The Asian Review of Civil Engineering
ISSN: 2249-6203 (P); 2583-7893 (E)
Vol.13 No.2, 2024, pp.34-44

www.crijournals.org
DOI: https://doi.org/10.70112/tarce-2024.13.2.4243

Assessing Traffic Congestion on Ikorodu Road, Lagos, Nigeria: A Comparative Analysis of Time-Based and Volume-Based Indices

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(Received 3 September 2024; Revised 25 September 2024, Accepted 15 October 2024; Available online 20 October 2024)

Abstract - **Urbanization and economic prosperity are often accompanied by severe traffic congestion in many cities. Lagos's fast-growing population and demand for mobility make it a victim of this ordeal, especially along key economic corridors like Ikorodu Road. This study aims to identify the most congested sections and assess how effective various indices are for measuring the traffic conditions of Ikorodu Road by using time-based and volume-based traffic congestion indices. Travel time data were estimated using Google Satellite over a two-week period, while traffic volume data were collected using the moving observer car method. The collected data were analyzed using various traffic congestion models, including travel rate, delay ratio, speed performance index, and level of service. The results consistently showed that the section from Ketu to Mile 12 Under-bridge is the most congested, while the Maryland Tunnel to Ojota section experiences the least congestion. However, during peak periods, all sections were found to be habitually gridlocked. Anomalies in the volume-based indices suggested that time-based indices are more effective for measuring congestion, particularly on routes prone to unidirectional traffic flow. This study highlights the severity of traffic congestion along Ikorodu Road and confirms that travel time-based indices are more reliable for assessing congestion in Lagos. These findings provide a foundation for improving traffic assessment strategies and mitigating congestion in the city.**
Keywords: **Traffic Congestion, Ikorodu Road, Time-Based Indices, Travel Time Data, Lagos**

I. INTRODUCTION

Transportation is a vital pillar of any functional settlement. An efficient transportation system enables better interconnectivity of people, goods, and services [1]. The overwhelming demand on a limited network introduces congestion [2], which hampers rather than fosters prosperity [3]. This reality extends to Nigeria, where the traffic system is characterized by unreliable infrastructure, exacerbating road congestion and undermining pavement reliability.

Congestion, being a consequence of urbanization [4], [5], has rapidly spread beyond traditional cities such as Ibadan, Benin, Port Harcourt, and Lagos [6]. Unchecked rapid urbanization and a relatively sophisticated road transportation system position Lagos as a model for addressing this widespread challenge in other Nigerian cities.

Despite extensive research on traffic congestion, there is a paucity of studies focusing specifically on Lagos's traffic challenges, particularly on Ikorodu Road, which is a significant route in the city's network. This research aims to evaluate the extent of traffic congestion on Ikorodu Road, identify its primary causes, and propose potential mitigation strategies.

This paper also discusses the contrast between time-based and volume-based indices for congestion evaluation. Traffic agencies, private firms, and researchers can use the results of this paper to gain insights when Ikorodu Road is of interest. Additionally, the analysis provides a foundation for estimating congestion on similar roads around Lagos.

A. Causes of Traffic Congestion

Traffic congestion can be classified based on micro-level and macro-level factors. Micro-level factors include the volume of people and vehicles present in a limited road space, while macro-level factors consist of land use patterns, car ownership trends, and geographic economic development [7], [2]. Poor driving habits, inadequate road networks, limited road capacity, and lack of parking facilities are significant causes of traffic congestion on Nigerian roads [6].

B. Impact of Traffic Congestion on Productivity

Traffic congestion reduces worker productivity as it consumes a significant portion of their time and salary. It also negatively impacts the effectiveness of workers, particularly younger ones. Recommendations include reducing peak-period traffic, expanding road intersections, providing adequate infrastructure, and improving road conditions to mitigate traffic congestion. Ultimately, reducing time loss would enhance the productivity of workers who use these routes [8].

C. Impact of Congestion on the Environment

Opinions on the environmental impact of traffic congestion vary. Researchers such as Owoputi and Kaniyio [9] described traffic congestion as a contributing factor to environmental degradation. In contrast, Bigazzi [10] challenged the conventional belief that congestion increases vehicle emissions. He established a mathematical framework to study the balance between travel speed and vehicle efficiency. Although the relationship between emissions, travel speed, and travel demand varies by location and type of pollutant, several consistent findings were noted.

D. Methods of Measuring Traffic Congestion

Measuring traffic congestion should focus on traffic system performance and users' experiences. Researchers have developed several congestion assessment indices that consider different criteria to form a comprehensive performance evaluation [2]. Depending on these criteria, traffic congestion can be measured in various ways independently or through a combination of methods. Commonly used traffic congestion indices include traffic density, travel time, travel speed, volume-to-capacity ratio, level of service (LOS), delay time, and queue length [2], [11].

A survey involving 3,500 transportation professionals and academics showed that 29% adopt delay studies, 20% use the level of service (LOS), 14% rely on the volume-to-capacity (V/C) ratio, 13% adopt travel speed, 4% use queue length, 1% use density, and 5% employ other unspecified methods [12].

E. Contributions

This study was conducted to measure traffic congestion on a section of Ikorodu Road: Mile 12 to Maryland. Empirically, this section is the most congested part of Ikorodu Road.

The aims of this research are:

1. To identify the most congested section of the study route.
2. To determine the most congested period.
3. To contrast different congestion assessment indices.
4. To identify the factors causing traffic congestion on the case study route.

II. METHODOLOGY

This study would be carried out at different subsections of the study route as shown in Table II.

