

The Urban Traffic Congestion Problem In Benin City And The Search For An ICT-Improved Solution

Wilson Nwankwo, Akinola S. Olayinka, Kingsley E. Ukhurebor

Abstract: Many hours are wasted often due to the intense traffic congestion on roads in highly populated cities with resultant loss of labour productivity. The reason is that while road infrastructure follows an arithmetic progression and often fixed in developed cities, population and road usage patterns follow a geometric progression. In Nigeria, as well other countries with huge road usage, traffic management is a critical challenge to the Government and traffic managers alike. Traffic officers complemented with time-based traffic control infrastructure have remained commonplace. A lot had been done on traffic control systems especially in high traffic density-prone cities. Many studies had proposed the use of sensor arrays. This study is centred around Benin City, the sixth largest city in Nigeria with its unique geography and socio-economic characteristics. In this paper, traffic management challenges are addressed through an improved model and with regard to the existing infrastructure and environmental factors. Two motion sensors are implemented per lane and placed at intervals apart with a range counter and an optical recognition module is interfaced with it. Any vehicle in between the sensors is considered the number of vehicles in the queue whereas once a vehicle gone pass the last sensor point, the counter is reduced accordingly. The design of the prototype is preceded by a 15-day road traffic usage survey in Benin City. The prototyped solution is a 3G/4G network-enabled integrated solution that enables the relay of traffic information from one location to another enabling the dissemination of traffic information to road users and traffic control authorities.

Keywords: Traffic Management, Traffic Network System, Sensor Arrays, Smart Traffic Monitoring, Benin City

1. INTRODUCTION

As rightly noted by [1] and many other researchers[2][3][4] 5], transport is the livewire of not just an economy but the global economy. However road transportation which is the commonest category of transportation is widely bedevilled by traffic congestion especially in large cities in developed and developing countries alike[6]. Traffic congestion is a global problem which does no one any good. It has been identified as a source of great concern especially in the highly urbanized cities where there is high influx of people and vehicles on a regular basis without a corresponding expansion in the road infrastructure to nor any other reliable artificial mechanisms to contain such rapid influxes. The term has been described by several authorities in different ways however, the definition by the Joint Transportation Research Centre (JTRC), an agency of the Organization for Economic Cooperation and Development (OECD) is widely recognized as a reference definition.

According to the JTRC, "Traffic congestion is a scenario in which the demand for road space exceeds supply". It is also defined by the JTRC as the "impedance vehicles exert on each other resulting from speed flow relationship in conditions where the use of transportation system approaches capacity." The causes of traffic congestion have been recognized by many authorities some of which are:

- Encroachment into the roads by traders[7][8][9]
- Increase in the number of vehicles required for a given volume of people or goods[10]
- Movement of heavy duty vehicles [11]

Research and experience has shown that traffic congestion is linked to socio-economic ills such as loss of productivity, accidents, stress and exhaustion, high costs of transportation, rise in prices of goods and services, epidemics, pollution, high cost of vehicle maintenance, wastage, etc.

1.1 Case Study: Benin City in Nigeria

Like many other urban cities in Nigeria such as Lagos, Abuja, Kano and Port Harcourt, Benin City is currently affected by the scourge of traffic congestion. Benin Metropolis in recent times have been experiencing untold recurrence of traffic congestion often lasting for hours leading to serious economic wastage. The major areas affected include: Uselu-Lagos road, Akpakpava road, Mission road, Airport road, Sapele road, Ore-oghene road.

1.2 Concise Geography of Benin City

Benin City is adjudged the largest urban area in mid-western Nigeria. It is the capital headquarters of Edo State comprising three local government areas (LGAs) out of the eighteen (18) local councils. The three local councils being Ikpoba-Okha, Egor, and Oredo. The city is located on Latitude: 6.34° N and Longitude 5.63° E. It is located approximately 40km north of the Benin River. It is classified as the 6th largest city in Nigeria with an estimated population of 1,125,058 and the centre of higher

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education[12]. With an estimated area of 68km² and a span of about 117.4km², the nodal city has an altitude of 80m above sea level. At its centre is a basin surrounded by undulating hills the most popular of which is the Ikpoba hill. The City is renowned for its unique position in Nigeria's rubber industry, and oil production. The city is also known for its high commercial activities. Majority of the natives are the Binis. Figure 1 is an aerial map of the city.

