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MOVING VEHICLE TECHNIQUE-BASED ANALYSIS OF TRAVEL TIME AND DELAY ALONG AN URBAN ROAD CORRIDOR IN ZARIA, NIGERIA.

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ABSTRACT

The study assessed travel time, traffic flow, speed, and delay along the 5 km Kwangila Flyover–PZ Plaza corridor in Zaria City, Kaduna State, Nigeria, using the Moving Vehicle Technique. Data were collected over seven consecutive days (6–12 January 2025) during relatively off-peak (9:00 a.m.–12:00 p.m.) and peak (4:00 p.m.–6:00 p.m.) periods. Average traffic volume increased from 1,203 to 1,307 vph westbound and from 1,197 to 1,321 vph eastbound during peak periods. Consequently, average travel time increased from 7.50 to 8.61 minutes westbound and from 7.31 to 8.31 minutes eastbound, while space mean speed decreased from 40.06 to 36.60 km/h and from

41.42 to 36.31 km/h, respectively. Additional travel time was estimated at 1.11 minutes westbound and 1.00 minute eastbound. Thursday recorded the highest traffic volumes, while Sunday had the lowest. Traffic congestion, road damage, street hawking, wrongful parking, and wrong-way driving accounted for approximately 75% of observed delays. The study concludes that increased traffic demand and roadway and operational constraints reduce corridor efficiency, requiring measures that address both traffic demand and these constraints.

KEYWORDS: Travel time; Traffic delay; Moving Vehicle Technique; Traffic congestion; Level of Service.

1.0 INTRODUCTION

Mobility is not only concerned with the provision of transport infrastructure and services but also with ensuring that people can move adequately and meaningfully through transport systems while overcoming social, economic, physical, and political barriers to movement (United Nations, 2014). Effective transportation enhances access to markets, employment, education, healthcare, and other opportunities and therefore contributes to economic development and poverty reduction. Maintaining an adequate level of traffic flow is consequently important for meeting the transportation needs of the population and promoting inclusive mobility (World Bank, 2002). This requires an integrated approach in which traffic flow is considered alongside the social, economic, and environmental effects of transportation, particularly in urban areas (Shittu & Rufai, 2022).

Transportation involves the movement of people and goods from one location to another through a transportation system (May, 2007; Tuffour, 2019). It is closely connected with social and economic activities because people depend on transportation to access employment, education, commerce, recreation, healthcare, and other services. An efficient transportation system facilitates the movement of people and goods and supports productivity and economic activity. However, transportation systems can also produce adverse social, economic, and environmental effects, with traffic congestion being one of the most visible problems (Asare-Twerefour, 2020).

Urbanisation and the concentration of population and economic activities within limited geographical areas increase transportation demand. When the demand for movement becomes greater than the available road capacity, congestion is likely to occur (Koźlak & Wach, 2018). Traffic flow, vehicle speed, travel time, and delay are therefore important measures for assessing the performance of urban roads and the severity of congestion. In addition, major urban roads often attract commercial, residential, and other activities along their corridors. These activities can interfere with traffic movement and result in increased travel time and delay, reduced road safety, and poorer road operating conditions.

Transportation demand is generally considered a derived demand because people do not usually travel for the movement itself but to undertake economic, social, recreational, political, and educational activities (Garber & Hoel, 2010). Consequently, changes in land use, population, economic activities, and travel behaviour can influence traffic demand and roadway performance. Where traffic demand is high and roadway capacity or operating conditions are inadequate, road users experience longer travel times, lower speeds, and increased delays.

The Gwangila Flyover–PZ Plaza corridor in Zaria City, Kaduna State, Nigeria, experiences high traffic volumes and considerable congestion, particularly during peak periods. The situation is partly associated with transportation policies that restrict buses from operating within the city, resulting in the concentration of bus operations along the highway. The corridor also experiences substantial use of private vehicles, tricycles (keke napep), and motorcycles. These conditions have contributed to traffic congestion, increased travel time and delay, and road safety concerns.

Travel time is the total time required for a vehicle or traveller to move along a specified route or road segment under prevailing traffic conditions (Asare-Twerefour, 2020; Garber & Hoel, 2010). It is one of the important measures used to evaluate roadway performance. Travel time may vary according to traffic conditions, roadway characteristics, traffic demand, vehicle characteristics, and activities occurring along the road. In practice, the time experienced by road users may differ from the time expected under free-flow conditions because of congestion, traffic control, roadside activities, and other interruptions.

