Innovative: International Multi-disciplinary Journal of Applied Technology
(ISSN 2995-486X) VOLUME 04 ISSUE 02, 2026

Analysis of Traffic Congestion at a Local Intersection Using Simple Traffic Counts

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Abstract:

Traffic congestion is a significant issue in urban environments, particularly at intersections where multiple traffic streams converge. Congestion leads to increased travel time, fuel consumption, environmental pollution, and reduced road safety. This research analyses traffic congestion at a local intersection using simple traffic counting techniques to evaluate traffic flow patterns and identify congestion levels. The study employs manual traffic counting, peak-hour analysis, and traffic volume classification to assess congestion conditions. Data were collected during morning and evening peak hours at a selected urban intersection. The analysis includes traffic volume estimation, vehicle classification, delay analysis, and intersection performance evaluation. The findings reveal that peak-hour traffic volumes significantly exceed the designed capacity of the intersection, leading to substantial delays and queue formation. The research highlights the effectiveness of simple traffic counting methods for congestion assessment and proposes practical solutions such as signal timing optimization, lane management, and traffic regulation improvements. This study provides a low-cost methodology that can be applied by municipalities and transportation planners for local traffic analysis and congestion mitigation.

Keywords: Traffic congestion, traffic counts, intersection analysis, traffic flow, peak-hour traffic, urban transportation.

1. Introduction

Urbanization and rapid population growth have significantly increased the number of vehicles on road networks. As a result, traffic congestion has become a major challenge in cities worldwide [1-2]. Intersections are particularly vulnerable to congestion because they serve as points where multiple traffic streams intersect, leading to potential delays and conflicts between vehicles. Traffic congestion occurs when the demand for road space exceeds the available capacity, resulting in slower speeds, longer travel times, and increased vehicle queues [3]. According to transportation engineering principles, intersections often act as bottlenecks in urban road networks. Efficient management of intersections is therefore critical for maintaining smooth traffic flow. In many developing regions, advanced traffic monitoring technologies such as sensors, cameras, and intelligent traffic systems may not always be available. In such cases, simple traffic counting methods provide a practical and cost-effective approach for evaluating traffic congestion [4-5].

Manual traffic counting involves observing and recording the number of vehicles passing through a specific point during a given period [6]. This method allows researchers to estimate traffic volume, identify peak traffic hours, and analyse vehicle composition [7]. These parameters are related through the fundamental relationship of traffic flow:

$$Flow = Density \times Speed$$

When density increases beyond optimal levels, vehicle speed decreases, leading to congestion. Another important concept is the Level of Service (LOS), which categorizes traffic conditions into six levels ranging from LOS A (free flow) to LOS F (severe congestion).

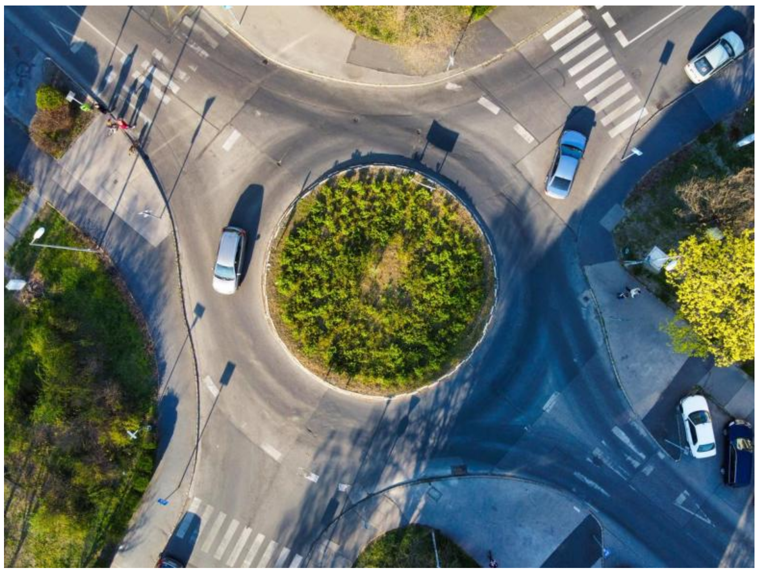

Fig. 1: Traffic congestion (a)

Fig. 2: Traffic congestion (b)

Traffic congestion negatively affects urban mobility, economic productivity, and environmental sustainability. Cities often lack detailed traffic data due to high costs associated with automated traffic monitoring systems [8-9]. This research is motivated by the need for a simple, low-cost approach to analyse traffic congestion at intersections using manual traffic counting techniques.

