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Assessment of Traffic Flow Patterns and its Characteristics at Major Road Intersections in Minna Metropolis, Niger State

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ABSTRACT

The urban road network plays a key role in the urban spatial structure. But rapid urban development has led into various increment in travel demand and motorization in urban areas. The current infrastructure has failed to meet-up with increasing demand leading to traffic delay, congestion and accidents. This study assesses the traffic flow patterns and its characteristics at major intersections in Minna Metropolis. A descriptive research survey was adopted in which data were collected through volumetric traffic count at selected traffic intersections from 6:00am to 6:00pm for a period of a week. Data collected were analyzed descriptively and was found that tricycles (42.5%) and cars (31.3%) were the two major traffic composition with total of 24,636. Also, the average traffic flow pattern in Minna occurs between 12:00pm-2:00pm and it takes an S-shape like flow trends. The average traffic volume composition indicates 86.5% of traffic composition were made up of Motorcycle (12.64%), Tricycle (42.55%) and Car (31.31% respectively. While, average traffic flow pattern shows that there is high volume of traffic around 8-10am at Kpakungu roundabout. While, Kpakungu and Mobil roundabout experienced the highest volume of traffic respectively (15,045 and 12, 293). Based on these findings, some recommendations were made, which include; the grade separation of intersections at Kpakungu and Mobil junction by the State Ministry of Works to reduce traffic delays and conflicts. Also, adequate and necessary road complementary facilities such as functional traffic lights, zebra crossing and others should be provided to ensure smooth flow of traffic.

Keywords: traffic-volume, flow-pattern, intersection-control, characteristics, road-network

INTRODUCTION

Traffic in an urban area is necessitated by the need for various parts and activities of the urban area to relate with one another. These various parts in the urban areas are land-use types which include residential, commercial, industrial, recreational, and institutional, amongst others. The volume of traffic generated by land-use varies during different periods of the day but there is usually a predictable pattern of such traffic volumes (Ajala, 2019). The urban road network plays a key role in the urban spatial structure. In other words, road network constitutes as an important element in urban development as roads provide accessibility required by different land uses (Weiping and Chi, 2010).

The proper functioning of urban areas therefore depends on efficient transport network, which

is the backbone to their very existence (Aderamo, 2003). Road intersections play an important role in the road network, they are the most complex locations in a traffic system and they have a very considerable influence on vehicle safety and movement efficiency. The traffic situation in urban areas is characterized by many small disturbances, in comparison to highways that in general show fewer disturbances (Xin, Yang, Chen and Li, 2011).

Urban road intersections easily become the worst hit of traffic delay. This is because, at intersections, vehicular flows from several different approach (link/edge) making either left-turn, through and right-turn movements seek to occupy the same physical space at the same time (Aderinola, and Owolabi, 2016). In addition to these vehicular flows, pedestrians also seek to use this space to cross the streets and thereby worsening the already bad traffic situation. Most often, the structure of urban land use fails to provide easy and convenient traffic movement (Ajala, 2019 and Leke, 2007).

Road traffic issues such as traffic delay especially at road intersections in urban centers in a developing nation like Nigeria draws significant attention each day (Adewuyi, 2013). Intra-urban movements to work, recreational centers, markets, shops and schools are becoming more and more difficult and are characterized by discomfort, delays, waste of time, energy and resources (Aderinola and Owolabi, 2016). The problem is more pronounced during the peak periods of morning and evening when vehicles stand still in long queues resulting in stress and reduction in the productive hours of commuters (Tolu, 2013). The traffic situations in Minna are gradually becoming alarming as signs of potential bottlenecks are already emerging along major traffic corridors resulting in delays and loss of productive hours. Thus necessitates the study in order to understand the various traffic flows and its characteristics occupying different traffic corridors in the city.

LITERATURE REVIEW

Traffic flow is the movement of individual drivers and vehicles between two points and the interactions they make with one another. The three main characteristics among which relationships can be established mathematically in traffic flow are: flow, density and velocity. These relationships help in planning, design and operation of roadway facilities (Litman 2013). Geographical theories have also been used to explain traffic flow. A basic geographical interest in flow is to provide answers to the question – "why do people and goods move in space?" Ullman (1956) postulated three conditions for spatial interaction (flow), namely; complementarity, intervening opportunity and transferability.