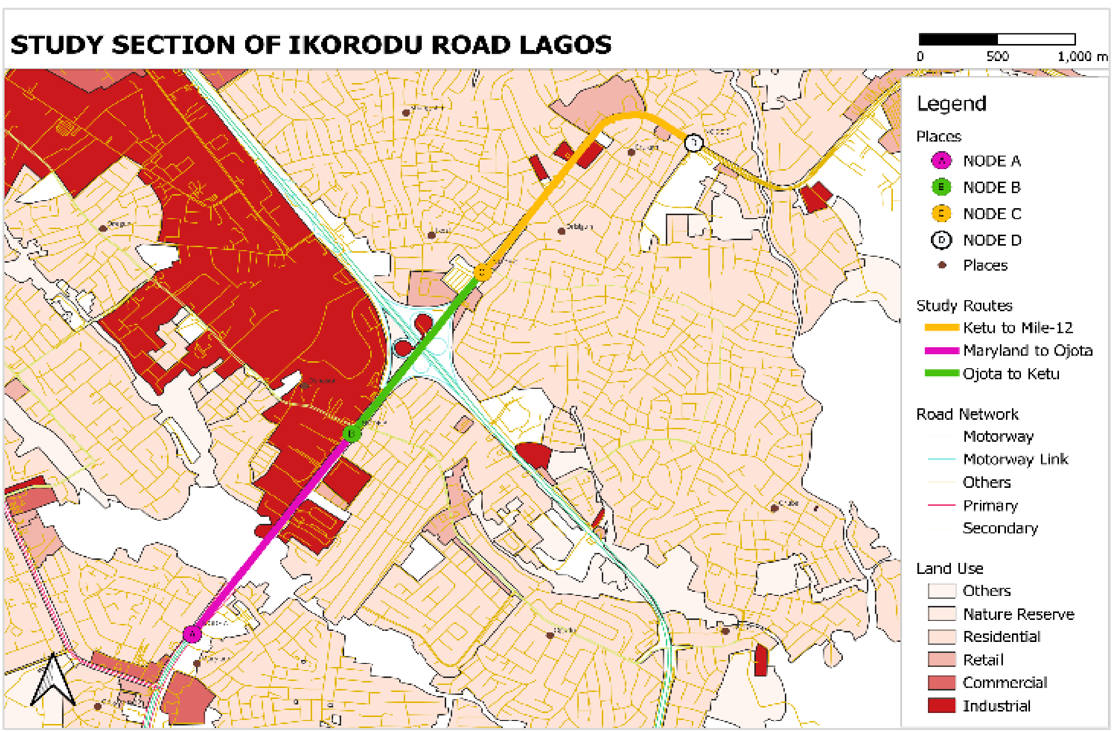


Fig. 1 Map of case study route (Section of Ikorodu Road, Lagos)

TABLE I STUDY NODES

Nodes	Landmark Feature
A	Maryland Tunnel
B	Ojota Bus stop
C	Ketu Bus stop
D	Mile 12 Under Bridge

TABLE II STUDY LINKS

Sections	Description	Distance
A-B	Maryland Tunnel- Ojota Bus stop	2.2km
B-C	Ojota Bus stop - Ketu Bus stop	1.3km
C-D	Ketu Bus stop - Mile 12 Under Bridge	2km
B-A	Ojota Bus Stop - Maryland Tunnel	2.2km
C-B	Ketu Bus stop - Ojota Bus stop	1.3km
D-C	Mile 12 Under Bridge - Ketu Bus stop	2km

The data were collected from 22nd of September 2021 to 16th of October 2022. Traffic pattern in this period can be considered representative with approximately 0% variance [13].

A. Travel Time

Travel time measures the duration taken for a vehicle to travel from one point to another on a given route. We obtained hourly travel time data from Google Maps. The study area was divided into sections using bus stops/bridges as cordon lines. The travel time was estimated using the following steps.

1. The study route was divided into sub-sections using known bus stops as checkpoints, with each sub-section spanning from one bus stop to the next with a known distance.
2. The distances for eastward and westward travel on the same route may vary; this was confirmed using Google Maps.
3. These routes were observed every hour using Google Maps Services, and the travel time for each section was recorded. The intensity of traffic congestion was represented by colors: red indicated heavy congestion, yellow indicated slight congestion, and blue represented relatively free flow. These color indicators were considered in estimating travel time.

We categorized the data based on the period of the day, as shown in Table III.

TABLE III PERIOD OF THE DAY

Time of the Day (Hours)	Period of the Day	Notation
4:00 to 8:00	Early Morning	EM
8:00 to 12:00	Late Morning	LM
12:00 to 16:00	Afternoon	A
16:00 to 20:00	Early Evening	EE
20:00 to 24:00	Late Evening	LM

B. Speed Performance Index (SPI)

The Speed Performance Index (SPI) quantifies the condition of urban road traffic using a scale ranging from 0 to 100. This index is calculated by dividing the average vehicle speed by the maximum permissible speed, as expressed in (1). The condition of road traffic is assessed using the classification criteria of this index, as shown in Table IV.

$$SPI = \left(\frac{V_{avg}}{V_{max}}\right) \times 100 \quad (1)$$

V_{avg} and V_{max} are the averages and maximum velocity respectively.

TABLE IV CLASSIFICATION CRITERION FOR SPI

SPI	Traffic State Level	Description of Traffic State
0-25	Heavy congestion	Poor road state, low average speed
25-50	Mild Congestion	Lower average speed, weak road state
50-75	Smooth	High average speed, good road state
75-100	Very Smooth	Higher average speed, better road state

C. Delay Ratio (D)

The delay ratio is another notable time-based index that measures the amount of delay experienced by vehicles. The extent of congestion is directly proportional to the value of D. This is mathematically expressed as:

$$D = \frac{D_r}{Tr_{ac}} \quad (2)$$

Where Delay rate Dr is expressed as:

$$D_r = Tr_{ac} - Tr_{ap} \quad (3)$$

Tr_{ac} and Tr_{ap} represents the actual travel rate and allowable travel rate respectively.

D. Volume Data Collection: Moving Car Technique

We adopted the Moving-Vehicle Technique (or Moving-Observer Technique) to estimate traffic volume. The test car was introduced into the traffic flow of the section of the route to be analyzed.

We established that eastward travel is directed toward Y-Y, and westward travel is directed toward X-X, as shown in Fig. 1 and Fig. 2.

1. The time taken to travel from the east(Y-Y) to the west(X-X) is denoted by T_w
2. The number of vehicles that overtakes the test car, is denoted by O_w

3. The number of vehicles overtaken by the test car. It is denoted by P_w
4. The number of cars traveling in the opposite direction (eastward). this is denoted by N_w

The test vehicle then takes a U-turn and travels from west(X-X) to east(Y-Y), and the following data are recorded.

