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# Analysis of Vehicular Traffic in the Central Business District of Maiduguri Using Unmanned Aerial Vehicle Technology

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**ABSTRACT**
This research focused on determination of vehicular traffic flow around the Central Business District(CBD) in Maiduguri township with the aid of Unmanned Aerial Vehicle (UAV). A field reconnaissance survey was conducted to designate the peak hour periods. The Unmanned Aerial Vehicle or drone which is remotely controlled to a high elevation captured the scene of traffic from all trajectories using aerial videography . Results of the traffic volume data were considered based on different compositions and converted to the equivalent passenger car unit (PCU). In addition, averages traffic volume in terms of PCU for the designated peak hours were considered for morning, afternoon and evening during the seven-day study period. The data obtained were recorded on a memory card and subsequently post-processed on a high-performance computer. The analysis of the showed that tricycles constituted between 76 to 86%, with the highest volume being 851 and 623 vehicles per hour which occurred along Ahmadu Bello Way East and West bounds during the morning and afternoon peak periods, respectively. Mogaram Road which evacuates traffic from the Monday Market area yielded 821 vehicles per hour during the evening peak. The Peak Hour Factors computed for the study period ranged between 0.52 to 0.92 which indicated concentrated flow patterns along all the trajectories within the CBD. On-street parking by tricycles is a major challenge to traffic flow in the CBD. The roads within the CBDs be dualize, provide parking bay, pedestrian walk way and enforce traffic rules.

**Keywords:** Unmanned Aerial Vehicle (UAV), Passenger car unit (PCU), Peak hour factor(PHF) and Central Business District (CBD).

## I. Introduction

Traffic congestion arises in the central business districts (CBD) as drivers, traders, shoppers, and pedestrians vie for limited space (Agyapong and Ojo, 2018). The CBD is the commercial and economic hub of a city or urban area. In transport management, it is a crucial area to consider because it is the primary destination for commuters and businesses. The CBD is typically characterized by high levels of pedestrian and vehicular traffic, which can create transportation challenges (Das and Keetse, 2015). Due to the high demand for transportation services in the CBD, there is often a need for efficient and sustainable transport systems.

The efficient management and control of ever-increasing traffic volumes and congestion levels, has become one of the most critical challenges faced by municipalities all over the world. This problem further magnifies particularly at urban intersections of CBDs where a high number of emerging conflict points, road safety issues and capacity constraints are featured. Intersections such as roundabouts and those signalized provide efficient alternatives for managing moderate traffic volume flow for at-grade intersections. Smooth and free flow of traffic within the CBD, being hampered by a high number of conflict points, presence of road frontages such as hawking, on-street parking and indiscriminate pedestrian movement. In this regard, the reliability of traffic measurement data becomes an essential prerequisite for road traffic studies. Traffic flow is an important microscopic characteristic in transportation management that predicts headway and gap acceptance (Chiou, 2012; Kong and Guo, 2016). Over the years, surveillance cameras have been used in traffic engineering for traffic flow studies because of the low cost of maintenance and ease of operation (Koutsia et al., 2008). However, traffic flow analysis can be conducted by video camera, Closed Circuit Television (CCTV), Geographic Information system (GIS) and Unmanned Aerial Vehicles(UAV) surveillance or (Drones). According to Mensah et al. (2010), the technique of closed-circuit television imagery requires less personnel to operate and the tapes can be reviewed several times to obtain the most accurate information. Similarly, Taylor et al. (2015) stated that video and recently developed automatic data-extraction techniques have the potential to provide cheap, quick, easy, and accurate methods of investigating traffic systems.

UAV provides high-resolution data that can be used to extract vehicle trajectories and estimate traffic parameters because they are equipped with cameras and communication gadget (AnujPuri, 2005; Coifman et al., 2006; Khan et al., 2018; Gupta et al., 2021) Nevertheless, some of the limitations to this technology are climatic and instrumental factors (Salvo et al., 2014). UAVs were used to collect traffic flow data at an intersection in Nigeria and were found to accurately capture the number of vehicles, speed, and traffic volume at the intersection with image processing techniques (Olugbara et al., 2019 Ogundele et al., 2021). In transportation engineering, UAVs are increasingly used to monitor and analyze traffic, as well as for surveillance, mapping, and remote sensing applications (Butila and Boboc, 2020; Azar et al., 2021). By using UAVs, traffic data collection becomes dynamic, incorporating aerial photography, Videography, remote sensing, and the creation of 3D models of traffic flow without influencing driver behavior (Liu et al., 2014; Xu et al., 2021).