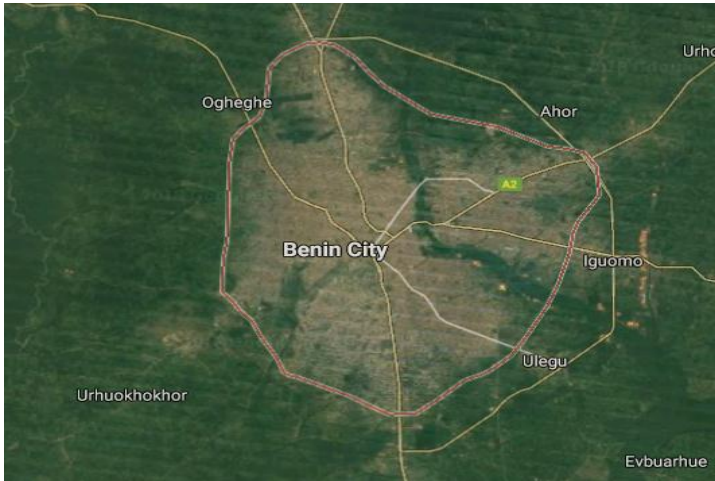


Fig 1: Aerial map of Benin City [source: google maps]

1.3 Statement of the Problem

The story of traffic congestion in Benin City is not new. Various measures have been proposed and tried in the past including the use of traffic policemen to tackle the menace which is fast crippling commercial activities in the State[13]. In its bid to contain the rising traffic congestion in Benin City several approaches have been considered some of which have been implemented. The Leadership of Edo State in 2016 established the Edo State Traffic Control and Management Agency (EDSTMA). "According to Governor Godwin Obaseki, the traffic agency will also eliminate the number of man-hours lost by workers and businesspeople to traffic congestion and the resulting chaos in parts of the state." [14]. As worrisome as the situation is many hours that could be used for productive concerns are often lost on traffic. Sadly, the situation in Benin City is not different from that in other major cities in Nigeria such as Lagos, PortHarcourt, Abuja, and Kano. There are two major common features of traffic and traffic control measures in the aforementioned cities. First, the increased traffic congestion in the morning (8-11 am); afternoon (12-2 pm) and evening (5-8pm). Second, the deployment of human traffic officers (often standing at the junctions) complemented by non-intelligent traffic control infrastructure that operates only on the basis of time allotments to the various lanes at major junctions. Ordinary time allotments have not shown to be anywhere close to an optimal solution to the customary traffic congestion. The specific objectives of this paper are:

1. To examine the traffic pattern in major urban areas of Benin City vis-à-vis the traffic control infrastructure in place
2. To appraise the effectiveness of the existing infrastructure in combating unusual traffic

patterns with a view to identifying the gaps that may need urgent solution

3. To model an intelligent and effective traffic control system that could be easily adapted to ease traffic congestions in highly dense urban areas.
4. To demonstrate the possibility of intelligent traffic control with a remote scheduling option

1.4 Review of Technology-based Solutions and Models to Traffic Management

Advances in electronics and computers have led to the adoption of better ways of doing things. Traffic control has not been left out owing to its peculiar problems the world over. Over the last decade there has been significant propositions some of which have been implemented. Figure 2 is a concise categorization of these traffic control technologies. Since the introduction of automated traffic technologies, there has been a continuous research by researchers and engineers [15]. In 2006, Albagul et al[16] designed and implemented a sensor based traffic light system which was able to sense the presence and absence of vehicles within certain ranges and accordingly switch the traffic lights. The system consists of four important components: the controller unit which is the brain to the system, the sensors which detect the presence of vehicles, the light emitting diodes (LED) and the countdown timers which were implemented in MATLAB software. When the system is switched on, it checked all the sensors on the lanes to determine if anyone was triggered, if any sensor on any lane is triggered. It releases that lane first before releasing any other lane in the same other with which their sensors was triggered (first in, first out). However the allowed time was fixed as a constant for each lane. Danladi et al[17] designed and implemented an automated traffic light controller (ATLC – 2007 DNM) using electronic instrumentation and experimental techniques in electronic engineering and physics, to manage the traffics at the busy four-way junctions along Sahuda road in Mubi North, Adamawa State, Nigeria. Mecocci & Micheli[18] demonstrated the use of laser sensors in identifying vehicles. In the project, a laser camera and television camera were used to capture vehicles in motion. The system generates 3D volume and computes the speed of the vehicles. It was submitted that their system gave reliable measurements in stop-and-go traffic conditions. Srinivasan et al[19] had demonstrated a smart traffic control prototype using arduino. The prototype uses camera and image processing technologies to capture and count the number of vehicles crossing a threshold line in any lane with regard to a set threshold value. In the experiment, the images of the vehicles in a lane are captured by a camera, the number of vehicles counted and compared to other lanes. The vehicle count is used to determine the traffic density in order to alter the timings of the traffic signal.