From the user's perspective, travel time is also associated with the reliability and predictability of a journey. Travellers are generally concerned not only with the average time required to complete a trip but also with the possibility of unexpected increases in travel time. Travel time variability may result from changes in traffic demand, crashes, vehicle breakdowns, roadworks, weather conditions, roadway constraints, and other irregular events (Wong & Sussman, 1973; Kwon et al., 2011). Measures such as standard deviation, coefficient of variation, percentile travel times, and the Buffer Index have been used to assess travel time variability (Tseng et al., 2005; Mazloumi et al., 2008; FHWA, 2006).

Traffic delay refers to the additional time spent by a vehicle or traveller beyond the time that would normally be required under ideal or free-flow conditions (Asare-Twerefour, 2020). Delay is an important indicator of roadway efficiency and can result from traffic congestion, traffic control devices, road crashes, roadway characteristics, pedestrian activity, roadside parking, street trading, and other physical or operational constraints (Islam, 2024). Delay is therefore closely related to roadway level of service and is useful for identifying locations where traffic management or infrastructure improvements may be required.

Delay can occur for several reasons. Fixed delay may result from traffic control devices and geometric constraints, while operational delay is caused by interactions among vehicles and interference from activities such as parking, pedestrian crossings, roadside access, and street trading (Abojaradeh, 2013; Islam, 2024; Srivastava & Kumar, 2023). Stopped-time delay occurs when vehicles are stationary, while travel-time delay represents the difference between the actual time required to travel along a road segment and the time expected under a specified operating condition (Asare-Twerefour, 2020; Garber & Hoel, 2010). These delays may be recurrent, such as those caused by high traffic demand during peak periods, or non-recurrent, such as those resulting from crashes, vehicle breakdowns, roadworks, and adverse weather conditions (Lian & Loo, 2024).

Roadside and traffic activities can also contribute significantly to delay. Pedestrian crossings, on-street parking, street trading, roadside commercial activities, and access to adjoining properties can create side friction and reduce roadway efficiency (Srivastava & Kumar, 2023; Islam, 2024). Vehicle characteristics can also affect travel time and delay. Large or older public transport vehicles may require more time to accelerate, manoeuvre, and stop for passenger boarding and alighting, thereby increasing running and stopped delays (Abojaradeh, 2013; Galadima, 2024).

The measurement of travel time and delay is important for traffic management, transport planning, and the identification of problem locations. Several techniques are available, including test-vehicle methods, non-test-vehicle methods, and modern probe-based technologies (Asare-Twerefour, 2020). Test-vehicle methods include the floating car technique and the moving observer or moving vehicle technique. In the floating car technique, the test vehicle attempts to travel with the traffic stream so that its speed and travel time represent the general traffic conditions. The moving observer method, developed by Wardrop and Charlesworth (1954), involves making repeated trips with and against the traffic stream while recording travel times and vehicle movements. These observations can be used to estimate traffic flow, travel time, and speed with relatively simple field equipment (Ahmad Raqib et al., 2005; Islam, 2024).

Other approaches include manual vehicle identification and matching, roadside surveys, and stationary traffic detectors. Modern methods increasingly use GPS, Bluetooth, Wi-Fi, and other probe technologies to obtain travel-time and speed data over wider areas. GPS-based floating vehicle data, for example, can provide detailed information on vehicle movement without requiring extensive roadside infrastructure (Lian & Loo, 2024). However, the choice of technique depends on the study objectives, available resources, roadway characteristics, and the type of traffic information required.

Previous empirical studies have demonstrated the importance of roadway, traffic, and vehicle characteristics in determining travel time and delay. Abojaradeh (2013), in a study of the Amman–Sweileh corridor in Jordan, found that public bus travel times were strongly influenced by bus size, vehicle model, and the number of passenger pick-up stops. The study indicated that replacing older and larger buses with newer and more efficient vehicles could substantially reduce travel time.

In Nigeria, Galadima (2024) investigated the Mararaba–Nyanya highway in Abuja using the floating vehicle technique. The study found considerable differences in travel performance among transport modes, with private cars recording shorter travel times and higher speeds than public mass transit buses. Vehicle size and vehicle model were identified as important factors influencing travel time. Similarly, Shittu and Rufai (2022) investigated Sokoto Road in Zaria and found that peak-period travel times were affected by high access-point density, eroded shoulders, and commercial activities along the corridor. In Kumasi, Ghana, Asare-Twerefour (2020) used the moving observer technique and GPS tracking to investigate Sunyani Road and found that congestion on single-carriageway sections was associated with heavy pedestrian crossings and high access-point density.