## II. Materials and Methods

Maiduguri CBD areas considered for this study includes; Ahmadu Bello Way, Mogaram Road, Shehu Sanda Kura Road, Shehu Laminu Way and Jos Road with a coordinate of N 11°50"00.0996E 13° 09'13.7952", elevation 323.74 m, with a postcode 600221. This generally comprises the Post Office and Monday Market areas. (Mapcarta.com 2023). The CBD is typically characterized by high levels of pedestrian and vehicular traffic, which can create transportation challenges. Predicting traffic behaviour requires accurate and reliable data that can be obtained from modern digital equipment such as Unmanned Aerial Vehicles. These areas, characterized by high populations and vehicle densities, often lack effective traffic management systems, leading to worsening congestion and delays (Jain and Vazirani, 2010; Thompson, 1968). UAVs utilization in civil engineering, particularly transportation engineering, has experienced notable growth in recent years, with a focus on monitoring and supervising traffic conditions (Giordan et al., 2020). (Fedorov et al., 2019) used data obtained from surveillance cameras to propose a vehicular movement. This study intends to use this novel technique to ascertain the traffic flow parameters, designate congested stretches at the periphery of the intersections of the CBD in Maiduguri.

The material used includes; Unmanned Aerial Vehicle DJI Phantom 4 Pro which has the following features; Flight time of 30 minutes, Transmission distance of 3.5 km, Altitude1000 m above sea level and mounted with 12.0 mp camera, Android Phone connected to the device to display the output data, DC Battery for powering the device, Storage device for data, computer system for processing the data. The DJI Phantom 4 is a sophisticated drone that uses a variety of sensors and software to fly, capture footage, and avoid obstacles. It has a combination of autonomous features and manual controls that make it a popular choice for aerial photography and videography. The UAV is considered along with the Google Earth GPS mobile application (Google Maps, 2019). The operation of the Unmanned Aerial Vehicle DJI Phantom 4 pro was controlled remotely and traveled with an average velocity from its base to an altitude of 120m and covered a radius of 100m for monitoring the study area. The UAV was raised from Centre of intersections as point of data collection by an individual remotely and Captured data from all trajectories, it was lowered down to changed battery because It used a DC-charged battery that lasted for at least 30 minutes, a memory card is inserted to store data captured and moves in the communication range of the sensor to collect data

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### 2.2 **Method of Data Collection**

Unmanned Aerial Vehicles (UAV) were utilized to record the classified automatic counts (videography) traffic flow of the chosen traffic corridors during the peak hours (morning, afternoon, and evening) within the study area. The peak hours were chosen as a result of the limited battery life of UAVs, because the traffic cannot be monitored for the whole day. It was therefore decided that the morning, afternoon, and evening peak 2-hour periods be recorded (7:00 a.m.– 9:00 a.m.; 12 p.m.– 2 p.m.; and 4 p.m.– 6 p.m.). The UAV uses 4 pieces of DJI Phantom-4, each with a maximum battery life of about 30 minutes (or 2 hours for the 4 set). Due to the security issues, before the UAV was in flight, the researcher obtained authorization from security personnel to avoid any sort of problem.

### 2.3 Data Processing

The data processing method for the videos acquired by the UAV has been realized by manual counts, which was conducted to determine the traffic count, directional flow pattern and vehicle classification. Five vehicle types were detected from the UAV video, which include cars, tricycles, buses, trucks and bicycles. Since the traffic is heterogeneous, it's common for it to standardize the vehicle into equivalent homogenous traffic to obtain the volume. Hence, Passenger Car Equivalents (PCE) or Passenger Car Units (PCU) factors are used to convert counts of heavy vehicles into counts of passenger cars such that a mixed flow of heavy and light vehicles is converted to an equivalent traffic stream consisting entirely of passenger cars. (See Table 3.1). Passenger car units were multiplied by the traffic composition to obtain the volume as obtained in Equation 3.2.

$$TV = TC \times PCU \quad \ldots\ldots\ldots\ldots 3.1$$

Where: TV = Traffic Volume; TC = Traffic Composition; PCU =Passenger Car Unit

**Table 3.2:** PCE/PCU Highway Capacity Manual

| Classification | Standard Equivalent |
|---|---|
| Tricycle | 0.4 |
| Car | 01 |
| Pick-up | 01 |
| Bus | 01 |
| Trucks | 03 |

Source: Highway Capacity Manual (2010)

**2.3 Method of Data Analysis**

The classification of the vehicles and conversion to common standard format were done in Microsoft Excel. All the field data from UAV were recorded and organized in Microsoft Excel format taking into consideration of the peak hours. The analysis of the traffic composition and conversion to percentages. This facilitated the data from the UAVs to be well-organized, formatted and calculated in spreadsheets. To better reflect the differences and achieve the study's objectives, traffic compositions were converted to traffic volume using PCU factors. All the results were presented in forms of charts and tables.

