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TRAFFIC PERFORMANCE AND DELAY ANALYSIS OF SIGNALIZED ARTERIALS WITH FREIGHT TRAFFIC: A STUDY OF BAPUNAGAR CORRIDOR USING MICROSIMULATION

Prachi. V. Pandya[1*], Dr. Yogesh S. Patel[2],

[1*]Research Scholar, Sankalchand Patel College of Engineering, Sankalchand Patel University, Visnagar- 384315, Gujarat
[2]Principal, Swami Sachchidanand Polytechnic College, Sankalchand Patel University, Visnagar-384315, Gujarat

***Corresponding Author:** Prachi.V.Pandya
[*]Research Scholar, Sankalchand Patel College of Engineering, Sankalchand Patel University, Visnagar- 384315, Gujarat

Abstract
Freight deliveries on urban roads with traffic signals frequently cause lane blockages, which exacerbates traffic congestion in cities. This issue has gained prominence as traffic engineers and city planners seek sustainable solutions within the constraints of limited road capacities. The focus of this study is to evaluate a model that assesses the impact of freight deliveries on road capacity and delays at signalized intersections in Ahmedabad. Adhering to the guidelines in the Highway Capacity Manual (HCM2010), the research aims to apply analytical tools to urban freight delivery strategies. It investigates delays and vehicle capacity by considering delivery locations, durations, and their varied effects on different lanes. By employing machine learning techniques, such as Support Vector Machines and Artificial Neural Networks, in conjunction with a microsimulation model, the study forecasts vehicle capacity and delays. The findings reveal a strong correlation between predicted and actual outcomes, underscoring the effectiveness of these methods in addressing and managing freight-related traffic challenges in urban settings.

Keywords: Freight delivery, blocked street, Capacity, delay time, Bapunagar Junction, microsimulation model

1. Introduction

Freight deliveries in urban areas with traffic signals frequently result in lane blockages along their designated routes. The escalating issue of traffic congestion caused by these deliveries has garnered significant attention recently. Addressing the growing demand while managing limited road capacity presents a substantial challenge for traffic engineers and urban planners. Current strategies include promoting deliveries during off-peak times to mitigate their impact on traffic congestion. A key reference in understanding the effects of heavy vehicles on traffic networks is the NCFRP Report 31 by Dowling et al., published in 2014. This report provides in-depth analysis of how trucks influence the speeds on mid-block arterials and offers enhanced methods for calculating truck-passenger car equivalent factors, aimed at improving the capacity analysis of signalized intersections.

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Abbreviations

Csr capacity of shared right turn lane
Ct capacity of through lane
C cycle length
ddl delay time with freight delivery
T duration of analysis period
td duration of blockage
G effective green time
Er equivalent no of through cars for a protected right turn.
G green time
Nsr no of lane in the shared right turn Lane
Nt no of lane in the through Lane.
lt phase lost time
Pr proportion of the right turning vehicle in the shared lane
AR red time
Cdl= revised lane group capacity
Vdl revised vehicle arrival rate
Ssr saturation flow rate for the shared right lane
St saturation flow rate of a through lane
v vehicle arrival rate
Y yellow time

Existing approaches struggle to effectively manage the problems caused by parked trucks obstructing roads. Keegan and Gonzales (2016) pointed out the difficulties associated with freight deliveries in urban environments, noting their impact on traffic flow, reduction in street capacity, and increase in vehicle delays. To address these issues, researchers have used the 'All or Nothing' model and Kinematic Wave theory to evaluate the effects of freight deliveries on traffic and develop suitable policies. Benekohal and Zhao (2000) examined the concept of passenger car equivalents to quantify the varying impacts of heavy vehicles on traffic flow. Due to their size and slower acceleration and deceleration, heavy vehicles can significantly disrupt traffic performance at intersections.

In 2006, Holguín-Veras and his team extensively analyzed policies promoting off-peak deliveries in urban areas. Their research focused on the conditions needed to establish agreements between receivers and carriers for off-hour deliveries and assessed the effectiveness of various policies in facilitating these changes, particularly in competitive markets. Holguín-Veras emphasized in 2008 the importance of incentivizing off-hour deliveries as a means to alleviate traffic congestion, considering the perspectives of government agencies and delivery drivers who benefit from less congestion during off-peak periods.