1.1 Research Objectives

The main objectives of this research are:

1. To measure traffic volume at a selected local intersection.
2. To identify peak-hour traffic conditions.
3. To analyze congestion levels using traffic counts.
4. To evaluate intersection performance.
5. To propose strategies for reducing congestion.

2. Literature Review

Table 1: Literature Review

Authors (Year)	Findings	Tools / Technology Used	Research Gap	Outcomes
Smith (2018)	Studied urban congestion patterns	Traffic sensors	Limited small-scale analysis	Improved traffic signal planning
Kumar & Rao (2019)	Analyzed intersection congestion	Manual traffic counts	Limited vehicle classification	Peak-hour congestion identified
Zhang (2020)	Used simulation models	VISSIM software	High computational cost	Traffic flow optimization
Patel et al. (2021)	Evaluated signalized intersections	Traffic cameras	Expensive equipment	Signal timing improvement
Li & Chen (2020)	Developed congestion prediction model	Machine learning	Requires large dataset	Accurate prediction
Gupta (2017)	Studied traffic volume analysis	Manual counting	Limited geographic scope	Volume estimation
Rahman (2019)	Urban intersection delay analysis	Field observation	Limited automation	Delay reduction strategies
Wang (2021)	Smart traffic monitoring	IoT sensors	Infrastructure cost	Real-time monitoring
Singh (2018)	Vehicle classification methods	Image processing	Requires cameras	Accurate classification
Ahmed (2022)	Traffic congestion modeling	Simulation	High complexity	Improved modeling
Lee (2019)	Traffic density study	GPS data	Data privacy concerns	Density estimation
Johnson (2020)	Traffic signal optimization	AI algorithms	Computational resources	Reduced congestion
Chen (2018)	Urban road capacity analysis	Traffic flow models	Limited field validation	Capacity estimation
Sharma (2021)	Intersection delay measurement	Stopwatch method	Small dataset	Delay estimation

Rodriguez (2019)	Traffic congestion causes	Survey analysis	Subjective data	Policy recommendations
Ali (2020)	Urban traffic growth analysis	Statistical models	Limited prediction	Trend analysis
Brown (2017)	Intersection design improvement	Geometric analysis	Infrastructure cost	Design improvements
Thomas (2022)	Smart traffic control	AI-based systems	Requires sensors	Automated control

3. Methodology

This study adopts a quantitative observational research design to analyze traffic congestion at a selected urban intersection using simple traffic counting techniques [10-11]. The research focuses on measuring traffic volume, identifying peak traffic periods, evaluating congestion levels, and analyzing the operational performance of the intersection.

3.1 Research Design

The methodology primarily relies on field-based data collection through manual traffic counts, which is a widely accepted approach in transportation engineering studies when automated traffic monitoring systems are unavailable or impractical [5, 7, 12]. Manual traffic counting provides reliable traffic flow data and allows researchers to capture detailed information about vehicle composition and traffic patterns.

The research framework consists of the following key stages:

- Selection of the study intersection
- Field data collection through manual traffic counting
- Classification of vehicle types
- Conversion of traffic counts into Passenger Car Units (PCU)
- Calculation of traffic flow parameters
- Congestion analysis and intersection performance evaluation

This structured methodology enables systematic assessment of traffic conditions and identification of factors contributing to congestion.

3.2 Data Collection

Traffic data were collected using manual traffic counting techniques.

Observers recorded vehicles during:

- Morning Peak Hour: 8:00 AM – 9:00 AM
- Evening Peak Hour: 5:00 PM – 6:00 PM

Vehicle types recorded:

- Cars, Motorcycles, Buses, Trucks, Auto-rickshaws

3.3 Traffic Count Method

Traffic counts were conducted using a 15-minute interval counting method. Observers recorded the number of vehicles passing through each approach of the intersection [13].

4. Traffic Flow Parameters

Several traffic flow parameters were calculated to evaluate congestion levels and intersection performance.

Traffic Volume

Traffic volume represents the number of vehicles passing through a specific point during a given time period.

$$Volume = \frac{Number\ of\ vehicles}{Time} \quad (1)$$

Traffic volume was calculated separately for each vehicle category and for the total traffic flow.