**2.4 Peak Hour Factor (PHF)**

This measures the traffic demand variation for the hourly analysis and describes the relationship between the hourly volume and the peak 15-min flow rate within the hour. It is calculated as presented in Equation 1

$$\textbf{PHF} = \frac{\text{V}}{\text{maximum flow rate}} = \text{V}/(4 \times \text{V}_{15}) \qquad (1)$$

where: V = hourly volume in v/h

$V_{15}$ = maximum volume during the peak 15-min of the analysis period (v/15-min).

PHF Value of 0.25 to 0.99 indicates Concentrated Flow and a value of 1.0 indicates uniformflow.

The data obtained from the UAV were computed using Microsoft Excel, the 15 minutes composition and volume of each trajectory were displayed on rows and columns. The highest $V_{15}$ is choosen to calculate the PHF, example from table 1, Ahmadu Bello Way (east bound) the highest fifteen minutes value is 248 and the total traffic volume is 723 thus Peak Hour factor is calculated from equation 1 as PHF = V/(4 x $V_{15}$) = 723/4 x 248 = 0.73

## III. Results and Discussion

The results of traffic composition and volume for the morning peak period are presented in Table 1. While Figure1 present the traffic variation in the study area. Tricycles constituted the highest composition from all the trajectories for all the peak hours. During the morning peak hours Mogaram road alone was found to have contributed 1669 tricycles being the highest number, whereas the least being Shehu Sanda Kura road with 1189 tricycles. Additionally, the PHF for the morning peak ranged between 0.73 to 0.99 which indicated that the flow was concentrated. The Highway Capacity Manual (TRB, 1985) stipulated that if the PHF is between 0.25 and 0.99 the flow is concentrated, while a PHF value greater than unity could be referred to as uniform flow. However, in terms of the traffic volume Mogaram Road was observed to have the highest volume (818 ve/h) followed by Ahmadu Bello Way Eastbound with 723 ve/h while Shehu Sanda Kura Road was the least (615 vh/h) and it's not surprising because of high concentration of Shops (Gidan Madara) along the Mogaram Road. This scenario justified the nature of economic activities having concentration of shops at the periphery of the Monday Market and Post Office which constituted the major CBD in Maiduguri Township

Figure 1 showed the Hourly Variation during the Morning Peak hours (8:00 – 9:00 am). The trend showed that tricycles increased significantly between the first 15 to 30 minutes, and continued until about 60 minutes. The trend for the cars seemed to be constant between the first 15 and 30 minutes, and then gradually increased up to 45 minutes and subsequently 60 minutes. These occurrences coincided with the opening time of the Monday market and the beginning of daily business activities around the CBD. However, the bicycles did not show any significant increase throughout the 60 minutes while during the afternoon the trend shows a significant decrease in Tricycle and slight decrease in cars as shown in figure 2. Generally, for the evening peak hour, the trend showed a slight increase both in the number of tricycles and cars between the first 15 to 60 minutes, while that of bicycles did not show any significant increase throughout the period. These scenarios could be likened to the closing time of the market and other businesses around the CBD (see fig.3).

**Table 1:** Traffic Composition and Volume Morning Peak (8:00–9:00 am)

| Vehicle Type | PCU | Trajectories | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Ahmadu Bello Way (Eastbound) | | Ahmadu Bello Way (Westbound) | | Mogaram Road | | Shehu Sanda Kura Road | | Total Vol. (v/h) |
| | | Composition | Vol (v/h) | Composition | Vol (v/h) | Composition | Vol (v/h) | Composition | Vol (v/h) | |
| Cars/Taxis | 1 | 95 | 95 | 100 | 100 | 129 | 129 | 126 | 126 | 450 |
| Tricycle | 0.4 | 1539 | 616 | 1505 | 602 | 1669 | 668 | 1189 | 476 | 2362 |
| Trucks | 3 | - | - | 1 | 3 | 3 | 9 | - | - | 12 |
| Pick-up | 1 | 3 | 3 | 2 | 2 | 1 | 1 | 3 | 3 | 9 |
| Bus | 1 | - | - | 1 | 1 | 2 | 2 | - | - | 3 |
| Bicycle | 0.1 | 92 | 9 | 80 | 8 | 92 | 9 | 95 | 10 | 36 |
| Total $V_{15}$ | | 1729 | 723<br>248 | 1689 | 717<br>183 | 1896 | 818<br>278 | 1413 | 615<br>156 | 2872 |
| PHF | | $\frac{723}{4\times248}$= 0.73 | | = $\frac{717}{4\times183}$ = 0.98 | | =$\frac{818}{4\times278}$= 0.74 | | = $\frac{615}{4\times156}$ = 0.99 | | |