Crainic and his team (2004) tackled the challenge of ensuring adherence to off-hour delivery schedules, which often requires store staff to be available for proper acceptance and handling. This may necessitate recipients being present after regular business hours or making prior arrangements if no designated receivers are available. Holguín-Veras et al. (2016) examined the dynamics of supply chain interactions, highlighting the significant influence of supply receivers on delivery timing and methods.

Their findings supported the implementation of Residential Loading Zone (RLC) programs, which could offer significant benefits for large urban areas by reducing freight vehicle miles traveled and easing congestion. Yannis et al. (2006) investigated the effects of restricting vehicle movements related to urban deliveries during peak hours, finding that limiting deliveries to specific business types during

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these times could enhance traffic and environmental conditions. Additionally, research aimed at optimizing urban freight transportation systems proposed a mobile check-in-based parking system for freight vehicles to boost delivery efficiency. Advances in computing technologies and machine learning models, as discussed by Vakharia et al. (2017), have proven valuable for data classification, prediction, and forecasting. These models enable real-time insights and data projections, facilitating the analysis of individual driver behavior to address traffic congestion and predict future traffic flow patterns based on historical data.

After reviewing existing literature and recognizing the need to evaluate traffic conditions in smart cities, it became evident that there was a research gap in applying machine learning models for forecasting and validating capacity and delay times related to freight deliveries on both obstructed and unobstructed streets. This study involved an experimental analysis using the 'All or Nothing' model, as outlined in the Highway Capacity Manual (2010), to calculate positions and delay times as part of the methodology.

2. Experiments conducted

Ahmedabad has emerged as one of India's fastest-growing cities in recent years, driven by substantial industrial and commercial growth. This rapid expansion has made managing traffic congestion a critical issue, impacting transportation capacity, economic performance, mobility, and environmental sustainability, all of which directly affect the city's residents.

This study focuses on the issues associated with urban freight deliveries in Ahmedabad, which often lead to traffic blockages, reduced street capacity, and increased vehicle delays. The research targets major intersection in the city that is Bapunagar Junction. Bapunagar intersections face significant traffic congestion primarily due to freight deliveries,

The analysis utilizes the 'All or Nothing' model, as outlined in the Highway Capacity Manual, to assess both free-flowing and freight-impacted streets. The results, including overall capacity, delay times, and parameters for various vehicle types on these streets, are detailed in Table 1 and Table 2.

The saturation flow rate for the shared right lane is determined by...

$$Ssr = St/(1 + \Pr(Er - 1)) \quad (1)$$

The capacity of each road group is assessed by accounting for factors such as saturation flow rates and signal timings. In cases with pre-timed traffic signals, the capacity for both through lanes and shared right-turn lanes can be determined using the procedures outlined in the 2010 edition of the Highway Capacity Manual. This manual offers standardized methods and formulas for traffic engineers to evaluate road capacities under different traffic conditions and signal setups. Adhering to these guidelines allows traffic analysts to accurately measure road segment capacities, which supports effective transportation planning and management.

$$Ct = StNtg/C \quad (2)$$

The capacity of the shared right-turn lane is determined using a detailed methodology and analytical process.

$$Csr = Ssr\ Nsr\ g\ /C \quad (3)$$

The assessment of control delay at the intersection is conducted separately for each lane group, providing a thorough analysis of traffic flow dynamics.

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d= (0.5c(1-g/C) ^2)/ (1-((min {1, v/c) g)/C)) (4)
The computation of capacity in the context of freight delivery, employing the All or Nothing model, proceeds in the subsequent manner.:"
Ssr, dl=Ssr(1- td/T) (5)

The methodology for determining the capacity of the shared right-turn lane is outlined as follows:
Csr,dl=Ssr,dl g/C (6)
The method for calculating delay associated with freight deliveries using the All or Nothing model is outlined as follows:
ddl=0.5 (C(1-g/C) ^2)/(1-min {1, vdl/cdl} g/C) (7)

Table 1 Total capacity, delay time and spot speed values for blocked location

No	Blocked location	Capacity (veh/hr)		total capacity	Delay time(sec)	Spot speed (km/hr)
		through lane	Shared right turn lane			
1	Bapunagar cross road	796	563	1359	17.15	31.27