The first condition, according to Hagget (1972) is a function of areal differentiation of places. In order for two places to interact, there must be a supply or surplus in one place and a demand or deficit in another which must be specifically complementary. Complementarity will however generate flows between two places only if no intervening opportunity occurs whereas intervening opportunity may reduce not totally eliminating complementarity. This means the absence of another location in between the two places may provide an alternative source of supply or demand. The third condition in Ullman's principles, transferability, refers to the ease or efficiency of moving a product. It is a function of distance measured in terms of time and monetary costs (Hagget, 1972).

However, all the concepts about flow can be summed up in a matrix-defined origin and destination with origin as rows and destination as columns. Smith (1970), postulated that there

are three characteristics of interest in the matrix, namely; volume, structure and efficiency. Providing efficient transportation system in terms of accessibility is one of the main objectives of policy makers and planners in metropolitan areas throughout the world (Saghapour et al., 2016). Road network constitutes an important element in urban development as roads provide accessibility required by different land uses and the proper functioning of such urban areas depends on efficient transport network, which is a backbone to their very existence (Aderamo, 2003). Road intersections are important components of road network systems, around which traffic elements influence mutually (Zhang, 2004).

Overall traffic flow depends on the performance of the intersections. It also affects the capacity of the road. Therefore, both from the accident perspective and the capacity perspective, the study of intersections is very important for traffic management especially in the case of urban scenario (Matthew and Krishna-Rao, 2006). Its main function is to guide vehicles to their respective directions (Aderamo and Atomode, 2012). Traffic intersections are complex locations on any highway. Drivers have to make split second decision at an intersection by considering his route, intersection geometry, speed and direction of other vehicles etc. Road intersections are important components of urban traffic road system, around which traffic elements influence mutually (Zhou and Yang, 2001). Traffic flow characteristics can reflect the actual problems at intersection (Li, Tang, and Xu, 2010).

Koko (2008) observed that urban land use typologies are major generators of urban goods transport and the land uses are major attractors of urban goods movement in the city. Adewuyi, (2013) asserted that the volume of traffic generated by land use varies during different periods of the day but there is usually a predictable pattern of such traffic volumes. In view of the reviewed literature, accessibility is one of the most important outcomes of the transportation system. Hence, traffic flow characteristics can reflect the actual problems at intersection. So, it is essential to collect and analyze comprehensively, data on traffic flow characteristics in order to rationalize and understand traffic organization at road intersections and to improve traffic capacity of the whole road network, to avoid traffic delays and to reduce traffic accidents

THE STUDY AREA

The study area is Minna which is the capital of Niger State. Minna is in the middle belt of Nigeria, situated in the wet tropical or guinea climate in the guinea savanna zone. It extends on latitude 9°36′22″ N and longitude 6°33′15″ E (topographic map, 1987). Minna lies on a valley bed (i.e., lowland) bordered to the east by Paida hill stretching eastwards toward Maitumbi and northwards to Maikunkele village, to the west and the southward is highland, with an area essentially savanna and quite conducive for farming. It extends on latitude 9°36′22″ N and longitude 6°33′ 15″ E. It therefore falls under the tropical continental wet and dry climate based on the Koppen classification scheme. Hence it has a distinct wet season as well as dry season. Minna is invaded by two distinct air masses, one from the north; dry and continental in origin, the Sahara air mass.