1. The time is taken to travel from the west(X-X) to the east(Y-Y) which is denoted by T_e
2. The number of vehicles that overtakes the test car, is denoted by O_e
3. The number of vehicles overtaken by the test car is denoted by P_e
4. The number of cars traveling in the opposite direction(westward) is denoted by N_w

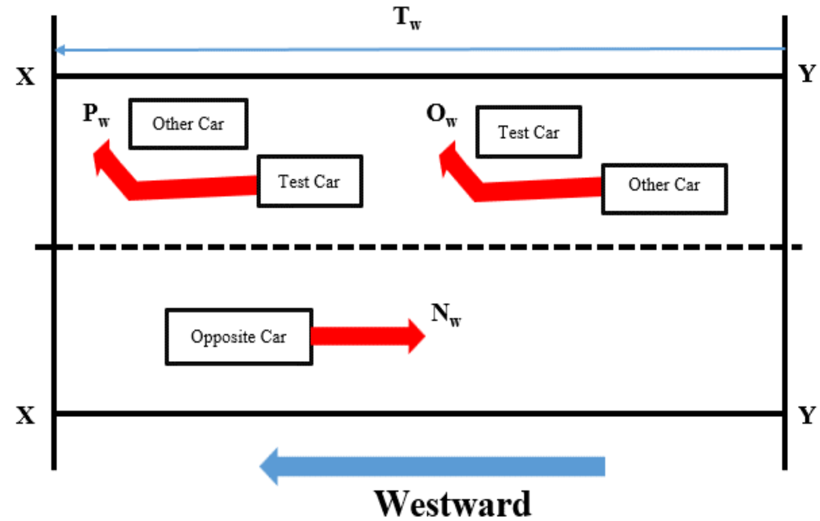


Fig. 1 Test Vehicle Going Westward

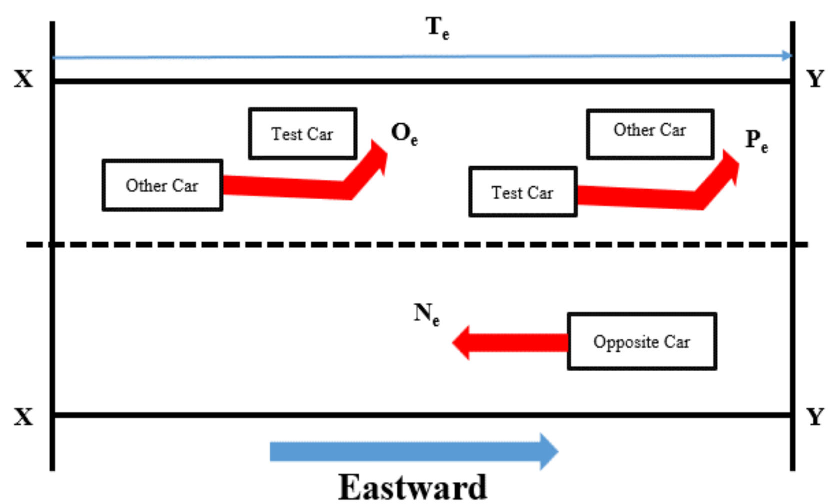


Fig. 2. Test Vehicle Going Eastward

After recording all these data, the average values are obtained. The volume, V_w in the westbound direction can then be obtained using the expression:

$$V_w = \frac{(N_e+O_w-P_w)60}{T_e+T_w} \quad (4)$$

The average travel time (T_w) in the westbound direction is obtained using the expression:

$$T_W = T_w - \frac{60(O_w-P_w)}{V_w} \quad (5)$$

Similarly, the volume V_e in the eastbound direction can then be obtained using the expression:

$$V_e = \frac{(N_w+O_e-P_e)60}{T_e+T_w} \quad (6)$$

The average travel time (T_e) in the westbound direction is obtained using the expression:

$$T_e = T_e - \frac{60(O_e-P_e)}{e} \quad (7)$$

E. Volume-Capacity Ratio (V/C)

The volume-to-capacity (V/C) ratio is an index used to measure the extent of traffic congestion on a route by dividing the volume of vehicles using the road (either current or projected) by the capacity the route is designed to accommodate. Since traffic congestion can be described as the demand for road space exceeding the available supply, the V/C ratio effectively expresses the extent of congestion. A V/C ratio of 1 or greater indicates congestion on the route. The Volume-to-Capacity Ratio is mathematically expressed as:

$$\frac{V}{C} = \frac{N_v}{N_{max}} \quad (8)$$

N_v stands for the spatial mean volume, N_{max} stands for the maximum number of vehicles the segment can contain. N_{max} is expressed as

$$N_{max} = \frac{L_s}{L_v} \times N_l \quad (9)$$

L_s is the length of road segment, L_v is the length of a vehicle. We assumed an average vehicle in Nigeria length of 4.57m, including safety distance.

F. Level of Service (LOS)

Level of Service (LOS) can be defined as a quantitative measure of the operating conditions of a route and how these conditions affect road users.

The level of service is classified from A to F, using a combination of indices such as traffic density and travel speed, as shown in Table.

TABLE V CLASSIFICATION OF TRAFFIC FLOW BASED ON LEVEL OF SERVICE

LOS	Quality	Speed (mph)	V/C	Density Range (pc/mi/in)
A	Free	80	0.6	0-11
B	Reasonable free	70	0.7	>11-18
C	Near free	60	0.8	>18-26
D	Medium flow	50	0.85	>26-35
E	Capacity flow	40	0.9	>35-45
F	Congested flow	15	1.0	>45