Table 2 Measurement and Analysis of Heterogeneous Vehicle parameters for Following Behavior on Urban Freeways

Parameter	Default	Min	Max	
Average Standstill Distance	2	0.39	2.8	2.00
Waiting time before diffusion	60	10	73	60.04
Min headway (Front/Rear)	0.5	0.15	0.8	0.50
Distance Standing (0 kmph)	1	0.4	1.2	0.99
Distance driving (50 kmph)	1	0.6	1.3	1.00

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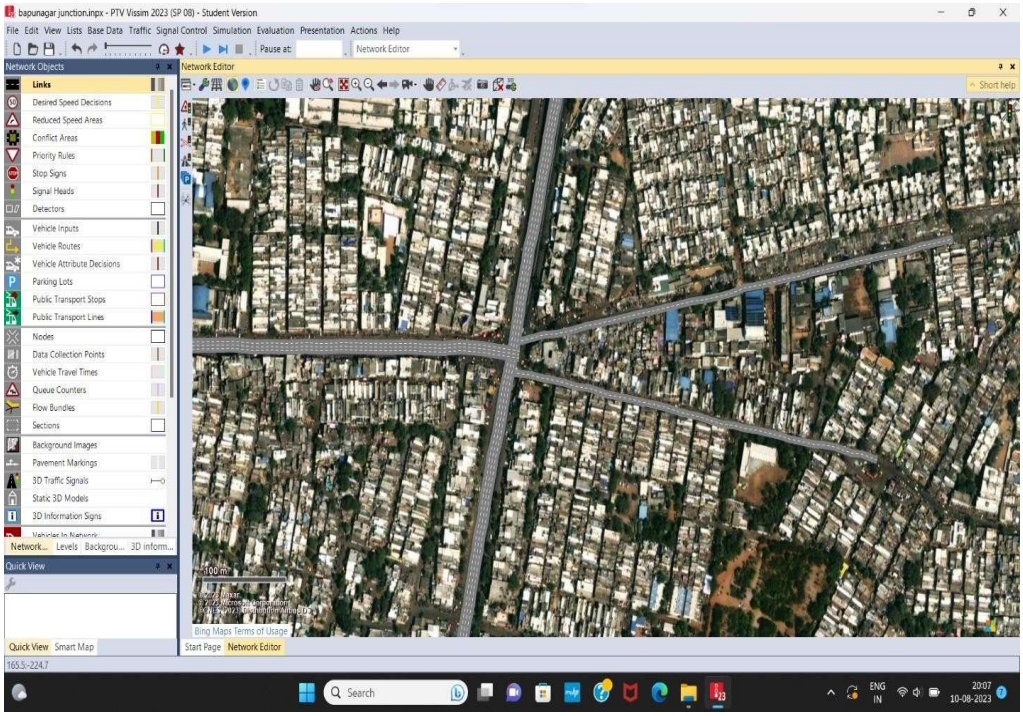