Studies from other regions have also shown that roadway and traffic conditions influence travel time reliability. Brennan et al. (2014) used probe vehicle data along the I-80 corridor in Northern New Jersey to identify recurring bottlenecks and assess the effects of winter storms on traffic conditions. In Melbourne, Australia, Mazloumi et al. (2008) used bus automatic vehicle location data to examine travel-time reliability and found relationships between travel-time variability and factors such as bus stop density, signalised intersection density, and departure delays.

Travel time and delay also have implications beyond roadway operation because they influence the daily activities and decisions of travellers. Economic studies have shown that travellers consider both travel time and schedule reliability when making travel decisions (Small, 1982; Noland & Small, 1995). The value attached to travel time can vary according to household income, trip purpose, travel distance, and transport mode (Tseng et al., 2005; Wardman et al., 2016). Delays can also force travellers to adjust their daily schedules, particularly discretionary activities such as shopping, leisure, and social activities, while more rigid activities such as work are less easily changed (Rasouli & Timmermans, 2013).

The reviewed literature indicates that travel time and delay are influenced by the interaction of traffic demand, roadway characteristics, vehicle characteristics, roadside activities, and operational conditions. Although several studies have examined travel time and delay on urban roads in Nigeria and other developing countries, the specific conditions of the Gwangila Flyover–PZ Plaza corridor require further assessment because of its high traffic demand, congestion, and roadside activities. A travel time and delay study can provide information on the amount of time required to traverse the corridor, the level of traffic flow, the prevailing speeds, the extent of delay, and the factors contributing to these conditions. Such information is useful for identifying problem locations and developing appropriate measures to improve traffic movement and roadway efficiency.

Therefore, this study assesses travel time, traffic flow, speed, and delay along the Gwangila Flyover–PZ Plaza corridor in Zaria City, Kaduna State, Nigeria, using the Moving Vehicle Technique. It focuses on identifying the factors contributing to congestion and delay and providing practical measures for improving traffic flow and transportation efficiency.

3.0 MATERIALS AND METHODS

3.1 Study Area and Research Design

The study was conducted along a 5 km urban road corridor extending from Kwangila Flyover to PZ Plaza in Zaria, Kaduna State, Nigeria. The corridor was selected because of its relatively high traffic demand, recurrent congestion, and associated travel time and delay problems, particularly during peak periods.

A field-based observational research design was adopted. The Moving Vehicle Technique (MVT) was used as the principal method for determining travel time, traffic flow characteristics, and delay along the selected road section. The technique involved repeated round trips by a test vehicle along the study corridor in both directions under prevailing traffic conditions.

3.2 Materials and Equipment

The materials and equipment used for the field survey consisted of a test vehicle, stopwatch, tally sheets, and tally books.

The test vehicle was a private vehicle used to conduct the survey runs in both directions of the study corridor. The vehicle was operated within the prevailing traffic stream rather than being driven at a predetermined speed, thereby allowing travel time and traffic interactions to be observed under actual traffic conditions.

A stopwatch was used to record the time taken by the test vehicle to traverse the selected road section. Tally sheets and tally books were used to systematically record opposing traffic, overtaking vehicles, vehicles overtaken by the test vehicle, travel times, and other relevant field observations.

Three enumerators participated in each survey run. Their responsibilities were clearly defined to ensure consistency and minimize errors during data collection. The first enumerator recorded the number of vehicles travelling in the opposite direction to the test vehicle, represented by (N_e) and (N_w). The second enumerator recorded the number of vehicles overtaking the test vehicle, represented by (O_e) and (O_w), while the third enumerator recorded the number of vehicles overtaken by the test vehicle, represented by (P_e) and (P_w).

3.3 Preliminary Traffic Survey

A preliminary traffic survey was conducted over three days to identify the traffic characteristics of the study corridor and establish the section and periods experiencing relatively high traffic volumes. Manual traffic counts were conducted at selected observation points along the corridor. The enumerators maintained continuous observation of the traffic stream and recorded vehicle movements using prepared tally sheets. The survey covered the relevant morning and evening periods to capture variations in traffic demand between relatively low- and high-flow conditions. The results of the preliminary survey were used to guide the subsequent travel time and delay survey, particularly in selecting appropriate survey periods for representing prevailing traffic conditions along the corridor.