III. RESULTS AND DISCUSSION

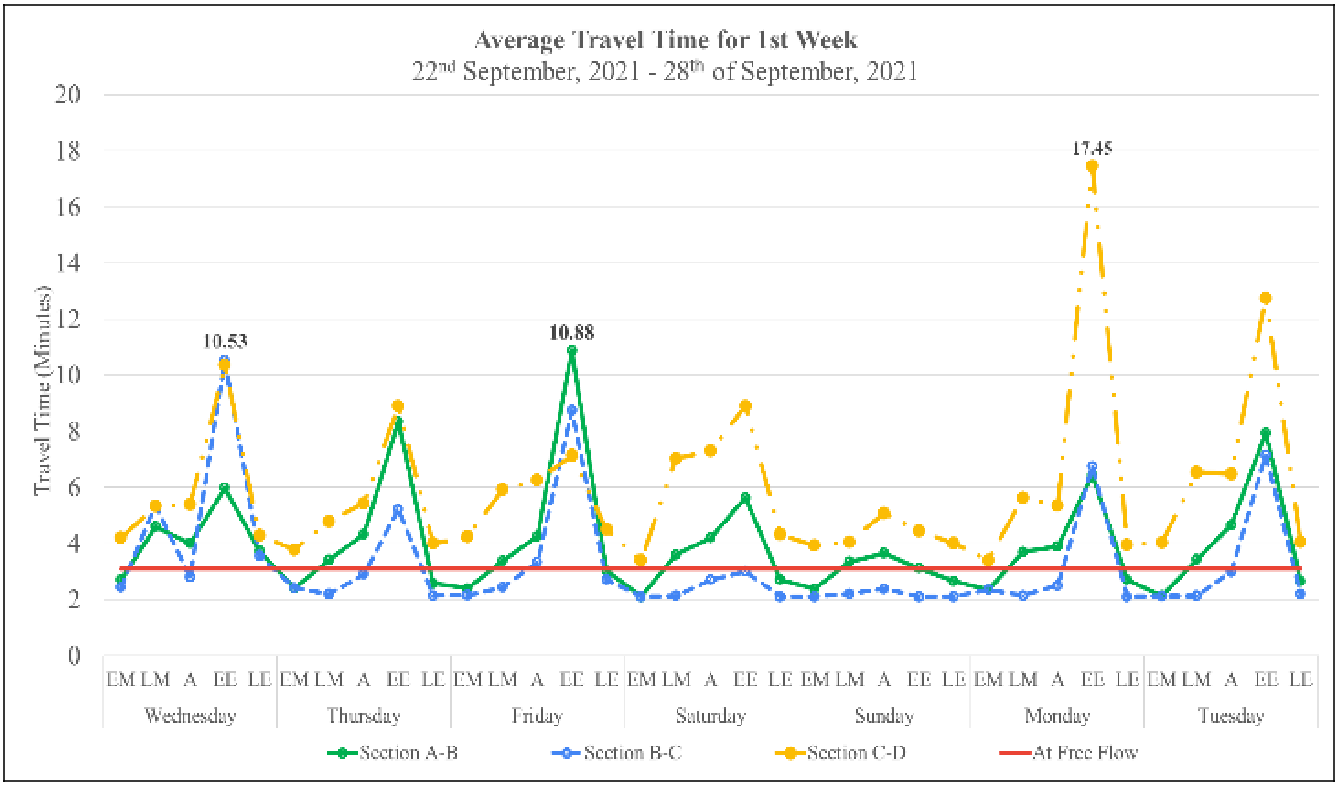
A. Travel Time

With a travel time of 2 minutes and 15 seconds, Section A-B during late morning on Sunday appears to be the least congested period. In contrast, with a travel time of 17 minutes and 45 seconds, Section C-D during early evening on Monday is the most congested. Section A-B consistently remains the least congested, while Section C-D is the most congested part of the study route.

TABLE VI CONGESTION PERIOD BASED ON AVERAGE TRAVEL TIME

Days	A-B		B-C		C-D	
	Period	Value	Period	Value	Period	Value
Wed.	EE	**10.53***	EE	5.98	EE	10.35
Thu.	EE	5.22	EE	8.35	EE	8.9
Fri.	EE	8.74	EE	10.88	EE	7.14
Sat.	EE	3	EE	5.63	EE	8.9
Sun.	A	2.38	A	3.65	A	5.08
Mon.	EE	6.74	EE	6.44	EE	**17.45***
Tue.	EE	7.15	EE	7.94	EE	12.75
Wed.	EE	10.23	EE	**15.34***	EE	15.42
Thu.	EE	3.95	EE	7.51	EE	14.77
Fri.	A	2.74	A	5.59	EE	8.57
Sat.	LM	2.65	LM	6.14	LM	6.4
Sun.	LM	2.15	EE	3.33	A	5.6
Mon.	A	4.18	EE	8.37	EE	13.19
Tue.	EE	5.52	EE	7.04	EE	13.9

Note: The sign * indicates the most congested period of each section



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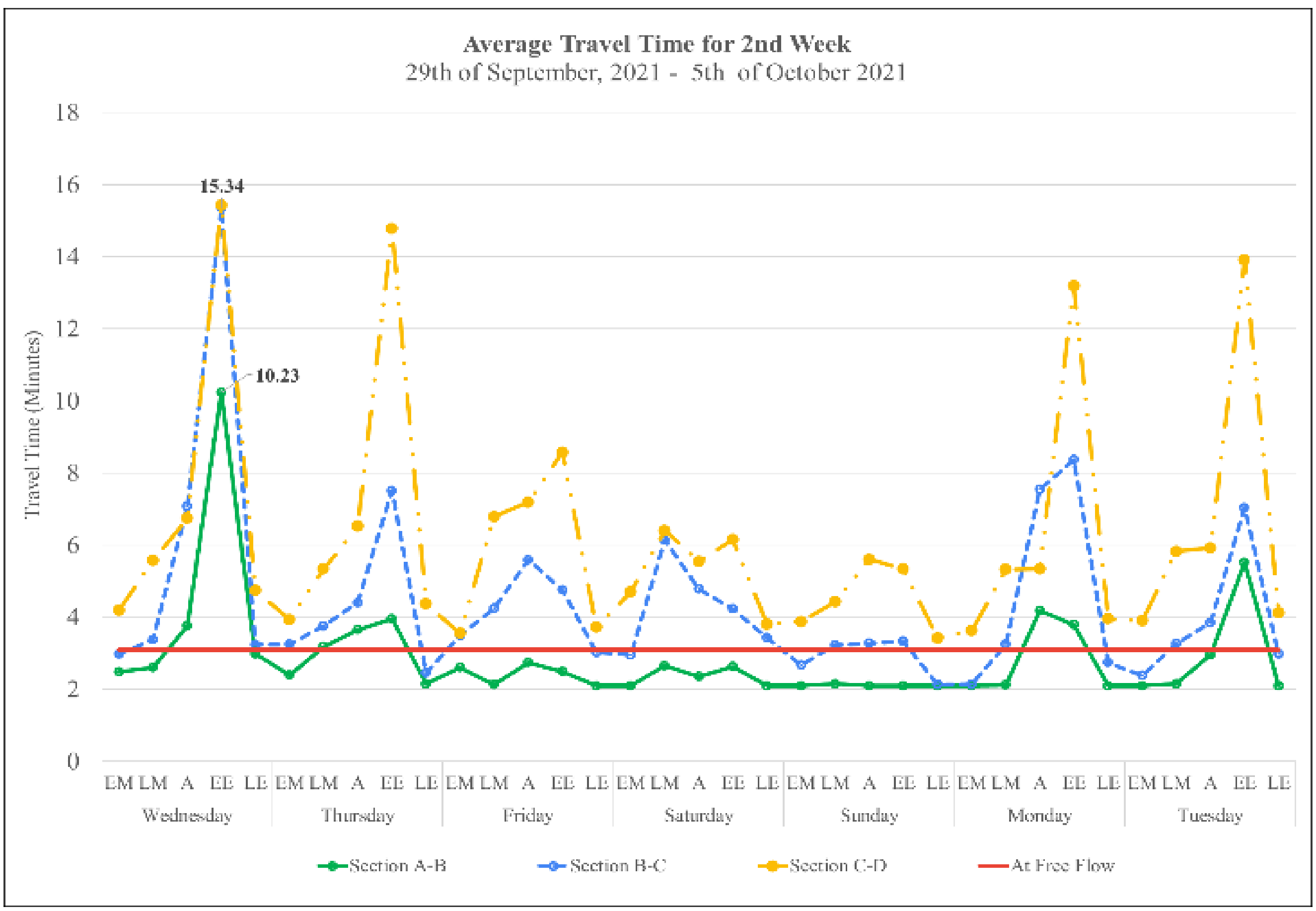