Fig. 1:- Location of Bapunagar Junction

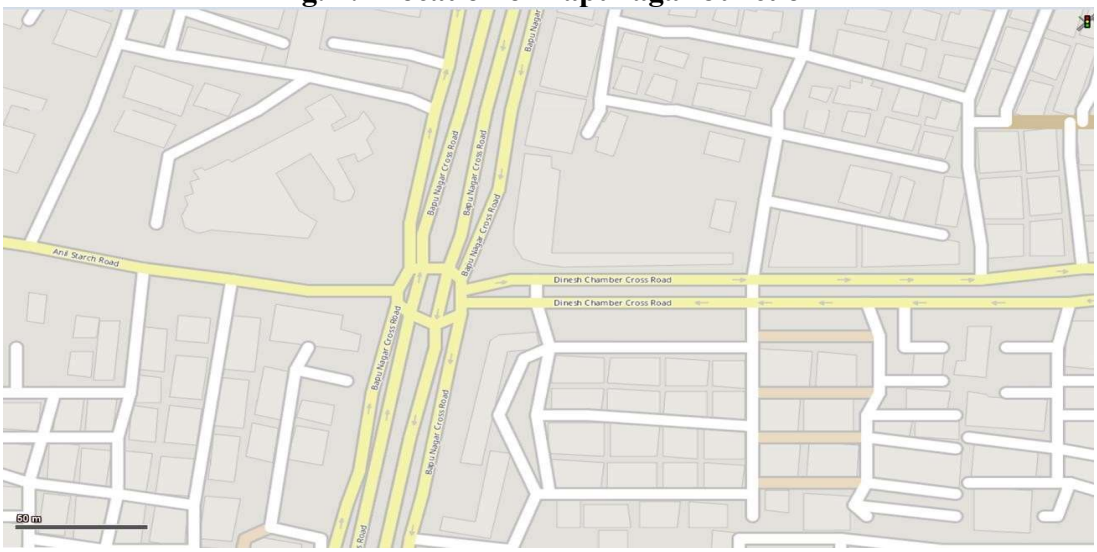

Fig. 2:- Bapunagar Junction Link

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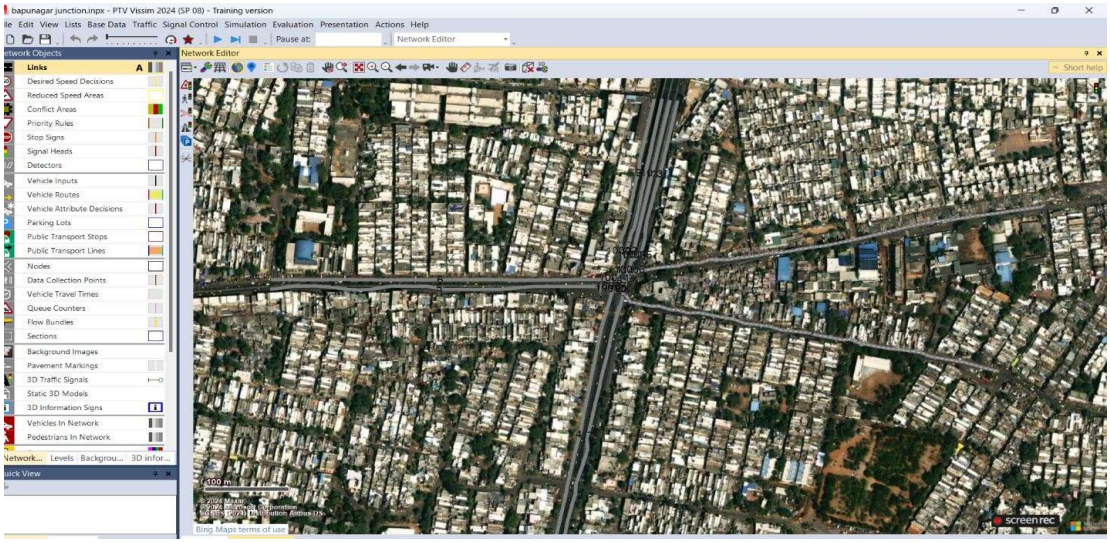