Traffic control systems and technologies

Generally traffic control systems may be classified according to: type and number of signals indicators; working principle and algorithm. Figure 2 is an abridged categorization of the various traffic control systems and technologies. The diagram provides insight into existing and

future technologies that may be explored for building traffic management systems.

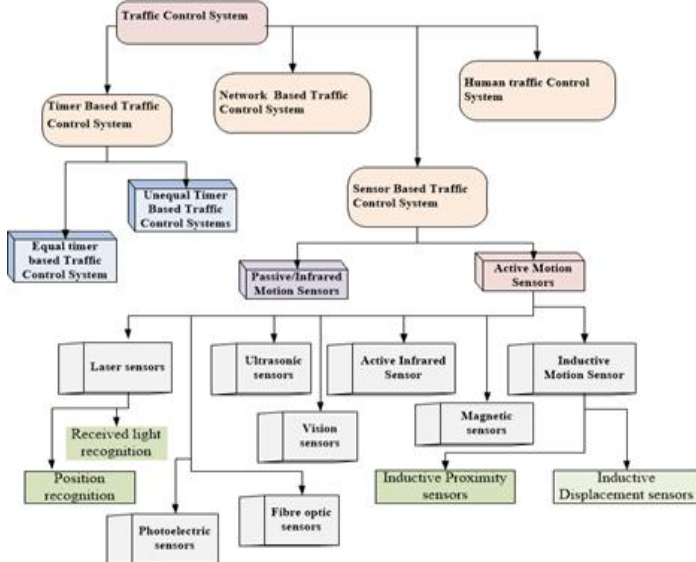


Fig 2: Classification of Traffic control systems and technologies

1.5 Closing the gap

Though current researches in traffic management emphasize more on image recognition and processing, it is very evident that majority of these technologies are cumbersome to implement in a real-life traffic management situation especially in developing countries owing to environmental conditions, poor maintenance culture, choice of technology, political will, and technical manpower for installation and maintenance among others. Having regard to the foregoing, this paper presents a model that could be implemented using resources that may be sourced from the local markets. This paper demonstrates an improvement over the existing traffic management system in Benin city, as it proposed a model that integrates traffic sensors[20] (for monitoring vehicle flow) and wireless networks component that permits the recognition of the volume of vehicles across each road and direct traffic accordingly with information sharing capability. Suitable algorithm is also integrated to dynamically assign “allowed times” to the roads depending on their forecasted traffic rates rather than their average traffic volumes making the system more flexible, dynamic more responsive to the changes in the traffic trends observed on the lanes being controlled. The outcome of the foregoing is that the allowed time will no longer be constant but vary.

2. MATERIALS AND METHOD

2.1 City survey

The first stage in the data collection process was the survey of major roads in Benin City. A survey was conducted on nine major roads at the heart of the city including two trunk ‘A’ roads (Federal Government-maintained roads), seven trunk ‘B’ roads (those roads owned and maintained by the State Government), and one trunk ‘A/B’ road (road with both State and Federal Government influence) within the city over a period of fifteen(15) days on work days (Monday-Friday) between the hours of 8-11 am; 12-2pm,

and 4-7 pm. The days were randomly selected between in the months of June, July, and August respectively. Observation was done through the use of six paid independent field observers who have no knowledge of each other and each mandated to emphasize on a given road.

Sampling

Six major roads were selected for survey through a purposive sampling. The selection was based on authors’ superior knowledge of the connectivity of the selected roads to the central city centre where economic activities are more prominent. The five roads are presented in Table 1.

TABLE 1: SELECTED ROADS FOR SURVEY

| S/No | Road label | Classification |
|------|----------------------------------|-----------------|
| 1 | Uselu-Lagos road | Trunk A |
| 2 | Mission road | Trunk B |
| 3 | Airport road(Ogba road) | Trunk A |
| 4 | Sapele road(Benin-warri road) | Trunk A |
| 5 | Akpakpava road(Benin-Asaba road) | Trunk B/Trunk A |
| 6 | Ore-Oghene road | Trunk B |

Figure 3 is a map showing the selected roads numbered 1-6.