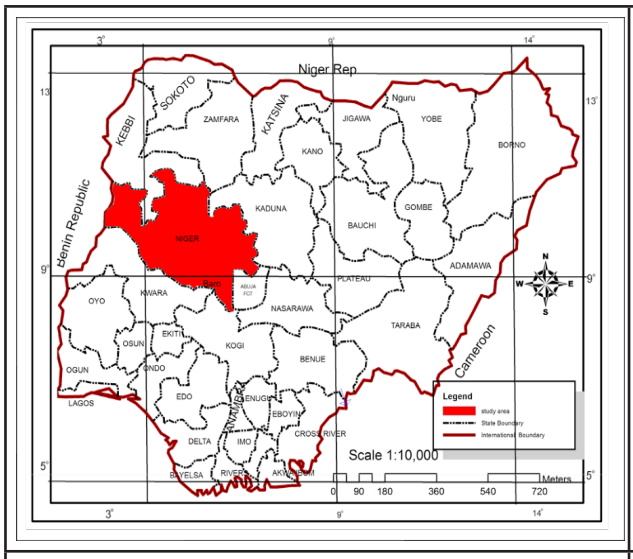

Fig. 1: Map of Nigeria showing Niger State

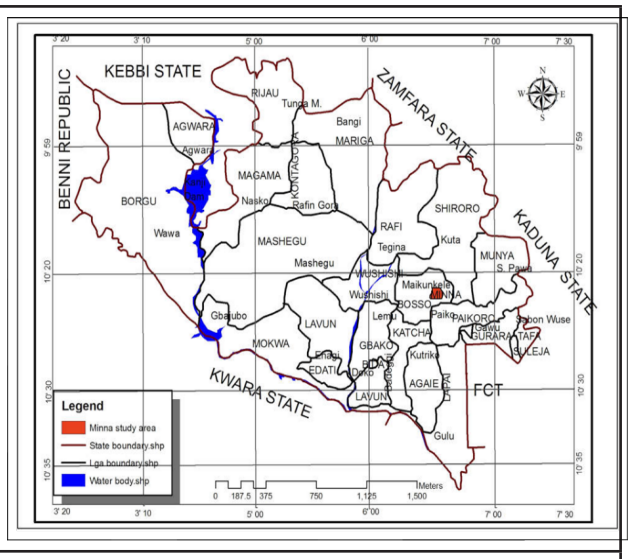

Fig. 2: Map of Niger State showing Minna

Source: Dept. of Logistics and Transport Technology, FUT, Minna. (2021).

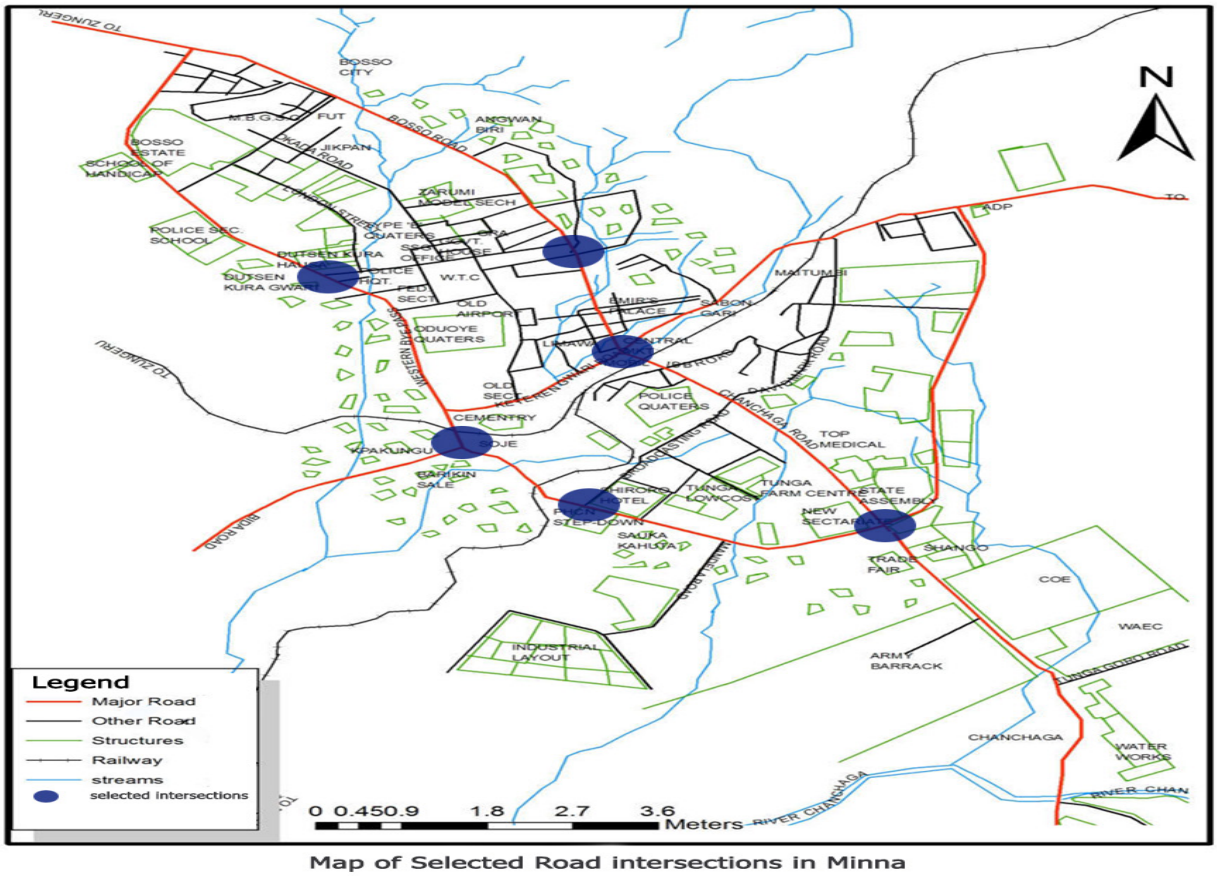

Fig. 3: Minna Township Road Network Map Showing Studied Intersections

Source: Department of Logistics and Transport Technology, FUT, Minna. (2021)