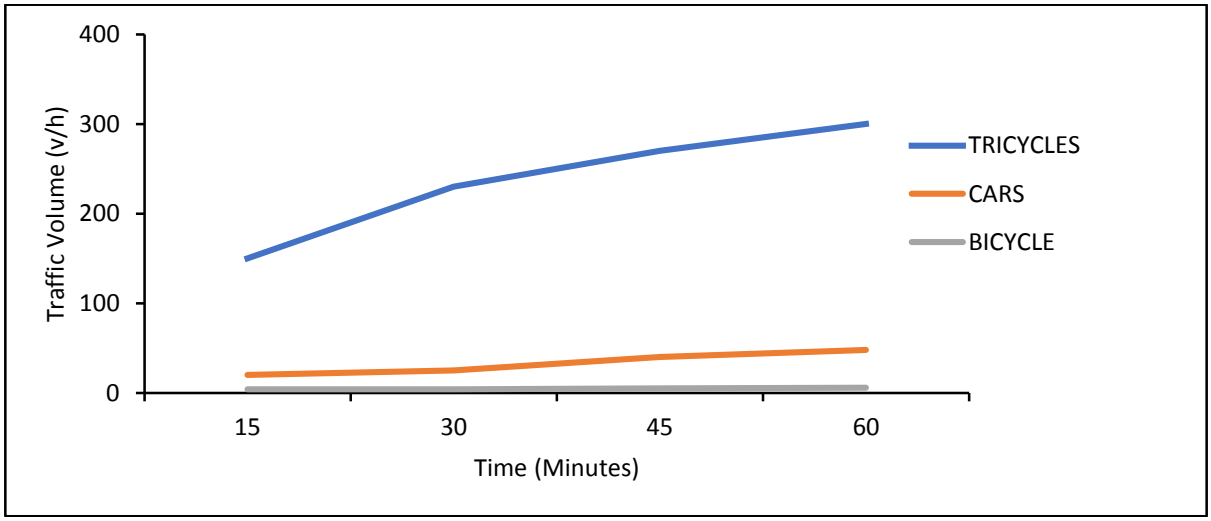


Fig.1: Hourly Traffic Variations, Morning Peak Period (8:00 – 9:00am)

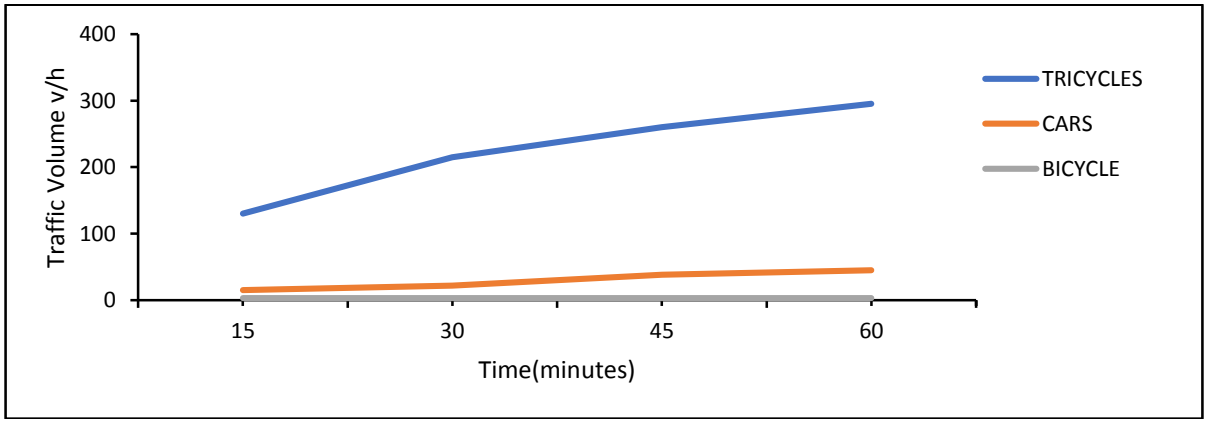


Fig.2: Hourly Traffic Variation, Afternoon Peak Hour (3:00 – 4:00pm)