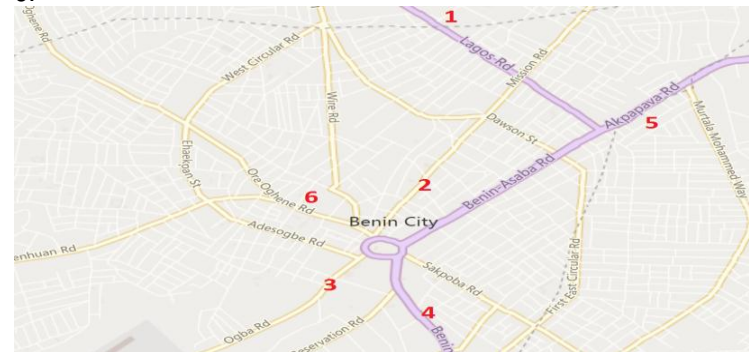


Fig. 3: Roads under investigation [Source: Microsoft maps]

Figure 4-8 show some of the scenes observed during city survey. The traffic scenes were not a subject of probability as majority of motorists affirmed its daily occurrence, however, it was necessary to establish the duration of the traffic in each road so as to create a pattern that could afford the realization of the objectives of this paper.



Fig 4: Traffic situation at Airport Road, Benin City at 9.00am



Fig 5: Traffic density at Airport road, Benin City @ 10am



Fig 6: Traffic situation at Airport road @ 4pm



Fig 7: Traffic midway into Akpakpava road @ 12 noon



Fig 8: Traffic at Akpakpava road @ 9 am

2.2 Hardware and Software

The tools and technologies used are presented in Table 2.

TABLE 2: TOOL AND TECHNOLOGIES

| S/No | Tools | Technologies |
|------|---------------------------------|--|
| 1 | Iron-tip cleaner Iron Holder | Wireless motion sensors A Siemens SFH 205f Wide Field of View Infrared Photodiode Detector |
| 2 | Steel wire brush | Arduino Uno V3 Board with Wireless Module |
| 3 | Soldering Iron | Microsoft Visual Studio 2019 community edition |
| 4 | Solder Flux/Lead | PC with 2.7GHZ Core-i7 processor, 16GB Ram, running Microsoft Windows 10 Pro |
| 5 | Sucker/Scraper | Multimeter |
| 6 | Cutter | |
| 7 | Screw Drivers | |
| 8 | Pliers(long & flat nose) | |
| 9 | Wire Strippers. | |
| 10 | Needle files | |
| 11 | Hammer | |

3. RESULTS AND DISCUSSION

3.1 Field data analysis

The observations of the independent observers are presented in 9-14. For simplicity, the roads are labelled Road 1-6 and reference may be made to Table 1. From the charts, the trend in traffic patterns across all the roads showed marked relationships. There is a strong relationship across all the roads during the hours of 8am-11am and 4-7pm respectively. The traffic during such periods appeared to maintain a recurrent posture in the sense that they are quite predictable to a large extent. The implication is that such hours reflect the daily peak periods. It may be submitted that the persistent recurrence is due to the fact that students, workers, business men and women leave

their homes within the hours of 8-9am. The period 4-7pm also follows a similar trend owing to the fact that workers and the business class often retire from their offices to their homes during that period. The period 12-2pm across all the roads appeared to witness some traffic though not similar to the peak periods. From all indications it is important to note that the volume of road users in those periods under study outweighs the capacity of the roads. It is also submitted that good traffic control and information relay network may also help road users to avert this social menace hence this paper.