Minna was chosen as the study area being the state capital and a socially heterogeneous city with a surge in varieties of economic activities, and high rate of urban mobility. Moreover,

Minna Road network is one of the most complex in terms of linkages, human and vehicular movements in Niger State.

METHODOLOGY

The population of the research comprises of the average daily traffic volume at intersections in the study area. This includes the entire volume of the traffic vehicles recorded from the selected intersections (i.e., Mobil roundabout, government house junction, Kpakungu roundabout, Shiroro junction, Dutse-Kura junction and City-gate roundabout). In assessing traffic flow pattern and its characteristics at major road intersections within Minna metropolis, data for this study were collected through traffic volume count.

The traffic volume count and flow pattern survey were conducted by manual vehicle counting at a designated intersection stated above using hourly flow count sheet and classified vehicular flow tally table to record vehicle flow at all arms of the different intersections. In order to get the directional flow pattern, the tally tables were used for each arm of the intersection. The survey was carried out between 6.00am and 6.00pm, 12 hours daily for 7days (i.e., Monday - Sunday).

RESULTS AND DISCUSSIONS

Traffic composition in the study area

Table 1: Traffic volume and vehicle composition at the studied intersections

S/N	Intersection	Intersection arm	Traffic volume composition							
			MC	TC	C	MB	B	T	AV	SV
	Mobil Roundabout	Tunga Road	327	1913	1314	315	116	128	1	12
		Bosso Road	310	1893	1339	285	111	127	0	12
		Kpakungu Road	341	1896	1293	327	111	110	0	12
		Total	978	5702	3946	927	338	365	1	36
	City Gate Roundabout	Tunga Road	351	1748	853	146	41	104	2	15
		Chanchaga Road	368	1641	856	156	49	102	3	12
		Eastern Bypass	195	822	639	74	8	87	0	4
		Western Bypass	213	992	673	90	13	97	5	8
		Total	1127	5203	3021	466	111	390	10	39
	Government House Junction	Bosso Road	410	1252	873	175	81	104	1	25
		Mobil Road	378	1270	911	186	87	88	0	46
		Govt. House Road	353	572	457	133	81	47	0	6
		Total	1141	3094	2241	494	249	239	1	77
	Dutse Kura Junction	Bosso Estate Road	432	402	446	95	101	66	2	5
		Govt. House Road	353	574	438	127	75	47	0	5
		Kure Market Road	355	685	526	172	86	67	0	10
		Total	1140	1661	1410	394	262	180	2	20

S/N	Intersection	Intersection arm	Traffic volume composition							
			MC	TC	C	MB	B	T	AV	SV
	Kpakungu Roundabout	Shiroro Road	723	2116	1716	429	152	110	6	16
		Kure Market Road	573	1897	1653	422	173	116	13	11
		Bida Road	651	1963	1632	405	140	100	14	14
		Total	1947	5976	5001	1256	465	326	33	41
	Shiroro Junction	Kpakungu Road	365	1062	862	218	80	59	5	11
		Tunga Road	290	953	830	215	91	61	6	5
		City Gate Road	329	985	818	206	73	52	6	6
		Total	984	3000	2510	639	244	172	17	22
Overall Total			7317	24636	18129	4176	1669	1672	64	235
Average			1220	4106	3022	696	278	279	11	39
Percentage (%)			12.64	42.55	31.31	7.21	2.88	2.89	0.11	0.41

MC = Motorcycle; MB = Mini-bus; AV = Articulated vehicle; TC = Tricycle; B = Bus; SV = Special vehicle; C = Car; T = Truck;
Source: Author's fieldwork (2021).