3.4 Travel Time and Delay Survey

The travel time and delay survey was conducted over a seven-day period using the Moving Vehicle Technique. The selected road section was measured and its start and end points were clearly identified. The test vehicle travelled along the entire study section in both directions, following the prevailing traffic stream.

For each survey run, the time at which the test vehicle crossed the starting point was recorded. The vehicle then travelled to the end point of the study section, where the arrival time was recorded. The same procedure was repeated in the opposite direction. Travel time was therefore obtained for both the eastbound and westbound movements.

The route was also divided into 30 m segments to facilitate the observation and recording of changes in travel conditions along the corridor. The time taken to traverse the designated segments was recorded where applicable, together with observations of traffic interruptions and delays.

The survey was undertaken during selected periods of the day to capture variations in traffic conditions. Particular attention was given to the morning and evening periods when traffic demand was expected to be relatively high. The collected observations provided the basis for assessing travel time, delay, traffic flow, and speed characteristics along the study corridor.

3.5 Moving Vehicle Technique

The Moving Vehicle Technique was applied by making a round trip over the study section. The road section was considered to run approximately in an east–west direction, with sections X–X and Y–Y representing the beginning and end points of the test section, respectively.

The test vehicle started at section X–X and travelled westbound to section Y–Y. Upon reaching Y–Y, the vehicle was turned around and travelled eastbound back to section X–X. During each journey, the enumerators recorded the travel time of the test vehicle and the number of vehicles encountered in the opposite direction. They also recorded vehicles that overtook the test vehicle and those overtaken by it.

The following variables were recorded during each survey run:

T_e = Time taken to travel eastbound from point X to Y (in minutes)

T_W = Time taken to travel westbound from point Y to X (in minutes)

N_e = Number of vehicles traveling westbound in the opposite lane while the test car travels east N_W = Number of vehicles traveling eastbound in the opposite lane while the test car travels west O_W = Number of vehicles that overtake the test car while traveling westbound from point X O_e = Number of vehicles that overtake the test car while traveling eastbound from point X to Y P_W = Number of vehicles that the test car passes while traveling westbound from point Y to X P_e = Number of vehicles that the test car passes while traveling eastbound from point X to Y L = Length of the test road section (in kilometers).

The variables obtained from the moving vehicle survey were used to estimate the traffic flow characteristics of the corridor. The method enables traffic volume, average travel time, average speed, and delay to be estimated from observations made during the opposing-direction and return trips.

The data obtained from the field survey were organized according to direction of travel and survey period. The travel times, opposing vehicle counts, overtaking movements, and vehicles overtaken were used to determine the principal traffic flow parameters.

The average travel time was determined from the travel times recorded during repeated runs along the study section. Traffic volume was estimated using the vehicle counts obtained during the moving vehicle surveys, while the travel speed was determined from the relationship between the length of the study section and the corresponding travel time. Travel time and delay measurements were subsequently compared across the survey periods and directions of travel to identify variations in traffic conditions and locations or periods associated with increased delay.

4.0 RESULTS AND DISCUSSION

4.1 Results

The field survey generated data on traffic volume, travel time, opposing traffic, overtaking movements, and vehicles overtaken by the test vehicle along the Kwangila Flyover–PZ Plaza corridor. Data were collected over seven consecutive days, from Monday, 6 January 2025, to Sunday, 12 January 2025, during two observation periods: 9:00 a.m.–12:00 p.m., representing relatively off-peak (uncongested) traffic conditions, and 4:00 p.m.–6:00 p.m., representing relatively peak (congested) traffic conditions.

The Moving Vehicle Technique was used to obtain travel-time and traffic-flow characteristics for both westbound and eastbound movements. The summary of the results is presented in Tables 4.1, 4.2, and 4.3

4.1.1 Traffic Characteristics during Off-Peak (Uncongested) Conditions

Table 4.1 summarises the traffic characteristics observed during the relatively off-peak period. The results indicate that the average weekly traffic volume was 1,203 vehicles per hour (vph) in the westbound direction and 1,197 vph in the eastbound direction. The difference between the two directional flows was relatively small, indicating that traffic demand was fairly balanced between the two directions during the off-peak period.