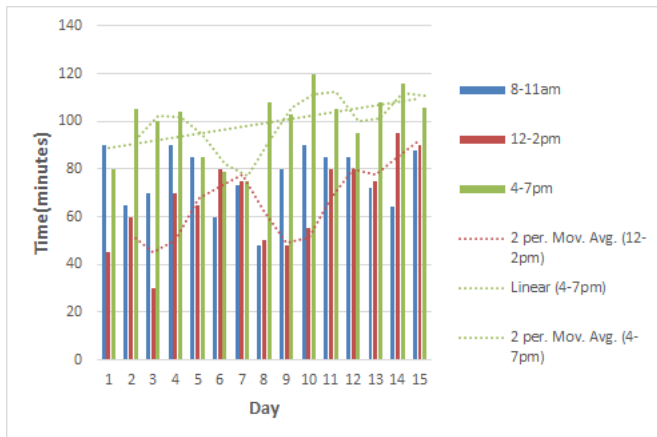


Fig 9: Chart of traffic pattern on Road 1

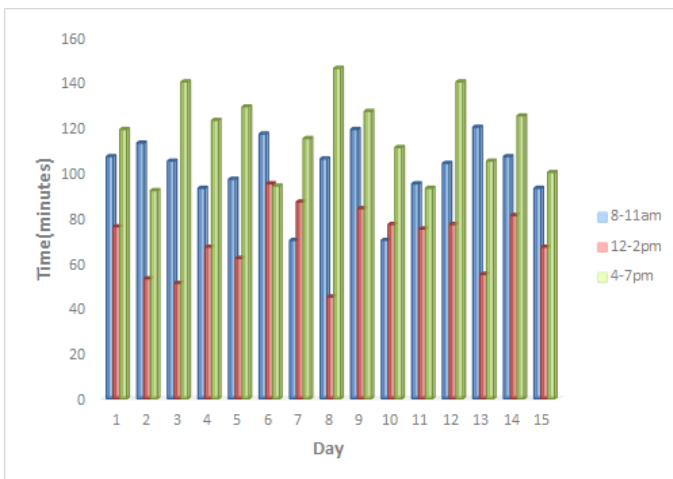


Fig 10: Clustered chart of traffic patterns on Road 2

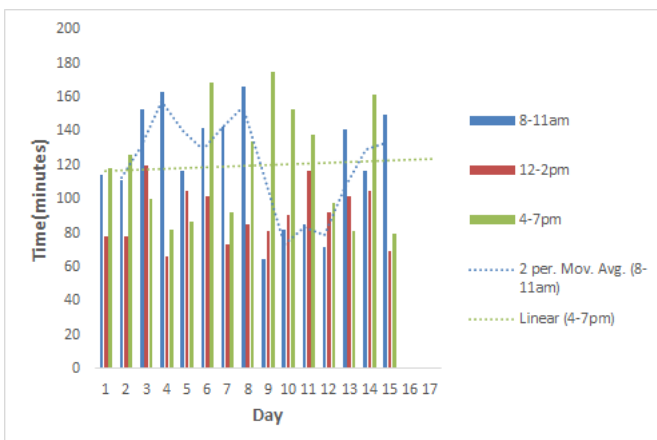


Fig 11: Clustered chart of traffic patterns on Road 3

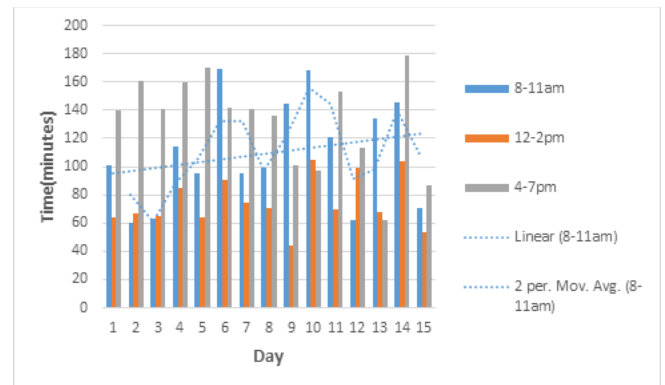


Fig 12: Clustered chart of traffic trends on Road 4

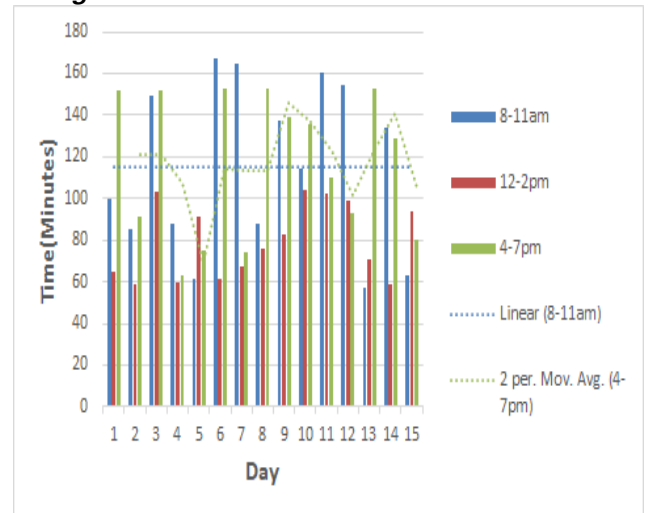


Fig 13: Clustered chart of traffic patterns on Road 5

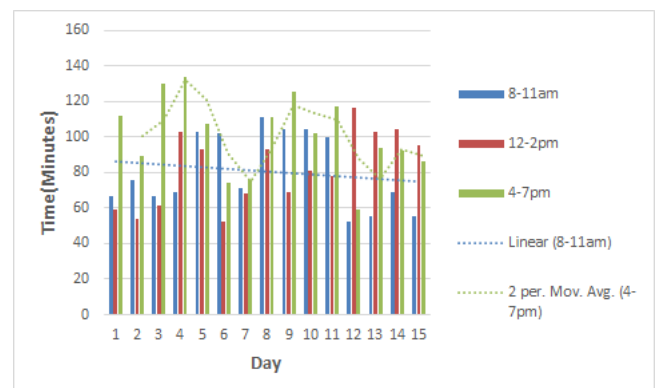


Fig 14: Clustered chart of traffic patterns on Road 6

3.2 Modelling a traffic management and information network

The block diagram of the proposed traffic management system is shown in figure 15. The power supply block is provided by cheap solar cells. The diagram reflects a typical scenario where there is an intersection of dualized roads (as seen in Benin City metropolis) forming a kind of 'cross'. The lanes are labelled A-F. Traffic indicators represent cheap liquid crystal displays (LCDs) placed at strategic points on each road especially at the strategic junctions.