Table 1, Figure 4 and 6 show the average daily traffic volume composition at the studied intersection. Of all the vehicle types recorded at the studied intersections, tricycles had the highest numbers with an average of 4,106 vehicles (42.55%). The dominance of tricycles shows the acceptance in the use of tricycles for public transportation in the city. This mode is now becoming more popular with the recent ban of motorcycles for public transportation due to bandit activities in Niger State. This has invariably helped a lot in reducing the transportation problems residents face in the city. Cars which are mostly privately owned with an average of 3,022 vehicles (31.31%) ranks second. This shows that cars are highly utilized as a means of movement in the study area to meet mobility needs of the citizens. Motorcycles ranked third with an average of 1,220 vehicles (12.64%).

Motorcycles are strictly prohibited for public transport in the study area due to some nefarious activities being perpetrated by some riders: kidnapping and banditry; hence, motorcycle users only utilize the mode for personal purposes. Mini-buses ranked fourth with an average of 696 vehicles (7.21%). They are majorly used for long distance public transportation and also for school bus services. They also recorded high cases of private use especially the Toyota Sienna brand. Trucks are also important mode in the traffic composition of the study area. They ranked fifth with 279 (2.89%) while buses ranked sixth with 278 (2.88%) leaving special vehicles (39 vehicles) and articulated vehicle (11 vehicles) seventh (0.41%) and eighth (0.11%) respectively. While trucks handle delivery demands of heavy goods, buses are used for long distance public transport (inter-city or inter-state). Special vehicles in the study area include ambulances, fire vehicles and other specialized delivery vehicles.

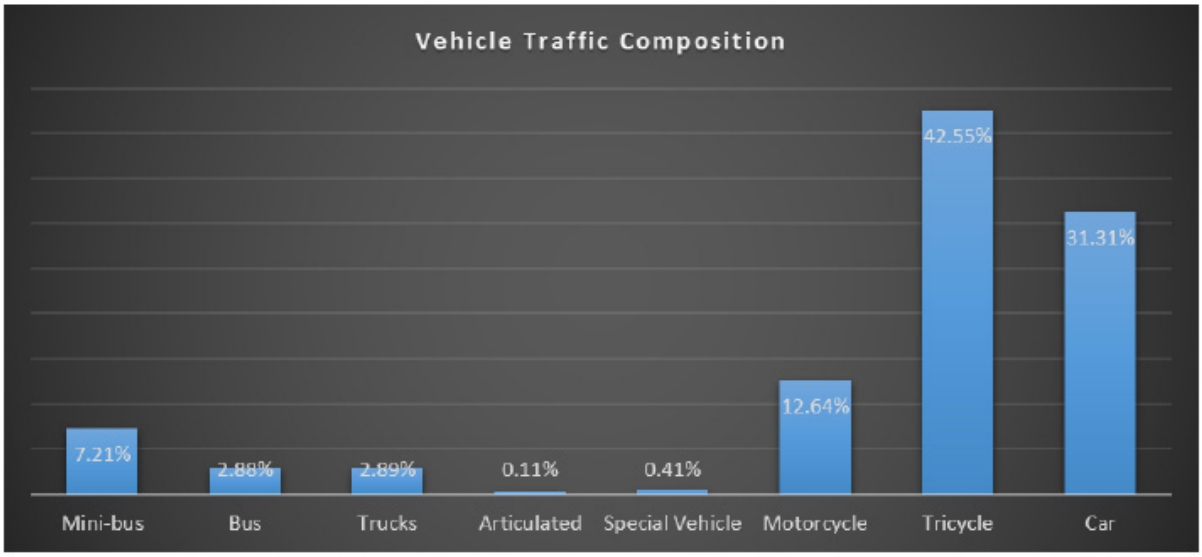

Fig. 4: Percentage of vehicle traffic composition

Source: Authors' computation (2021)

This result satisfies the study objective of examining the traffic composition in the study area. It is also observed that traffic composition in the study area include motorcycles, tricycles, cars, buses, mini-buses, trucks, articulated vehicle and special vehicles.

Pattern of traffic flow at the selected intersections in Minna

The traffic flow pattern at the studied intersections is analyzed using vehicles per hour (vph) as shown in Table 2. From the analysis, Kpakungu roundabout recorded the highest number of vehicle volume of 15,045 vehicles per day, followed by Mobil roundabout with a total of 12,293 vehicles recorded per day. City gate roundabout is next with a volume of 10,367, then followed by Shiroro junction with a record of 7,588 vehicles per day while, Government house junction (7,536) and Dutsen Kura junction (5,069) ranked 5th and 6th respectively.