Table 4.1: Off-peak hour flow characteristics in a week.

Day/Direction	Volume of Vehicle (vph) Westbound Vw	Eastbound Ve	Average (min) Westbound Tw	Travel time Eastbound Te	Space Mean Speed (Km/h) Westbound Sw	Eastbound Se
Monday	1274	1264	7.9	8.14	38	37.3
Tuesday	1348	1250	7.5	6.8	40	44.1
Wednesday	1349	1358	7.8	7	38.5	43
Thursday	1390	1395	7.08	7.06	42.3	43.5
Friday	1276	1265	7.03	7	42.7	43
Saturday	984	1056	7.7	7.4	38.9	40.5
Sunday	797	792	7.5	7.8	40	38.5
Week Average	**1203**	**1197**	**7.5**	**7.31**	**40.06**	**41.42**

The highest westbound traffic volume during the off-peak period was recorded on Thursday (1,390 vph), while the highest eastbound volume was also recorded on Thursday (1,395 vph). The lowest traffic volumes were recorded on Sunday, with 797 vph westbound and 792 vph eastbound. This substantial reduction in Sunday traffic compared with weekday traffic suggests a strong day-of-week effect on travel demand along the corridor.

The average travel time during the off-peak period was 7.50 minutes westbound and 7.31 minutes eastbound. The corresponding average space mean speeds were 40.06 km/h westbound and 41.42 km/h eastbound. The slightly higher eastbound speed indicates that vehicles generally experienced marginally better operating conditions in the eastbound direction during the off-peak observation period.

The relatively high space mean speeds and lower travel times recorded during this period indicate comparatively favourable traffic operating conditions. Nevertheless, the traffic volumes demonstrate that the corridor carries substantial traffic even during the off-peak period.

4.1.2 Traffic Characteristics during peak (Congested) Conditions

Table 4.2 presents the traffic characteristics observed during the relatively peak (congested) period between 4:00 p.m. and 6:00 p.m. The weekly average traffic volume increased to 1,307 vph westbound and 1,321 vph eastbound, representing increases of approximately 8.6% and 10.4%, respectively, compared with the corresponding off-peak period volumes.

Table 4.2: Peak hour traffic flow characteristics in a week

Day/Direction	Volume of Vehicle (vph)Westbound Eastbound VwVe		Average time Travel (min) Westbound Eastbound Tw Te		Space Mean Speed (Km/h) Westbound Eastbound SwSe	
Monday	1136	1527	8.7	7.7	34.5	39
Tuesday	1421	1430	8	8.4	37.5	35.7
Wednesday	1375	1280	9.7	8.5	40	35.3
Thursday	1671	1684	8	7.53	37.5	39.8
Friday	1563	1534	9.13	9.25	33.3	32.4
Saturday	995	846	9.13	9.4	33	32
Sunday	986	947	7.63	7.4	39.17	40
Week Average	**1307**	**1321**	**8.61**	**8.31**	**36.6**	**36.31**

The increase in traffic volume was accompanied by an increase in travel time and a reduction in space mean speed. Average travel time increased from 7.50 to 8.61 minutes westbound and from 7.31 to 8.31 minutes eastbound. This represents an increase of approximately 14.8% in the westbound direction and 13.7% in the eastbound direction.

Conversely, average space mean speed decreased from 40.06 to 36.60 km/h westbound and from 41.42 to 36.31 km/h eastbound. Thus, the peak period was characterized by higher traffic volumes, longer travel times, and lower operating speeds.

The highest westbound traffic volume during the peak period was recorded on Thursday

(1,671 vph), while the highest eastbound volume was also recorded on Thursday (1,684 vph). These values correspond with the relatively high traffic volumes observed on Thursday during the off-peak period and suggest that Thursday experienced the highest overall traffic demand during the study week.

Friday also recorded relatively high traffic volumes, with 1,563 vph westbound and 1,534 vph eastbound. In contrast, Sunday recorded considerably lower volumes of 986 vph westbound and 947 vph eastbound. This further demonstrates the influence of daily travel patterns on traffic conditions along the corridor.

4.1.3 Comparison of Off-Peak and Peak Periods Traffic Conditions

A comparison of Tables 4.1 and 4.2 shows a clear deterioration in traffic operating conditions between the relatively off-peak and peak periods.