(b)

Fig. 3 Congestion Evaluation Using Travel Time for: (a) First Week (b) Second Week

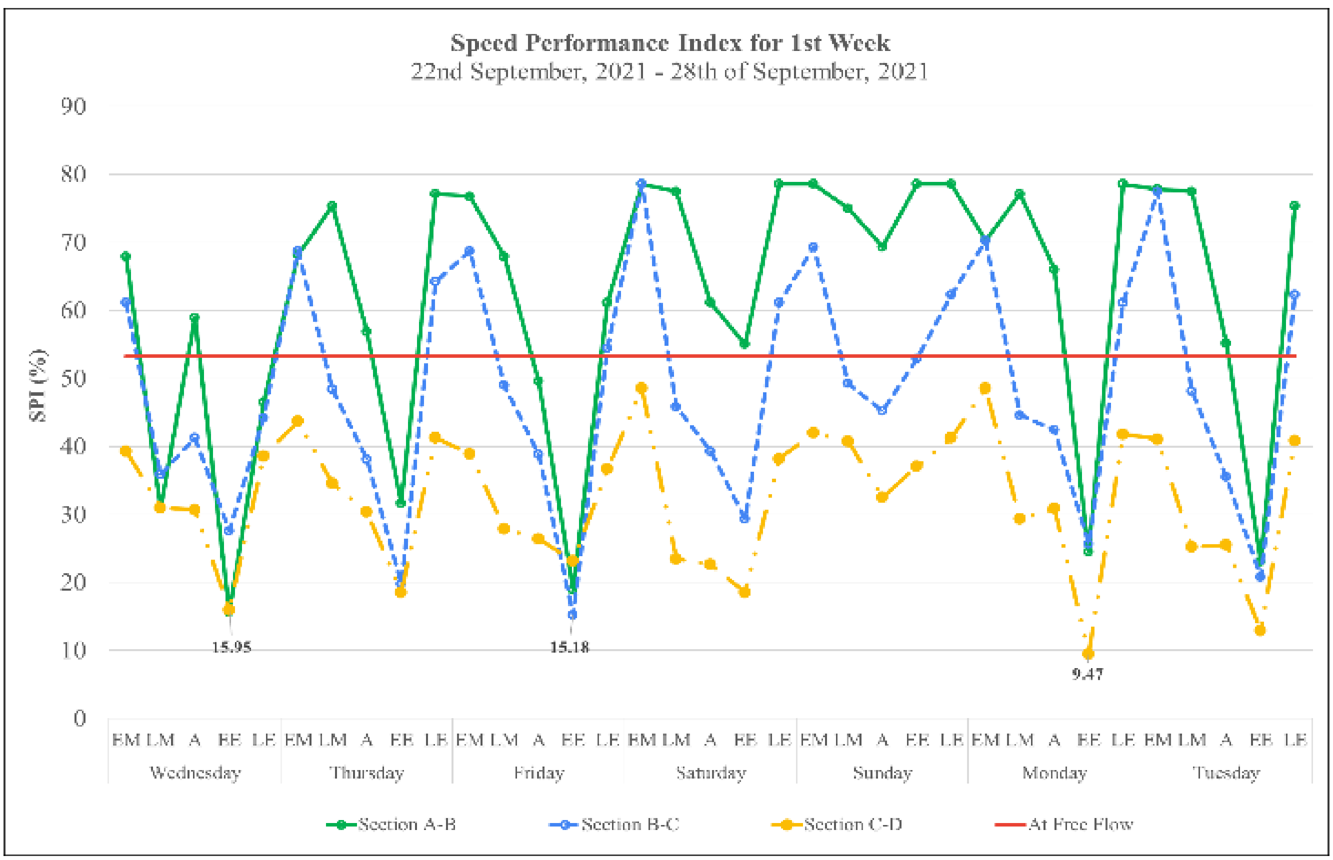
B. Speed Performance Index

The most congested period, based on the Speed Performance Index (SPI), corresponds to the period with the lowest SPI value. Similar to travel rate and travel time, the most and least congested periods remain the same.

TABLE VII CONGESTION PERIOD BASED ON SPEED PERFORMANCE INDEX

Days	A-B		B-C		C-D	
	Period	**Value**	**Period**	**Value**	**Period**	**Value**
Wed.	EE	**15.68***	EE	27.6	EE	15.95
Thu.	EE	31.62	EE	19.77	EE	18.55
Fri.	EE	18.89	EE	15.18	EE	23.12
Sat.	EE	55	EE	29.32	EE	18.55
Sun.	A	69.34	A	45.22	A	32.49
Mon.	EE	24.49	EE	25.63	EE	**9.47***
Tue.	EE	23.09	EE	20.79	EE	12.95
Wed.	EE	16.14	EE	**10.77***	EE	10.72
Thu.	EE	41.78	EE	21.98	EE	11.18
Fri.	A	60.23	A	29.53	EE	19.27
Sat.	LM	62.28	LM	26.88	LM	25.79
Sun.	LM	76.75	EE	49.55	A	29.48
Mon.	A	39.48	EE	19.73	EE	12.52
Tue.	EE	29.9	EE	23.44	EE	11.88

