the pedestrian, traffic flow, and queue length.

Recommendations

- A geometric element can provide information regarding the pavement width, number of lanes, gradient, and cross slope (Yang *et al*. 2020). A geometric element is required to be implemented to improve the study design that can enhance traffic safety and the traffic flow on the road.

- Traffic signals need to be redesigned to manage the traffic conditions and the existing roadway based on the type of intersection.

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