The most important changes are summarized as follows:

Table 4.3: Comparison between off-peak and peak periods traffic conditions.

Traffic Direction	Uncongested Traffic Flow	Congested Traffic Flow	Change Traffic Flow
Westbound volume (vph)	1,203	1,307	+104 vph
Eastbound volume (vph)	1,197	1,321	+124 vph
Westbound travel time (min)	7.50	8.61	+1.11 min
Eastbound travel time (min)	7.31	8.31	+1.00 min
Westbound space mean speed (km/h)	40.06	36.60	−3.46 km/h
Eastbound space mean speed (km/h)	41.42	36.31	−5.11 km/h

The results demonstrate the expected relationship between traffic volume, travel time, and speed. As traffic volume increased during the peak period, travel time increased while space mean speed decreased. This relationship indicates that the additional traffic demand placed greater pressure on the available road capacity, resulting in slower vehicle movement and increased travel time.

The effect was more pronounced in the eastbound direction in terms of speed reduction. The eastbound space mean speed declined by approximately 12.3%, compared with a reduction of approximately 8.6% westbound. This suggests that the eastbound traffic stream may have experienced greater sensitivity to increased traffic demand or additional sources of interruption during the peak period.

4.1.4 Travel Time and Delay Analysis

Travel time delay was determined as the difference between the average travel time observed during the peak (congested) period and that observed during the relatively off-peak (uncongested) period. The calculated values are presented in Table 4.3.

The results indicate an average travel time of 8.61 minutes westbound and 8.31 minutes eastbound during the peak period. During the off-peak period, the corresponding travel times were 7.50 minutes westbound and 7.31 minutes eastbound. Accordingly, the estimated delay was 1.11minutes westbound 1.00 minute eastbound.

Thus, the average additional travel time associated with congested conditions was 1.11 minutes per trip westbound and 1.00 minute per trip eastbound.

The slightly higher westbound delay indicates that motorists travelling westbound experienced marginally greater additional travel time under congested conditions. However, the difference between the two directions is relatively small, suggesting that congestion affected both traffic streams in a broadly similar manner.

Although the absolute delay per trip appears relatively small, its significance becomes greater when considered over a large number of daily trips. Recurrent delays can result in considerable cumulative time losses for road users, increased vehicle operating costs, increased fuel consumption, and reduced efficiency of movement along the corridor.

4.1.5 Relationship between Traffic Volume, Travel Time and Speed

The results demonstrate a consistent relationship among traffic volume, travel time, and space mean speed. During the relatively uncongested period, the corridor recorded lower average traffic volumes of 1,203 vph westbound and 1,197 vph eastbound, together with shorter travel times and higher average speeds.

During the congested period, traffic volumes increased to 1,307 vph westbound and 1,321 vph eastbound. At the same time, travel time increased and space mean speed declined. This indicates that the road was operating under greater traffic pressure during the afternoon period.

The results are particularly important because the increase in traffic volume was not accompanied by a proportional increase in roadway capacity. As demand approached or exceeded the effective operating capacity of the corridor, vehicle interactions increased, resulting in lower speeds and longer travel times.

The occurrence of increased overtaking and opposing traffic movements in several of the individual survey runs also indicates considerable interaction between vehicles within the traffic stream. Such interactions can reduce traffic efficiency, particularly where roadside activities, conflicting movements, pedestrian activity, parking, or other interruptions are present.

4.1.6 Daily Variation in Traffic Conditions

The daily results show considerable variation in traffic demand throughout the study week. Weekday traffic was generally higher than weekend traffic, with Thursday recording the highest traffic volumes in both directions. The relatively high volumes observed on Monday through Friday suggest that the corridor serves substantial routine travel demand associated with employment, commercial activities, education, and other urban activities.

Weekend traffic was generally lower. Sunday recorded the lowest traffic volumes during both observation periods. This reduction in traffic demand was accompanied by comparatively favourable travel conditions.

An important observation is that traffic volume alone does not completely explain travel time. For example, some days with relatively moderate traffic volumes still recorded comparatively high travel times. This suggests that other factors, including roadside activities, traffic conflicts, road surface conditions, incidents, and other interruptions, may contribute to delay along the corridor.

4.1.7 Factors Contributing to Travel Time Delay

The field observations and analysis identified traffic congestion, road damage, street hawking, wrongful parking, and wrong-way driving as major contributors to delay as the major factors contributing to travel time delay along the study corridor. These factors were reported to account for approximately 75% of the total delay.