Note: The sign * indicates the most congested period of each section



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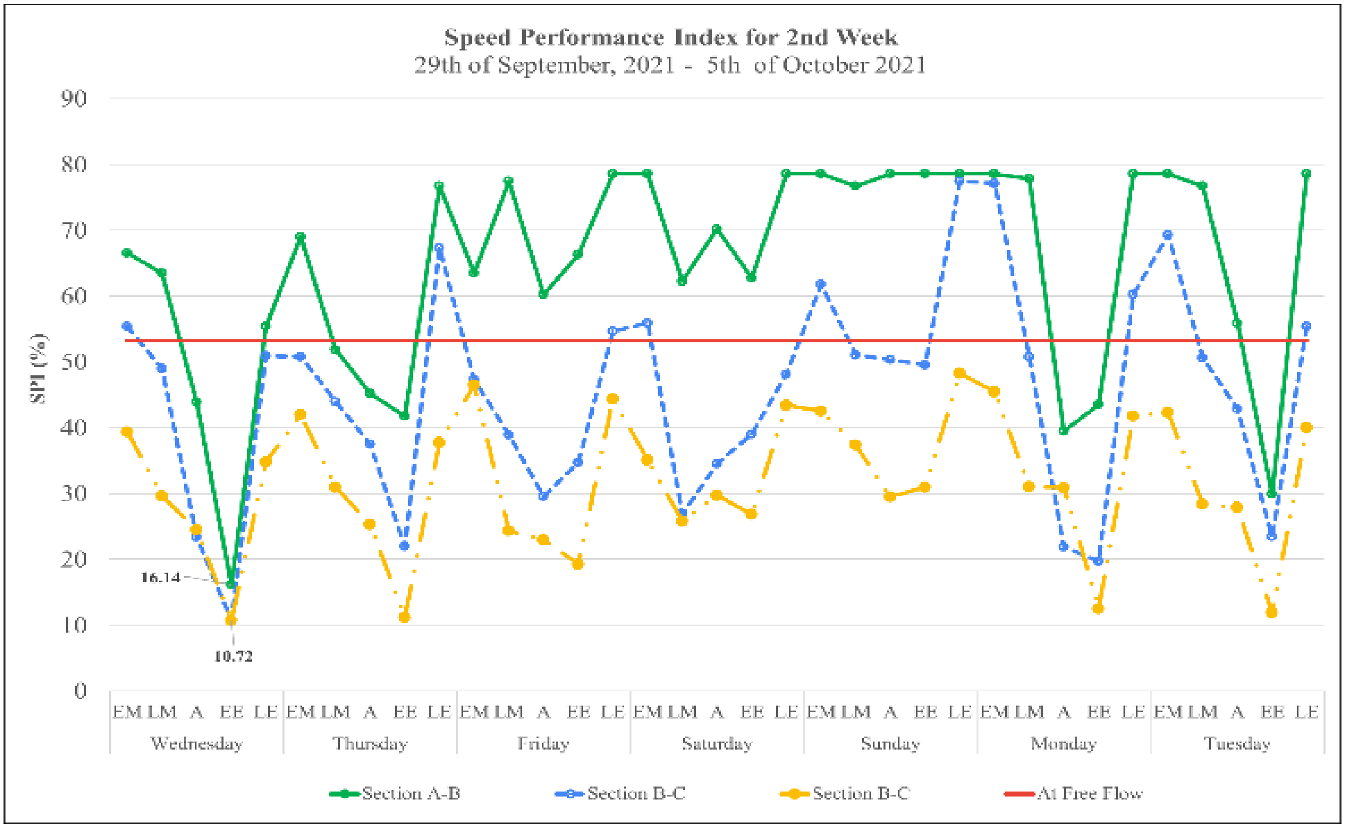


(b)

Fig. 4 Congestion Evaluation Using Speed Performance Index: (a) First Week (b) Second Week