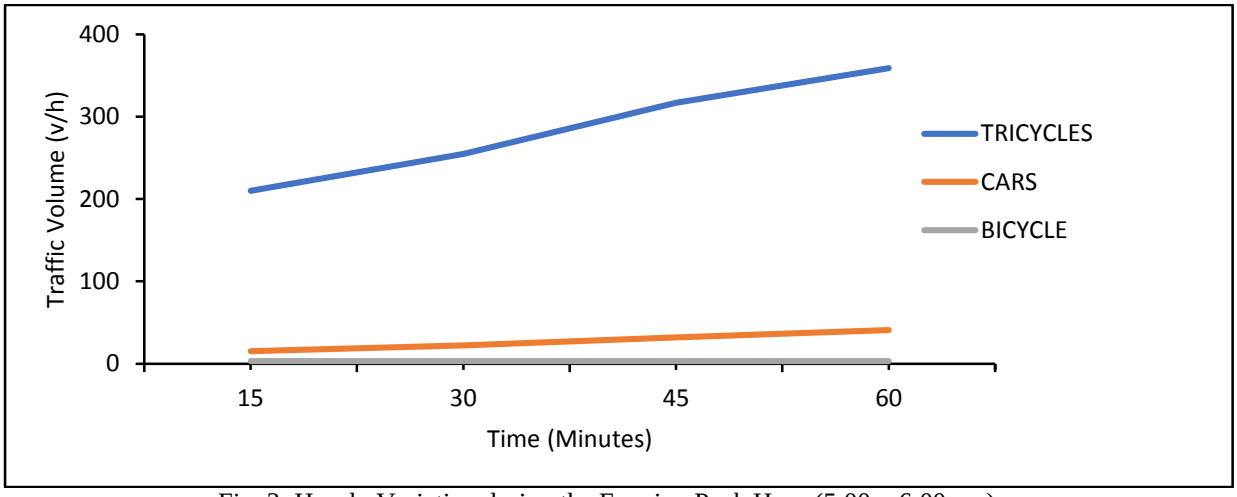


Fig. 3: Hourly Variation during the Evening Peak Hour (5:00 – 6:00 pm)

Table 2 shows that during the afternoon peak hour, tricycles yield high traffic volume with 2426 veh/hr which represents 82%, this is because it's the most flexible and affordable means of public transportation Couple with the Banned on motorcycles in Maiduguri. Ahmadu Bello Way Eastbound contributing 737veh/hr which represented 25%. Mogaram road constituted 694 veh/hr or 24% and Ahmadu bello West Bound and Shehu Sanda Kura Road constitute 642 veh/hr (22%) and 353veh/hr(12%) respectively. The lowest volume with 5 veh/h was for the pick-up vans represented as 1%.This shows that commercial activities are at its peak in the afternoon and traffic is distributed and generated towards the market, which indicates a typical behavior of a CBD. The least traffic category is the buses having minimal effect, except in cases such as directional turning movement. The highest traffic composition was observed along Ahmadu Bello Way with a total of 1842 and the least composition having 883 from Shehu Sanda Kura Road. However, the total volume of vehicles passing through all the trajectories of the intersection was obtained as 2941veh/h. Also, the values of PHF for the afternoon peak as depicted in Table 2 ranged between 0.56 to 0.92, which indicated concentrated flow for the trajectories of the intersection.

Similarly, the evening peak hour (Table 3) was also dominated by the tricycle on all the trajectories. The volume in terms of PCU showed a total volume of 2973 veh/h and 87% constituted tricycles, 417 veh/h (14%) for cars and 30 veh/h (1%) for bicycles, Trucks 21veh/h (0.70%) and the lowest volume was buses with 2 veh/h (0.06). A possible explanation for this results may be due to banned of Motorcycles and Taxes were not patronized. Comparatively, evening peak hours has the highest traffic volume because it is the rush hour as the Market closed and the CBD distributes high number of traffic which lead to Traffic congestion at all the trajectories