Although all the intersections show two peak periods and two off-peak periods at varying degrees, they all have distinct but similar traffic flow patterns. From the analysis shown in Figure 5, Kpakungu roundabout recorded its peak flow between the hours of 5-6pm and a minimum flow between 6-7am. Traffic flow increases from 7-8am, reaching its peak at 9-10am. From 10-11am traffic flow decreases at the intersection to a lower point to the period between 12-1pm, then a small increase at 1-2pm, and another decrease between 2-3pm then a steady increase from 3-4pm, 4-5pm till 5-6pm. Table 2 shows that only Shiroro junction experienced an exact traffic flow pattern like that of the Kpakungu roundabout.

Mobil roundabout like all the other intersections starts its flow with a low count in the first period and maintained a steady rise till it hits its first peak between 9-10am. Unlike the other intersections, Mobil roundabout experience a longer peak period from 9-10am till 10-11am, followed by a decreasing flow to an off-peak period between 1-2pm. Then the intersection experience continues to increase from 2-3pm till 4-5pm where it recorded its second peak point, then a small decrease at the last period 5-6pm. Similarly, City gate roundabout also recorded its lowest number of vehicles per hour in the first period, maintaining a steady increase to a peak point at 9-10am period. Traffic flow decreases steadily to a lower point at 1-2pm, with another steady increase afterwards till a final peak point at 5-6pm.

Government house junction had a closely similar flow pattern with Dutsen Kura junction. They also started with a low count at the beginning of the day with a continuous rise till first peak period. Government house junction had a peak point at 10-11am, then a steady decrease till a lower point at the period between 2-3pm, then a continues increase afterwards, while Dutsen-Kura hits its first peak at 9-10am, it had a distorted flow between 10-11am to 1-2pm where it had a lower point. Both the Government house junction and Dutsen-Kura junction had a flow increase from 2-3pm to 3-4pm, then a slight decrease at 4-5pm and a final increase to a highest peak point between 5-6pm. Figure 6 shows an average traffic flow pattern in Minna.

Table 2: Vehicular traffic volume per hour at the studied intersections

Intersection	Intersection arm	Traffic Volume (am to pm)												Total
		6–7	7–8	8–9	9–10	10–11	11–12	12–1	1–2	2–3	3–4	4–5	5–6	
Mobil Round-about	Tunga Rd.	125	213	339	424	442	355	297	279	345	406	462	439	4126
	Bosso Rd.	124	194	316	439	434	363	304	277	349	391	436	450	4077
	Kpakungu Rd.	121	219	321	433	420	347	300	281	339	412	454	443	4090
	Total	370	626	976	1296	1296	1065	901	837	1033	1209	1352	1332	12293
City Gate Round-about	Tunga Rd.	70	161	338	317	298	249	255	256	254	336	344	382	3260
	Chanchaga Rd.	56	162	323	301	278	260	227	212	249	345	364	410	3187
	Eastern bypass	44	103	172	195	187	171	160	136	137	160	181	183	1829
	Western bypass	63	129	211	238	201	187	146	136	157	188	215	220	2091
	Total	233	555	1044	1051	964	867	788	740	797	1029	1104	1195	10367
Govt House Junction	Bosso Rd.	64	150	243	292	303	281	254	248	229	269	283	305	2921
	Mobil Rd.	52	138	211	264	279	291	267	240	277	303	309	335	2966
	Govt House Rd.	58	117	137	161	155	153	140	138	117	149	143	181	1649
	Total	174	405	591	717	737	725	661	626	623	721	735	821	7536
Dutse Kura Junction	Bosso Est. Rd.	54	96	145	151	140	123	113	124	130	146	149	178	1549
	Govt House Rd.	58	117	137	161	125	153	140	130	120	147	143	188	1619
	Kure Mkt. Rd.	60	111	158	173	177	171	143	138	166	201	187	216	1901
	Total	172	324	440	485	442	447	396	392	416	494	479	582	5069
Kpakungu Round-about	Shiroro Rd.	172	348	468	481	457	447	419	456	430	490	526	574	5268
	Kure Mkt Rd.	145	328	446	453	460	425	401	387	391	442	464	516	4858
	Bida Rd.	145	320	440	451	426	419	393	428	400	461	497	539	4919
	Total	462	996	1354	1385	1343	1291	1213	1271	1221	1393	1487	1629	15045
Shiroro Junction	Kpakungu Rd.	90	176	236	243	231	227	210	230	216	248	264	291	2662
	Tunga Rd.	75	167	224	229	232	214	203	195	196	223	233	260	2451
	City Gate Rd.	74	160	222	227	216	210	196	216	201	232	252	269	2475
	Total	239	503	682	699	679	651	609	641	613	703	749	820	7588
Grand Total		1650	3409	5087	5633	5461	5046	4568	4507	4703	5549	5906	6379	57898
Average (VPH)		275	568	848	939	910	841	761	751	784	925	984	1063	9650
Percentage (%)		2.85	5.89	8.79	9.73	9.43	8.72	7.89	7.78	8.12	9.58	10.20	11.02	100.00