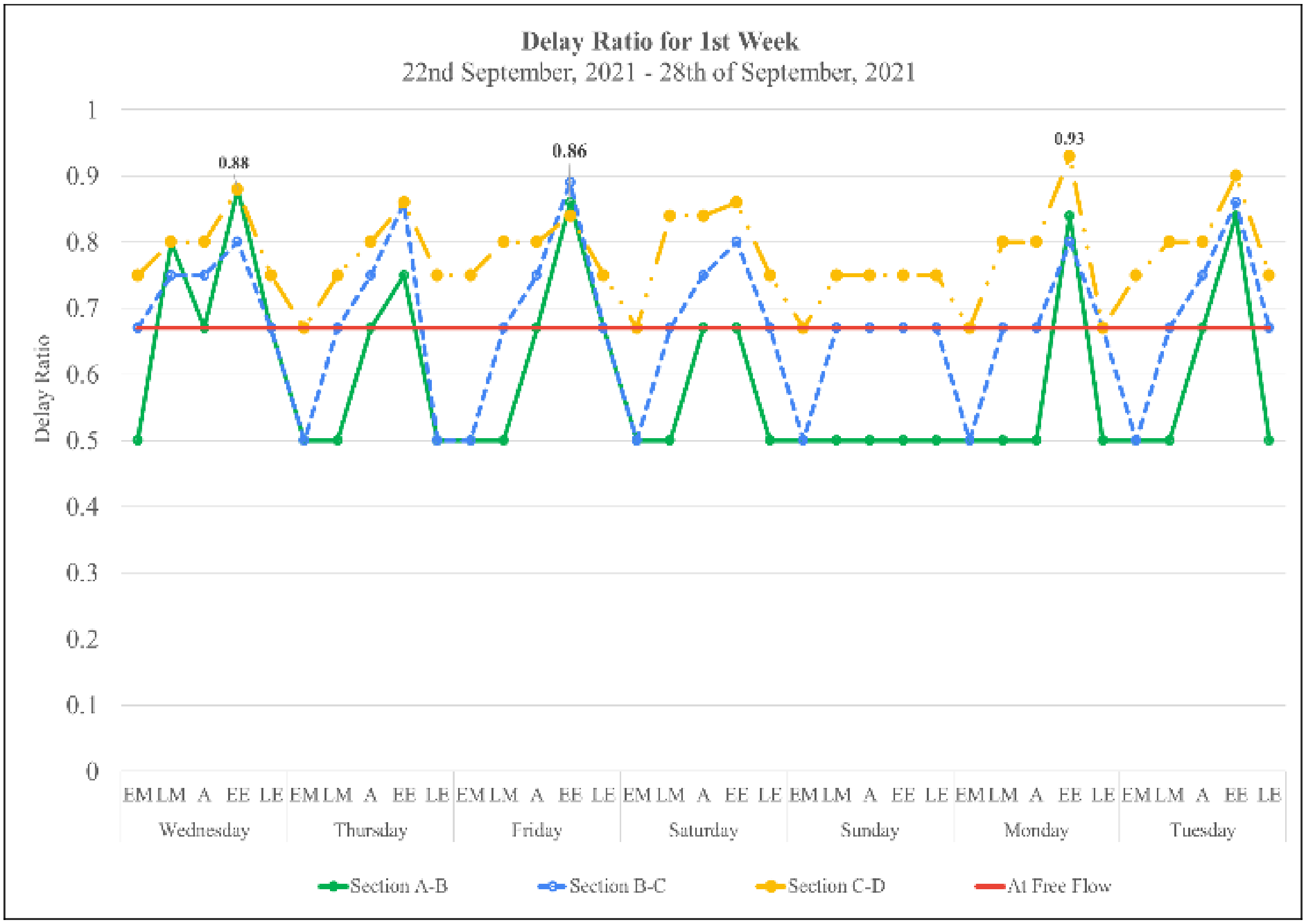
C. Delay Ratio

The least congested period was Section A-B on Sunday afternoons of the first week and late Sunday mornings of the second week, both with a delay ratio of 0.5. The most congested period was Section C-D on Monday evening, with a delay ratio of 0.93.

TABLE VIII CONGESTION PERIOD BASED ON DELAY RATIO

Days	A-B		B-C		C-D	
	Period	**Value**	**Period**	**Value**	**Period**	**Value**
Wed.	EE	**0.88***	EE	0.8	EE	0.88
Thu.	EE	0.75	EE	0.86	EE	0.86
Fri.	EE	0.86	EE	0.89	EE	0.84
Sat.	EE	0.67	EE	0.8	EE	0.86
Sun.	A	0.5	A	0.67	A	0.75
Mon.	EE	0.84	EE	0.8	EE	**0.93***
Tue.	EE	0.84	EE	0.86	EE	0.9
Wed.	EE	**0.88***	EE	**0.92***	EE	0.92
Thu.	EE	0.67	EE	0.84	EE	0.92
Fri.	A	0.67	A	0.8	EE	0.86
Sat.	LM	0.67	LM	0.8	LM	0.8
Sun.	LM	0.5	EE	0.67	A	0.8
Mon.	A	0.75	EE	0.86	EE	0.9
Tue.	EE	0.8	EE	0.84	EE	0.91

Note: The sign * indicates the most congested period of each section



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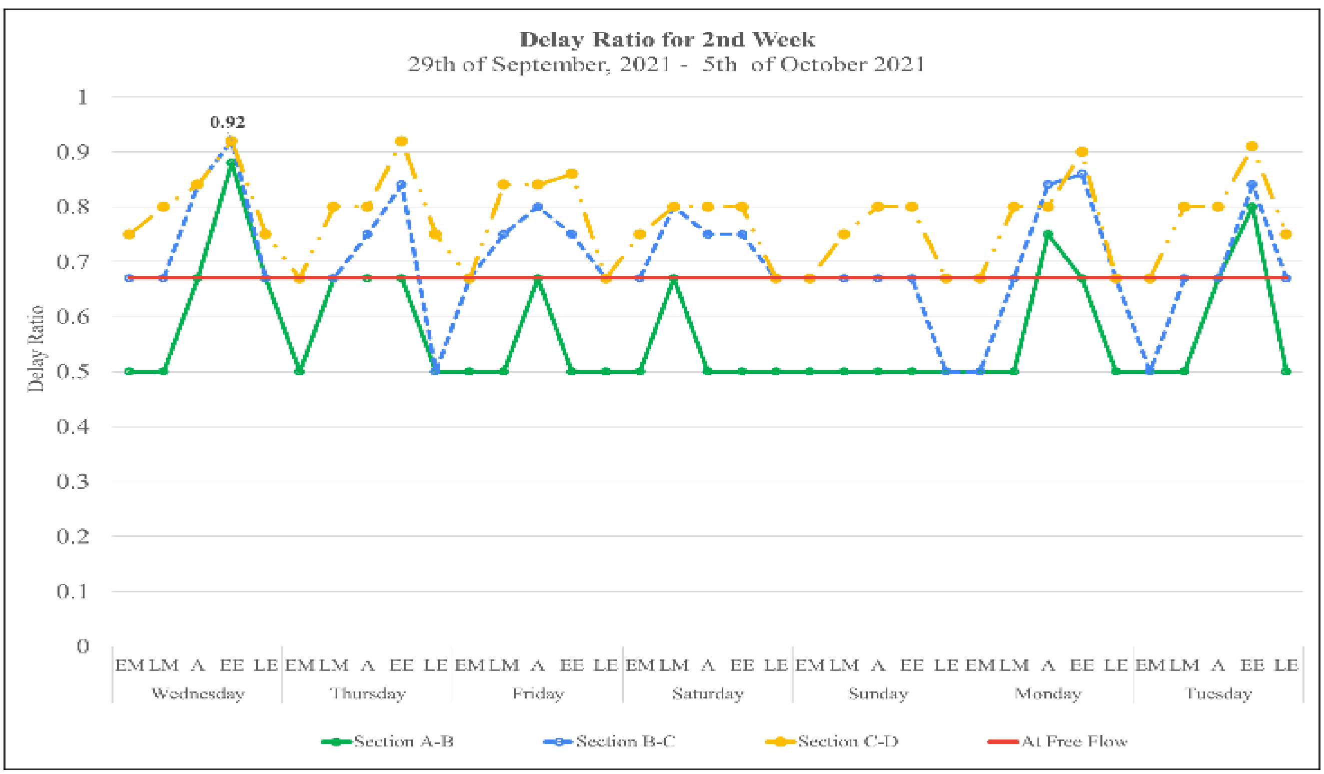

(b)

Fig. 5 Congestion Evaluation Using Delay Ratio: (a) First Week (b) Second Week

D. Volume Study of Section A-B

Volume studies from Section A-B, shown in Table IX (a) and (b), indicate the least congestion with a V/C ratio of 1.5 on Tuesday and 0.81 on Wednesday, both in the early evening. The most congested period occurred on Tuesday late morning and Wednesday early evening in the B-A direction. All sections have V/C ratios above 1, except for Section A-B on Wednesday morning, confirming congestion on these roads.