Traffic congestion represents the most direct contributor because increasing traffic demand reduces the available operating space and increases interactions between vehicles. As traffic density increases, vehicles experience more frequent speed reductions, queuing, and interruptions, resulting in longer travel times.

Road damage can further aggravate congestion by forcing motorists to reduce speed, change lanes, or avoid damaged sections of the carriageway. Such manoeuvres may increase conflicts between vehicles and reduce the effective capacity of the road.

Overall, the results indicate that travel time delay along the Kwangila Flyover–PZ Plaza corridor is influenced by a combination of increased traffic demand and physical or operational constraints on the roadway. Consequently, measures aimed only at increasing road capacity may not be sufficient. Effective intervention should also address roadway condition, traffic management, roadside activities, and other sources of traffic interference.

4.2 Discussion of Findings

The findings establish that the Kwangila Flyover–PZ Plaza corridor experiences noticeable variations in traffic operating conditions between relatively uncongested and congested periods. The increase in traffic volume during the afternoon period was accompanied by longer travel times and lower space mean speeds in both directions.

The westbound travel time increased by 1.11 minutes, while the eastbound travel time increased by 1.00 minute. Correspondingly, the westbound and eastbound space mean speeds decreased by

3.46 km/h and 5.11 km/h, respectively. These results confirm that increased traffic demand and congestion adversely affect the operational performance of the corridor.

The relatively high traffic volumes recorded on Thursday and Friday indicate that particular weekdays experience substantially greater demand. This suggests that traffic management measures may need to be particularly targeted at periods of high demand rather than applied uniformly throughout the week.

The lower traffic volumes recorded on Saturday and Sunday further indicate that congestion is strongly associated with temporal variations in travel demand. The findings therefore support the need for traffic management strategies that consider both time-of-day and day-of-week variations in traffic flow.

The results also show that travel time delay cannot be attributed exclusively to traffic volume. Road damage and other identified sources of traffic interference may contribute to speed reductions and increased travel time even when traffic volumes are comparatively moderate. Addressing these factors through appropriate road maintenance, traffic management, and control measures would therefore improve the operational performance of the corridor.

In general, the findings demonstrate that the Moving Vehicle Technique provides useful information for assessing traffic conditions along the study corridor. The observed differences in traffic volume, travel time, speed, and delay provide a quantitative basis for evaluating congestion and identifying appropriate measures for improving traffic flow along the Kwangila Flyover–PZ Plaza corridor.

5.0 CONCLUSION

The study assessed travel time, traffic flow, speed, and delay along the Kwangila Flyover–PZ Plaza corridor in Zaria City using the Moving Vehicle Technique. The findings demonstrate a clear difference between relatively uncongested and congested traffic conditions along the corridor.

During the relatively uncongested period, the corridor recorded average traffic volumes of 1,203 vph westbound and 1,197 vph eastbound, with corresponding average travel times of 7.50 and 7.31 minutes. During the congested period, traffic volumes increased to 1,307 vph westbound and 1,321 vph eastbound, while average travel times increased to 8.61 and 8.31 minutes, respectively. The increase in travel time was accompanied by reductions in space mean speed from 40.06 to 36.60 km/h westbound and from 41.42 to 36.31 km/h eastbound.

The estimated additional travel time associated with the congested period was 1.11 minutes per trip westbound and 1.00 minute per trip eastbound. Although the delay per individual trip appears relatively small, its cumulative effect can become substantial when experienced by a large number of road users.

The study also established that traffic conditions varied considerably by day of the week. Thursday recorded the highest traffic volumes in both directions, whereas Sunday recorded the lowest. This indicates that traffic demand along the corridor varies temporally and that congestion is particularly associated with periods of increased demand.

Furthermore, the field observations identified traffic congestion, road damage, street hawking, wrongful parking, and wrong-way driving as major contributors to delay to travel time delay, accounting for approximately 75% of the observed delay. The findings therefore indicate that travel time and delay along the corridor are not determined by traffic volume alone but are also influenced by roadway and operational conditions.

Overall, the study concludes that increased traffic demand, combined with physical and operational constraints, reduces the efficiency of movement along the Kwangila Flyover–PZ Plaza corridor. Improving traffic flow will consequently require measures that address both traffic demand and the identified roadway and operational constraints.

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