The LCDs unlike the traditional 'GREEN→AMBER→RED' display could be used to display useful information on alternative routes to motorists. The inclusion of a GPS-integrated 3G wireless module is intended to achieve communication of traffic information across to different locations. This information is displayed on the LCDs so as to provide advice on traffic scenarios within the city to road users in real time.

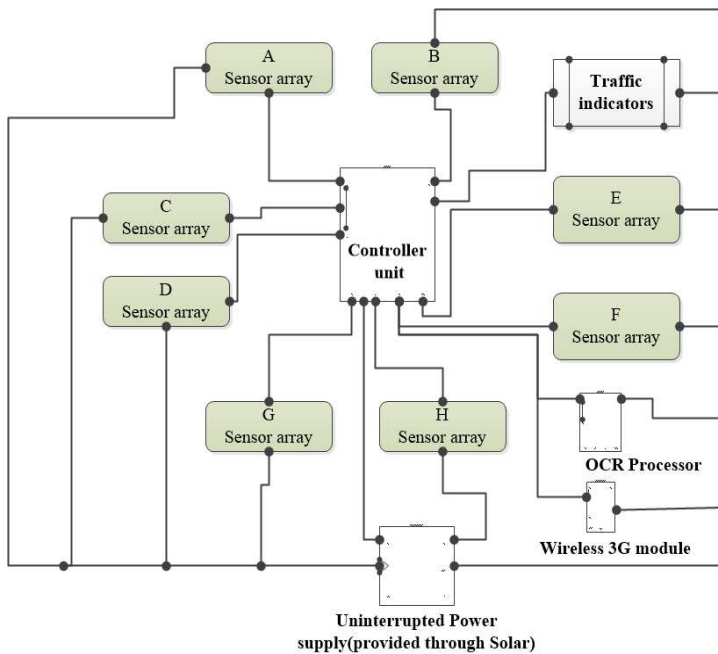


Fig 15: Model of the Traffic Management System

3.3 Power Supply Unit (PSU)

The PSU provides the required voltage for the operation of the traffic system. The circuit of digital components and an array of light emitting diodes (LED). The volt specification of the digital components is +5VDC, while the light emitting diodes are connected to a +15VDC supply. Figure 10 shows the circuit diagram for the power supply. TR1 represents a step-down transformer integrated for the purpose of converting the regular AC (220V) to 15V. BR1 is the full wave bridge rectifier arrangement whose function is to regulate the stepped down voltage to a tolerable peak DC level(V_{peak})

$$V_{peak} = 1.44V_{sec}$$

(1)

where V_{peak} is the peak voltage and V_{sec} is the secondary output voltage.