TABLE IX (A) VOLUME STUDIES FOR SECTION A-B FOR: (A) TUESDAY

Tue	Late Morning				Early Evening			
	V	Ls	N_{max}	V/C	V	Ls	N_{max}	V/C
A-B	3526	2.2	1926	1.84	2871	2.2	1926	1.5
B-A	4738	2.2	1926	2.47	2668	2.2	1926	1.39

TABLE IX (B) VOLUME STUDIES FOR SECTION A-B FOR: (B) WEDNESDAY

Wed	Late Morning				Early Evening			
	V	Ls	N_{max}	V/C	V	Ls	N_{max}	V/C
A-B	4008	2.2	1926	2.09	1549	2.2	1926	0.81
B-A	5104	2.2	1926	2.66	17121	2.2	1926	8.89

E. Volume Study of Section B-C

Volume studies from Section B-C, as shown in Table X (a) and (b), indicate the least congestion with a V/C ratio of 0.57 on Tuesday late morning and 1.95 on Wednesday early evening. The most congested period occurred on Tuesday late morning in the C-B direction. Except for Tuesday late morning, all sections have V/C ratios above 1, further indicating heavy congestion.

TABLE X (A) VOLUME STUDIES FOR SECTION B-C FOR: (A) TUESDAY

Tue	Late Morning				Early Evening			
	V	Ls	N_{max}	V/C	V	Ls	N_{max}	V/C
B-C	640	1.3	1138	0.57	1568	1.3	1138	1.38
C-B	2793	1.3	1138	2.46	2435	1.3	1138	2.14

TABLE X (B) VOLUME STUDIES FOR SECTION B-C FOR: (B) WEDNESDAY

Wed	Late Morning				Early Evening			
	V	Ls	N_{max}	V/C	V	Ls	N_{max}	V/C
B-C	3279	1.3	1138	2.89	2214	1.3	1138	1.95
C-B	3991	1.3	1138	3.51	3720	1.3	1138	3.27

F. Volume Study of Section C-D

Volume studies from Section C-D, presented in Table 4.2.1.1(a) and (b), indicate the least congestion in the D-C direction, with a V/C ratio of 0.02 on Wednesday and 0.63 on Tuesday, both in the early evening. The most congested period was Tuesday late morning in the C-D direction, with a V/C ratio of 4.21. Overall, the volume-to-capacity ratio in this section is relatively low compared to earlier sections.

TABLE XI (A) VOLUME STUDIES FOR SECTION C-D FOR: (A) TUESDAY

Tue	Late Morning				Early Evening			
	V	Ls	Nmax	V/C	V	Ls	Nmax	V/C
C-D	4381	2	1751	2.51	1516	2	1751	0.87
D-C	3437	2	1751	1.97	1093	2	1751	0.63

TABLE XI (B) VOLUME STUDIES FOR SECTION C-D FOR: (B)WEDNESDAY

Wed	Late Morning				Early Evening			
	V	Ls	Nmax	V/C	V	Ls	Nmax	V/C
C-D	4469	2	1751	2.56	1404	2	1751	0.81
D-C	7363	2	1751	4.21	19	2	1751	0.02

G. Level of Service (LOS)

The highest LOS classification, with a V/C ratio of 1, indicates severe congestion and an increased risk of accidents. As shown in Table XII, the peak periods for each section significantly exceed this threshold, with the highest V/C reaching 8.89 - 7.79 above the standard - indicating extreme congestion. For this study, Level of Service (LOS) F is assigned to all sections, despite the V/C values being disproportionately high and beyond the scale.

TABLE XII PEAK PERIOD BASED ON LEVEL OF SERVICE

	Tuesday			Wednesday		
	Period	V/C	LOS	Period	V/C	LOS
A-B	LM	1.84	F	LM	2.09	F
B-A	EE	2.47	F	EE	8.89	F
B-C	EE	1.38	F	LM	2.89	F
C-B	LM	2.46	F	LM	3.51	F
C-D	LM	2.51	F	LM	2.56	F
D-C	LM	1.97	F	LM	4.21	F

H. Time vs. Volume

Based on the sample data in Table III, while the average travel time clearly indicates that Section C-D is the most congested on Tuesday, the volume study does not yield the same conclusion without further context.

The volume data for Section C-D and A-D includes an unusual negative value, complicating the analysis. This anomaly suggests unidirectional traffic, a common occurrence in Lagos's transport network during peak periods.

TABLE XIII (A) SAMPLE (A) AVERAGE TRAVEL TIME

Period	**A-D**			**D-A**		
	A-B	**B-C**	**C-D**	**B-A**	**C-B**	**D-C**
LM	2.42	4.34	5.55	4.62	4.84	10.6
EE	5.72	7.9	**21.58**	3.17	3.14	4.92

TABLE XIII (B) SAMPLE (B) TRAFFIC VOLUME

Volume						
Period	**A-D**			**D-A**		
	A-B	**B-C**	**C-D**	**B-A**	**C-B**	**D-C**
LM	3526	640	4381	4738	2793	3437
EE	2871	**-2219**	**-1018**	2668	2435	1093

IV. CONCLUSION

Based on our analysis of the congestion on Ikorodu Road, Lagos, the most congested section of the route is Section C-D, spanning from Ketu Bus Stop to Mile-12 Under-Bridge, while the least congested section is Section A-B, from Maryland Tunnel to Ojota Bus Stop. The most congested period occurs during the early evening (EE), and the least congested period is late evening (LE). During peak periods, all sections are heavily congested and prone to road accidents. Although time-dependent congestion parameters may have varying value ranges, they consistently point to Section C-D and the early evening period as the most congested. Congestion in one section often has a ripple effect, leading to traffic buildup in other sections in the direction of travel. Furthermore, time-dependent indices are more efficient in measuring congestion than volume-based indices. The moving vehicle analysis, however, may not be effective in estimating traffic volume in a transport network with predominantly unidirectional flow. Congestion along the study area is highly influenced by work hours.

ACKNOWLEDGMENT

We acknowledge the support of the Lagos State Transportation Management Authority during our data collection exercise.

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