Table 2: Traffic Composition and Volume for Afternoon Peak (3:00–4:00 pm)

| Vehicle Type | PCU | Ahmadu Bello way (Eastbound) | | Ahmadu Bello Way (Westbound) | | Mogaram Road | | Shehu Sanda Kura Road | | Total Volume (v/h) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | composition | Vol (v/h) | Composition | Vol (v/h) | Composition | Vol (v/h) | Composition | Vol (v/h) | |
| Car | 1 | 107 | 107 | 112 | 112 | 133 | 133 | 108 | 108 | 460 |
| Tricycle | 0.4 | 1842 | 737 | 1605 | 642 | 1736 | 694 | 883 | 353 | 2426 |
| Trucks | 3 | 1 | 3 | 2 | 6 | 1 | 3 | 1 | 3 | 15 |
| Pick-up | 1 | - | - | 2 | 2 | 1 | 1 | 2 | 2 | 5 |
| Bus | 1 | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 6 |
| Bicycle | 0.1 | 60 | 6 | 90 | 9 | 59 | 6 | 75 | 8 | 29 |
| Total V15 | | 2012 288 | 855 | 1813 229 | 773 | 1932 232 | 839 | 1069 217 | 474 | 2941 |
| PHF (veh/h/lane) | | $\frac{855}{4\times288} = 0.74$ | | $\frac{773}{4\times229} = 0.84$ | | $= \frac{839}{4\times232} = 0.92$ | | $= \frac{474}{4\times217} = 0.56$ | | |

Table 3: Traffic Composition and Volume for Afternoon Peak Hour (5:00–6:00 pm)

| Vehicle Type | PCU | Ahmadu Bello way (east bound) | | Ahmadu Bello Way (west bound) | | Mogaram road | | Shehu sanda kura road | | Total Volume (veh/h) |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Composition | Vol (v/h) | Composition | Vol (v/h) | Composition | Vol (v/h) | Composition | Vol (v/h) | |
| Car | 1 | 107 | 107 | 95 | 95 | 116 | 116 | 99 | 99 | 417 |
| Tricycle | 0.4 | 1886 | 754 | 1779 | 712 | 2053 | 821 | 1714 | 686 | 2973 |
| Trucks | 3 | 2 | 6 | 3 | 9 | 1 | 3 | 1 | 3 | 21 |
| Pick-up | 1 | 4 | 4 | 4 | 4 | 3 | 3 | 4 | 4 | 15 |
| Bus | 1 | - | - | 1 | 1 | 1 | 1 | - | - | 2 |
| Bicycle | 0.1 | 81 | 8 | 64 | 6 | 70 | 7 | 87 | 9 | 30 |
| Total<br>V15 | | 2080<br>295 | 879 | 1946<br>265 | 827 | 2244<br>261 | 951 | 1905<br>260 | 801 | 3458 |
| PHF (veh/h/lane) | | $= \frac{879}{4\times295} = 0.75$ | | $= \frac{827}{4\times265} = 0.78$ | | $= \frac{951}{4\times261} = 0.85$ | | $= \frac{801}{4\times260} = 0.77$ | | |

Fig. 1: UAV image showing the traffic situation of the study area

## IV. Conclusions

The result of traffic data obtained by Unmanned Aerial Vehicle indicated traffic congestion along all the studied trajectories within Maiduguri CBD. The congestion was found to be largely due to intersection of Ahmadu Bello Way, Mogaram Road and Shehu Sanda Kura Road and the associated economic activities. It is clear that light vehicles dominated all the peak periods with tricycles having the highest number. Traffic from the Post office area along Ahmadu Bello Way (Eastbound) constituted the highest volume followed by Mogaram Road (Evening peak) then Ahmadu Bello Way (Westbound) and lower traffic from Shehu Sanda Kura Road. The most noticeable congestion problem in the study area was found during the evening peak due to the concentration of economic activities culminating in to rush period from the CBD, particularly along Mogaram Road and Ahmadu Bello Way. The peak hour factors of 0.52 to 0.92 indicates concentrated flow due to heterogeneous traffic movement and indiscipline on the part of the driver with associated on-street parking and hawking along the road shoulders.

It was found that roads and intersections within the CBD were characterized by daily traffic congestion; which necessitates the following recommendations:

- The major roads around the central business area should be dualized to enhance free flow of traffic.
- The roads should not be encroached with temporary/permanent shops or other structures thus, authorities such as the Ministry of Transport, Urban Development Board, and Borno Traffic Management Agency

(BOTMA) should enforce existing traffic laws, restrict parking, parking charge, revolutionize traffic light management, and create and encourage the use of alternative roads.

- The CBD lacks a parking bay and thus on-street parking inhibits the free flow of traffic should be regulated.

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