With the expected secondary voltage as 15V, then

$$V_{peak} = 1.44 * 15 = 21.21 \text{ volts}$$

C1 is the input filter capacitor, whose value can be derived from the expression below.

$$V_{ripple} = \frac{I}{fC}$$

(2)

Where V_{ripple} is the ripple voltage, I is the maximum current drawn by the circuit, f is the frequency and C is the value of the input capacitance a stiff design rule is to ensure that the ripple voltage is at least a third of the peak input voltage. This implies that

$$V_{ripple} = \frac{V_{peak}}{3}$$

(3)

$$V_{ripple} = \frac{21.21}{3} = 7.07V$$

The maximum current (I) that the circuit can draw is limited to the maximum current the regulators can supply, which is 1.5A The frequency of a full wave rectified voltage is normally twice the input frequency of 50Hz i.e.

$$2 \times 50\text{Hz} = 100\text{Hz}$$

Substituting for f, V_{ripple} and I in the above equation yields

$$C = \frac{I}{f \times V_{ripple}}$$

(4)

$$C = \frac{1.5}{100 \times 7.07} = 2121.64\mu F$$

Nearest preferred value for the input capacitance = 2200 μF

C2 and C3 are the output capacitances that improve the transient response of the DC output voltage. It is typical to have an output rise time of about 50 μsec for a micro-controller circuit. The rise time is dependent on the output capacitance and the output equivalent resistance of the voltage regulator. The equivalent output resistance for a +5V fixed regulator that can supply a fixed 1.5A is computed as:

$$R_{out} = \frac{5}{1.5} = 3.3\Omega$$

$$\text{Output rise time} = R_{out} \times C2$$

$$\text{Therefore } C2 = \frac{50\mu\text{sec}}{3.3\Omega} = 15.15\mu F$$

Nearest preferred value = 10 μF

Therefore $C2 = C3 = 10\mu F$

The fixed voltage of +15V is derived from a 15V fixed voltage regulator implemented through a LM7815 device.

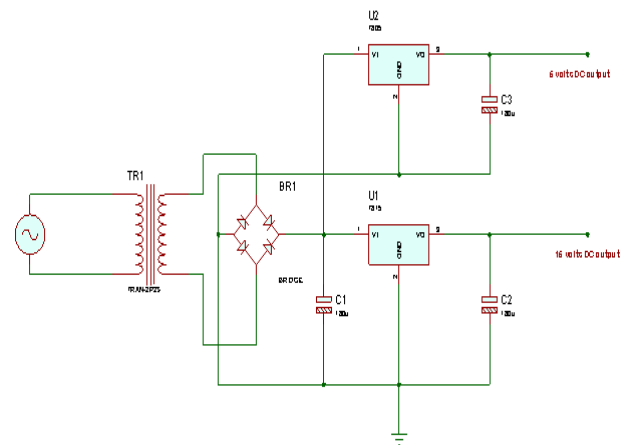


Fig 9: Power supply circuit diagram

3.4 The Controller logic

Table 3 shows the possibility logic deduced from figure 9 above. Table 4 presents the possible combinations. "NA" depicts a continuous traffic flow not affected by traffic controls, and can work at the same time with each of the other four(4) dependent traffic flow channels(BROWN, GREEN, BLUE and AMBER). Each of

BROWN, GREEN, AMBER, BLUE, permits traffic from the affected lanes. Figure 16-17 show the implementation of the logic.

TABLE 3: POSSIBILITY LOGIC

| | H | A | E | D |
|---|---|---|---|---|
| C | 1 | 1 | 1 | 1 |
| B | 1 | 1 | 1 | 1 |
| F | 1 | 1 | 1 | 1 |
| G | 1 | 1 | 1 | 1 |

TABLE 4: TRAFFIC FLOW LOGIC(WORST-CASE)

| | H | A | E | D |
|---|-------|-------|-------|-------|
| C | GREEN | NA | AMBER | GREEN |
| B | BROWN | GREEN | NA | BLUE |
| F | NA | GREEN | GREEN | AMBER |
| G | GREEN | BROWN | BLUE | NA |