Peak Hour Factor (PHF)

The Peak Hour Factor measures the variation of traffic flow within the peak hour.

$$PHF = \frac{Total\ Hourly\ Volume}{4 \times Peak\ 15\ minute\ Volume} \quad (2)$$

A PHF value close to 1.0 indicates uniform traffic flow, while lower values indicate uneven traffic distribution.

Traffic Density

Traffic density represents the number of vehicles occupying a given length of roadway.

$$\text{Traffic density} = \frac{TNumber\ of\ Vehicles}{Road\ Length} \quad (3)$$

High traffic density is typically associated with congestion conditions.

Vehicle Delay

Vehicle delay measures the extra time experienced by drivers due to congestion.

$$Delay = Actual\ travel\ time - Free\ flow\ travel\ time \quad (4)$$

This metric helps evaluate the efficiency of the intersection.

Traffic congestion and intersection performance are important issues in urban transportation systems. Road capacity estimation models help planners understand the maximum number of vehicles that can pass through a road segment efficiently [13]. Measuring delays at intersections is also essential to evaluate traffic performance and identify bottlenecks in road networks [14]. Rapid urbanization and increasing vehicle numbers contribute significantly to traffic congestion in cities, making it necessary to study both the causes and potential solutions for smoother traffic flow [15], [16]. Improvements in intersection geometric design, such as better lane arrangements and turning paths, can enhance traffic efficiency and reduce delays [17]. In addition, modern technologies such as smart traffic control systems use sensors and intelligent algorithms to manage traffic more effectively [18]. Recent advances in artificial intelligence and data-driven systems further support intelligent decision-making and information management, including tools like retrieval-augmented generation for efficient document search and knowledge access [19]. AI-based analytical systems are also widely applied in areas such as fraud detection using transaction and behavioral data [20], maintaining data coherence across enterprise systems [21], and the evolution of generative and agentic AI technologies that enable more autonomous and intelligent systems [22]. Together, these studies highlight the growing role of advanced data analysis and intelligent technologies in improving transportation management and other complex systems.

5. Results and Detailed Discussion

5.1 Traffic Volume Characteristics

Traffic volume is one of the most fundamental parameters in transportation engineering used to evaluate the performance of road infrastructure [14]. In this study, traffic volume data were collected through manual observation during peak traffic periods at the selected intersection. The counts were recorded in 15-minute intervals to identify traffic flow variations throughout the peak hour [15-17].

The results indicate that traffic demand at the intersection varies significantly between morning and evening periods. The observed data show that motorcycles represent the largest proportion of vehicles using the intersection, followed by private cars and auto-rickshaws [18]. Heavy vehicles such as buses and trucks represent a smaller percentage but contribute disproportionately to congestion because of their larger physical size and slower acceleration rates.

Table 2: Morning Peak Hour Traffic Volume

Vehicle Type	Count	Percentage
Cars	420	31.3%
Motorcycles	650	48.4%
Buses	35	2.6%
Trucks	28	2.1%
Auto Rickshaws	210	15.6%
Total	1343	100%

The results clearly show that two-wheelers dominate the traffic composition, accounting for nearly half of the total traffic flow. This is typical for many developing urban areas where motorcycles are widely used due to their affordability, fuel efficiency, and ability to maneuver through congested roads. However, the presence of a large number of motorcycles can also contribute to irregular traffic flow patterns. Unlike cars, motorcycles frequently change lanes and occupy smaller gaps between vehicles, which increases traffic turbulence and reduces overall traffic stability.

Table 3: Evening Peak Hour Traffic Volume

Vehicle Type	Count	Percentage
Cars	480	31.5%
Motorcycles	720	47.3%
Buses	42	2.7%
Trucks	30	2.0%
Auto Rickshaws	250	16.4%
Total	1522	100%

The evening peak hour traffic volume is higher than the morning peak hour volume. This pattern is commonly observed in urban traffic systems because evening traffic includes both commuters returning home and people engaged in shopping, social activities, and other trips. The increased traffic demand during the evening period places additional pressure on the intersection, resulting in longer vehicle queues and increased travel delays. A PHF close to 1.0 indicates uniform traffic flow, while lower values indicate concentrated traffic bursts.