Source: Authors' fieldwork (2021)

Analysis revealed therefore that traffic flow in Minna experience an off-peak period in the early hours of the day between 6am – 8am and a peak period between 8am – 11am. Followed by an off-peak period between 11am – 3pm and finally an evening peak period between 3pm – 6pm. It is observed that low vehicular flow is experience in the early hours of the day, this is not surprising as businesses, schools and workplaces generally open from 8am. Therefore, from the time of opening of businesses and workplaces, traffic flow begins to increase as people try to access their daily social and economic functions. Traffic is low in the afternoon as people are settled in the workplaces and schools, no wonder traffic flows increase as evening approaches because people need to return home after closing from work.

The figure 5 and 6 show that traffic volume is lowest at 6-7am maintaining steady increase from 7-8am to a peak point at 9-10am. From 10-11am, traffic volume decreases continuously till the hour of 1-2pm, then the flow takes an upward turn increasing steadily between the periods of 2-3pm, 3-4pm, 4-5pm and 5-6pm where it attains its highest peak. It is seen that traffic flow pattern in Minna takes an S-shape – from lowest point to a high point and back to a lower point and then to a highest point.

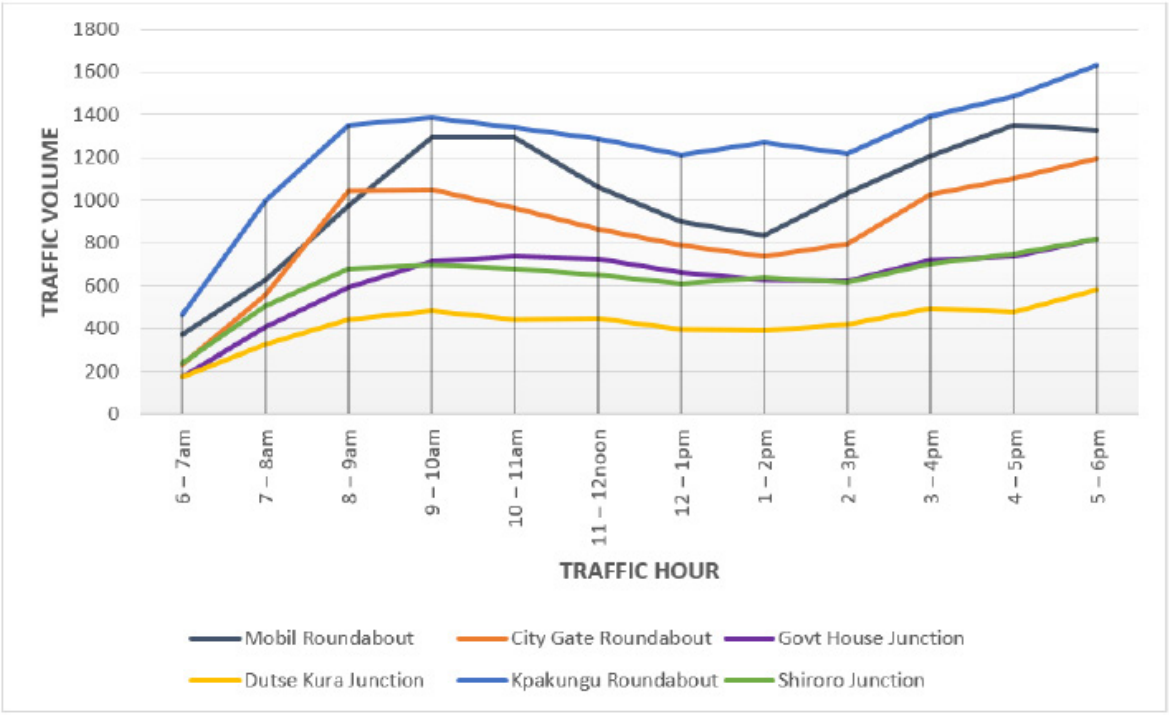

Fig. 5 Traffic flow pattern at studied intersections. *Source: Author's computation, 2021*