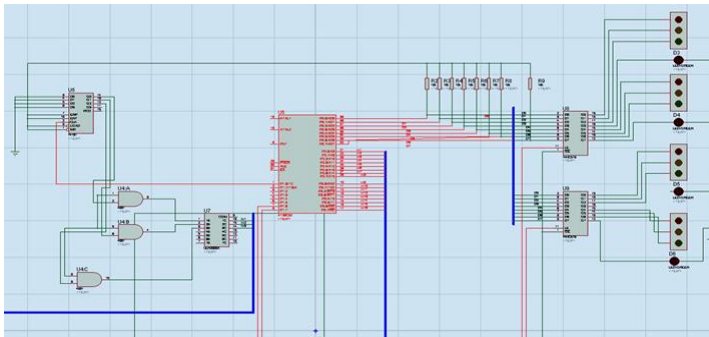


Fig 16: Circuit Diagram of the System

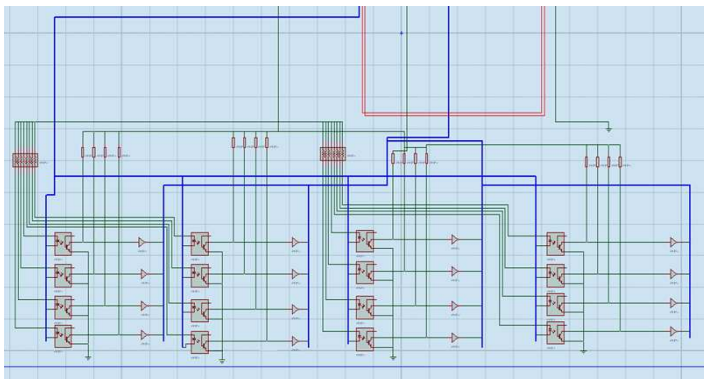


Fig.17: Circuit Diagram of the Sensor-based Traffic Control.

3.4.1 The Micro-controller

The choice of Microcontroller is AT89C52, a low-power; cost-effective, flexible, and high performance CMOS 8-bit microcomputer with 8K of erasable programmable read-only memory (EPROM). It is compatible with the 80C51 and 80C52 instruction set and pin-outs. The on-chip flash allows the program memory to be reprogrammed in-system or by a conventional non-volatile memory programmer. By combining a versatile 8-bit CPU with flash on a monolithic chip, the ATMEAL AT89C52 is a powerful microcomputer is one of the top choices for implementing cheap embedded systems. The main features of this micro-controller are as follows;

- Compatible with MCS-51TM Products

- 8K Bytes of In-system reprogrammable Flash Memory
- Endurance: 1,000 write/erase cycles
- Fully static operation: 0 Hz to 24 MHz
- Three-level Program Memory Lock
- 256 x 8-bit internal RAM
- 32 Programmable I/O lines
- Three 16-bit Timer/Counters
- Eight Interrupt Sources
- Programmable Serial Channel
- Low-power Idle and Power-down Modes

3.4.2 System Prototyping

- Vero-boards were used to provide a neat assembly and they incorporate copper line patterns and can be manipulated in some way such as drilling holes on them to enable the placement of circuit components various locations where component and interconnecting jumper wires would be soldered. Prior to the assembly, all components were tested to ensure functional components are soldered on the board. The sensors were pretested using multimeter; state change from logic state 1 (≈ 5 volts) to logic state 0 (≤ 4.4 volts)

The assembly involved:

- Placement of integrated circuits into appropriate socket/base
- Soldering of infrared LEDs.
- Verification of continuity of the circuitry at each point to ensure short-circuitry or open circuit was prevented
- Mounting a sensing unit with the microcontroller on a breadboard and subsequent testing using the test program. Inputs to the pins of sensors through the program initiates a change of state once the inputs exits the infrared sensors.

The prototyping process involves interfacing all hardware components in the breadboard in accordance with the circuit diagram. The prototype was tested using small opaque solid object (particularly small rectangular wooden blocks to represent the vehicles. In the testing process, the system was powered by connecting the indicator unit to live AC source (220V), the relays were connected to the converted 12VAC. The control and sensor units were connected to the regulated 5VDC.

4. CONCLUSION

This study is conceived in search of a viable cost-effective solution for traffic management in Benin city, the capital and economic hub of Edo State, South-South of Nigeria. Armed with the results from the city survey, we proposed an integrated traffic management system which is wholly dependent on technology. Consequent upon the foregoing, we presented a model of an integrated traffic management system. Unlike the existing unintelligent traffic management infrastructure that is based on simple time slicing without regard to the volume of traffic on any lane, the proposed solution considers the queue on each lane from a reference point. Included in the design is the integration of information sharing capability to ensure that the traffic status at strategic points in the city are relayed to roads users at other locations. A worst-case scenario is

adopted at strategic junctions where the roads form a '+' or an 'x' pattern in which case intelligent traffic control becomes imperative not only to prevent logjam but to avert any accident that may ensue. Having demonstrated the foregoing, we conclude that it is feasible to create a city traffic network whereby all the traffic systems in a city are controlled by a central server that utilizes the city's road network to ensure that traffic is evenly distributed and effectively managed and communicated to motorists in real-time.

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