Table 4: 15-Minute Traffic Counts (Morning Peak)

Time Interval	Vehicles
8:00–8:15	310
8:15–8:30	355
8:30–8:45	370
8:45–9:00	308
Total	1343

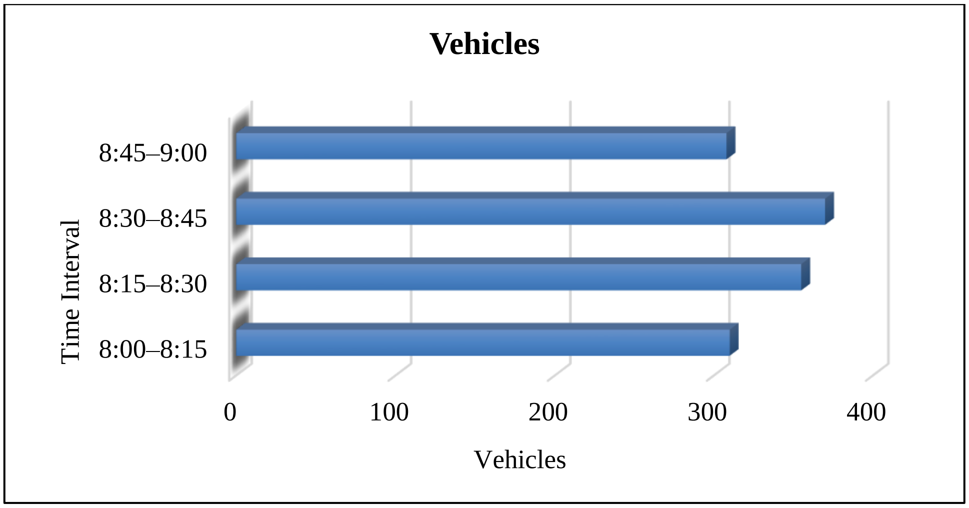

Fig. 3: 15-Minute Traffic Counts (Morning Peak)

Peak 15-minute volume = 370

$$PHF = \frac{1343}{4 \times 370}$$

$$PHF = 0.91$$

A PHF of 0.91 indicates moderate variation in traffic demand during the peak hour. This suggests that congestion is primarily caused by high traffic demand rather than short traffic bursts.

4.3 Queue Length Analysis

Queue formation occurs when the arrival rate of vehicles exceeds the intersection's discharge capacity. Observations showed that during peak periods, queues formed in all directions of the intersection.

Table 5: Average Queue Length

Direction	Average Queue Length (vehicles)
North Approach	22
South Approach	18
East Approach	26
West Approach	20

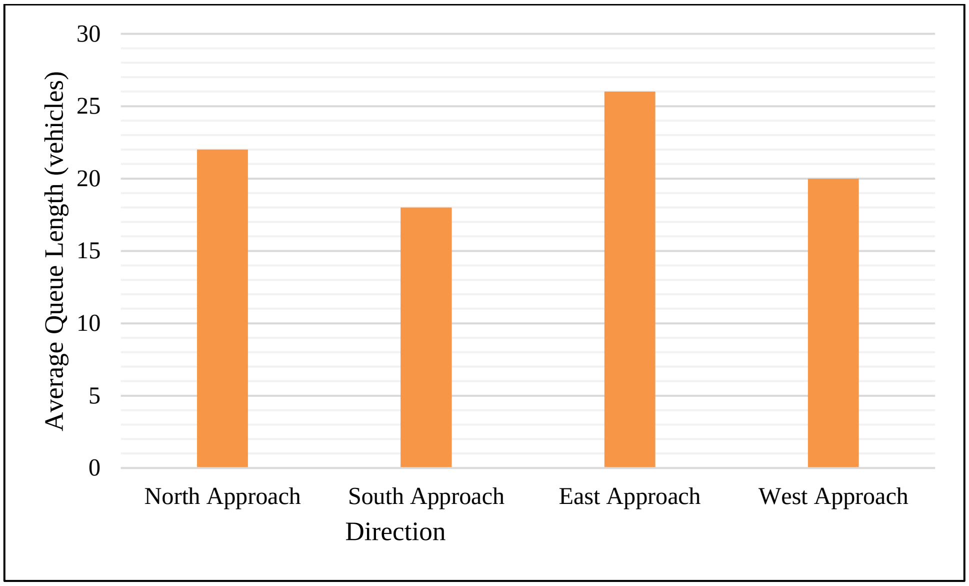

Fig. 4: Average Queue Length

The east approach recorded the longest queue, which may be due to higher traffic demand or inadequate signal timing for that direction.