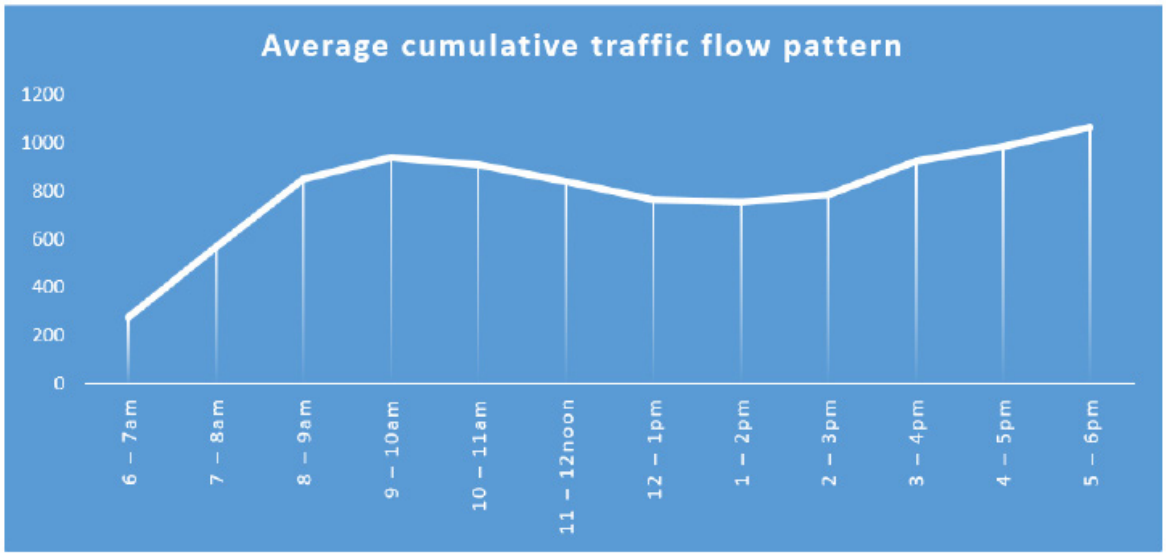

Fig. 6 Average cumulative traffic flow pattern for all the selected intersections in Minna. Source: Authors' computation, 2021

CONCLUSION

This study assesses the traffic flow pattern and its characteristics at selected road intersections in Minna, Niger State. The findings shows that the major traffic composition in Minna are tricycles and cars with about 73.86%. Traffic flow pattern takes an S-shape like flow trend maintaining an upward trend between 7am-10am morning peak period, with a slight downward trend in the afternoon between the hours of 10am – 2pm and finally a steady rise till peak between 2pm – 6pm in the evening. The study concludes that road intersections in Minna experience influx of varying composition of traffic in different degrees of flow pattern daily. This has resulted to unfavorable traffic conditions such as delays and congestions which have resulted into various social and economic challenges especially man hour loss, pollution and increase travel time along daily journeys.

POLICY IMPLICATIONS AND RECOMMENDATIONS

The above findings have some policy implications, one of which is urban travel delays and chaotic traffic flow which are intricately related to supply chain in-effectiveness and loss of socio-economic productivity. Secondly, land use in the study area attracts so much traffic at various time of the day, hence, effective and efficient traffic control strategy of system should be put in place to ensure smooth and hitch free movement along major road corridors in Minna. Based on these implications the following recommendations are hereby proffered:

1. Government should provide adequate road facilities such as functional traffic lights, zebra crossings, and road junctions' improvement to ensure the smooth flow of traffic.
2. Kpakungu round about and Mobil roundabout generate the largest traffic flow, therefore, the two intersections should be upgraded by State Ministry of Works to grade separated intersection in order to reduce traffic delays and conflicts observed during the course of study.
3. Tricycles constitute the major vehicular traffic in the city; therefore, government should focus more on educating tricycle operators on safe road use and respect for the right of other road users.
4. Transport management agencies should intensify efforts at improving traffic safety and efficient flow through education in order to enhance motorists' behavioral modification towards better traffic rules adherence. Therefore, public enlightenment, traffic education and proper enforcement must be ensured.

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