Fig. 3:- Links for Bapunagar Corridor

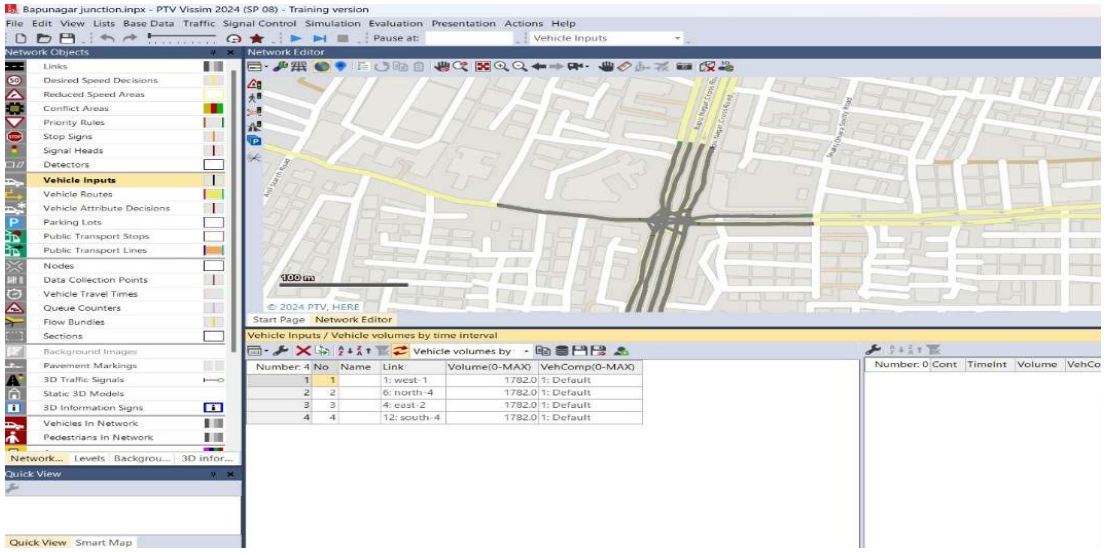

Fig 4: - Vehicle Inputs for Bapunagar Corridor

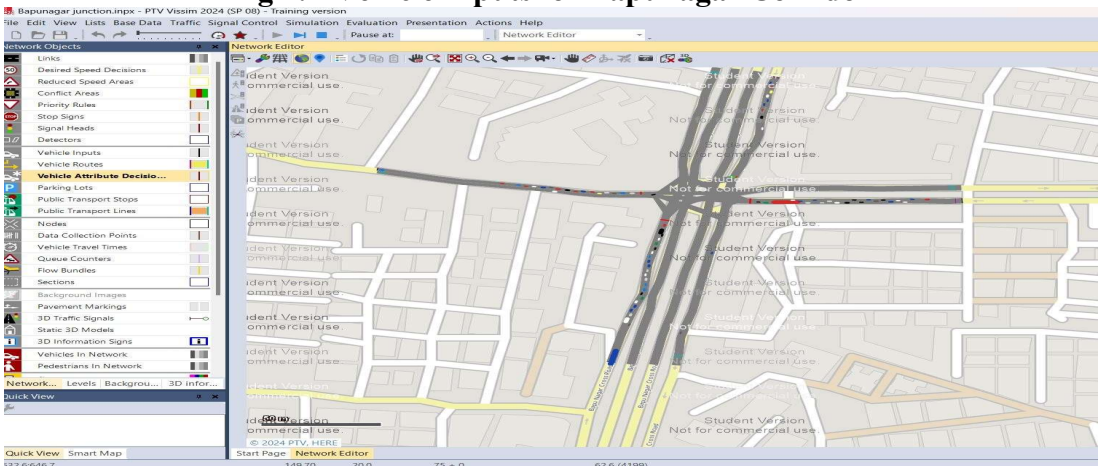

Fig. 5: - Microsimulation Model Bapunagar Corridor

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6. Results and Discussion

In this research, an 'All or Nothing' model was employed to assess street capacity and delay times under both clear and freight-impeded conditions. The findings indicate a significant reduction in road capacity and an increase in delays when freight deliveries obstruct the street. This study highlights the impact of urban freight deliveries on traffic flow in city settings, leading to diminished street capacity and extended vehicle delays. Despite the growing academic interest in urban freight issues, there remains a need for quantitative approaches to evaluate how delivery vehicle blockages influence the performance of signalized streets. Since deliveries can occur intermittently and are not confined to specific locations, they complicate service for various road users. By utilizing a microsimulation model, this research seeks to demonstrate how these theoretical insights apply to real-world street scenarios. The results showed that as freight deliveries become more frequent, delays increase, road capacity declines, and vehicle speeds decrease. Moreover, incorporating these factors into the analysis of diverse traffic scenarios using car-following theory revealed that, although the average standstill distance remains consistent, the waiting time before vehicle movement increases due to higher congestion.

6. Conclusion

This study addresses the issue of urban freight deliveries that disrupt traffic flow in city environments, leading to reduced street capacity and increased vehicle delays. Despite growing academic focus on urban freight, there remains a need for quantitative methods to assess the impact of delivery vehicles obstructing lanes on the performance of signalized streets. Delivery operations can occur at various locations along a block and often extend for several minutes, affecting the ability to serve different road users effectively. To explore this, the study initially applies the 'All or Nothing' model from the Highway Capacity Manual and further validates the findings by developing a microsimulation model. The aim is to offer a clearer understanding of how these theoretical models translate to practical street conditions.

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