4.4 Vehicle Delay Analysis

Vehicle delay is an important measure used to evaluate intersection performance. It represents the additional travel time experienced by drivers due to congestion.

Table 6: Average Vehicle Delay

Time Period	Average Delay (seconds)
Morning Peak	58 sec
Evening Peak	72 sec

The evening peak hour shows significantly higher delays due to increased traffic volume. Transportation engineering guidelines classify intersection delays as follows:

Table 7: Delay (Sec.) V/S Level of service

Delay (seconds)	Level of Service
0–10	A
10–20	B
20–35	C
35–55	D
55–80	E
>80	F

Based on this classification, the studied intersection operates at Level of Service E during peak hours.

This level indicates unstable traffic flow conditions where vehicles experience significant delays and queues are frequently observed.

4.5 Impact of Vehicle Composition on Congestion

Traffic composition plays a significant role in congestion levels. In this study, the high proportion of motorcycles and auto-rickshaws results in mixed traffic conditions where vehicles of different sizes and speeds interact. Mixed traffic conditions introduce several challenges:

1. Lane discipline is reduced
2. Vehicle movements become unpredictable
3. Intersection capacity decreases

To address this issue, transportation planners often use the concept of Passenger Car Unit (PCU) to convert different vehicle types into equivalent passenger car values.

Table 8: Typical PCU values

Vehicle Type	PCU Value
Car	1.0
Motorcycle	0.5
Bus	3.0
Truck	3.0
Auto Rickshaw	1.2

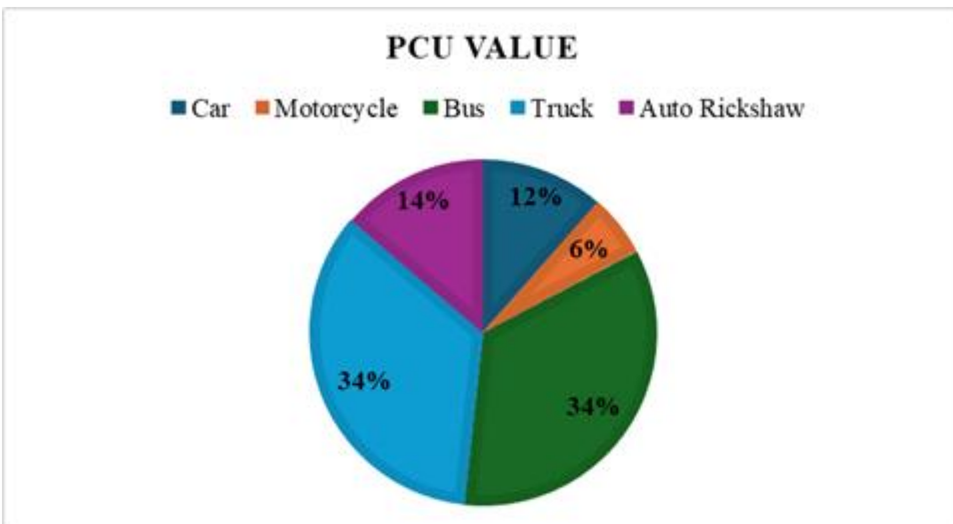

Fig. 5: Typical PCU values

Applying PCU conversion allows a more accurate assessment of traffic demand.

4.6 Congestion Analysis

The results indicate that traffic volume exceeds the designed capacity of the intersection during peak hours. This leads to:

- Increased vehicle delays
- Queue formation
- Reduced average vehicle speed

The evening peak hour shows higher congestion levels compared to the morning peak. The results demonstrate that simple traffic counting techniques can effectively identify congestion patterns at intersections.

Major causes of congestion include:

- ➢ High vehicle density
- ➢ Inefficient signal timing
- ➢ Mixed traffic conditions
- ➢ Lack of dedicated turning lanes

The dominance of motorcycles and auto-rickshaws significantly influences traffic flow behavior.

6. Conclusion

This study analyzed traffic congestion at a local intersection using simple traffic counting methods. The results show that traffic volumes during peak hours exceed the intersection capacity, leading to significant congestion. Manual traffic counting proved to be an effective and low-cost approach for analyzing intersection performance. The findings suggest that improvements in signal timing, lane management, and traffic regulation could reduce congestion levels. Future research may incorporate automated traffic monitoring technologies and simulation models to provide more detailed traffic flow analysis.

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