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Sensor-Based Intelligent Traffic Light Control System: A Panacea to Traffic Congestion in Nigerian Motorways

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Abstract
Traffic congestion is one of the major problems in our nation motorways. As a result, many man-hours are being lost on daily bases. Traffic congestion occurs when a volume of traffic or modal split generates demand for space greater than the available road capacity. There are a number of specific circumstances which cause or aggravate congestion; most of them reduce the capacity of a road at a given point or over a certain length, or increase the number of vehicles required for a given volume of people or goods. It is the impedance vehicles impose on each other, due to the speed-flow relationship, in conditions where the use of a transport system approaches capacity. It has been causing many critical problems and challenges in the major and most populated cities. Due to these congestion problems, people lose time, miss opportunities, and get frustrated. There is also loss in productivity from workers, trade opportunities are lost, and delivery gets delayed. Health hazards are on the increase due to emission of carbon dioxide from the exhausts of idling vehicles on the roads. Accident risks are also escalating as traffic density increases. Traffic congestion is essentially a relative phenomenon that is linked to the difference between the roadway system performance that users expect and how the system actually performs. The congestion control system available has not yielded the needed result as they are pre-timed in which case, each lane will be allocated a pre-signed time even when there is no vehicle on queue. Hence, the need for a knowledge-based system which can use pressure sensors/switches that can know and keep track of vehicular movement on each lane so as to be able to influence appropriately the timing allocated to each of the traffic lights pointing at the roads. This removes the normal allocation of same timing to the lane that has less or no vehicle at all and allocates it to that with higher vehicular density. This paper is aimed at showing how a Sensor-based Intelligent Traffic Light Control System can be employed to significantly enhance traffic congestion management and to effectively manage traffic jam and incidents, reduce pollution and improved public transport services and by implication reduce accidents on our road junctions and the health hazards associated with it.
Keywords: Sensor, Congestion, Traffic Signal, Stop Light, Traffic Lamp, Semaphore

1.0 Introduction

The invention of the motor vehicle which added to already road users like pedestrians and animal called for improvement of the state of the roads in order to withstand the increased pressure, speeds and conflict these users will exert on the road. This then called for a proper control or channelization of traffic to increase efficiency of the roads in traffic performance. It is quite clear that the earliest controllers of traffic were traffic wardens, privately employed or employed by the government or town authorities. Definitely there were conflicts at intersections that needed to be resolved as man is limited in his stamina, and could be biased and unfair in the way they conduct the flow of traffic. They could get tired and feel hungry or they could be ill and at this time could leave the roundabout to the detriment of the road users. The traffic wardens' lives are also endangered, as non-looking road users' vehicles or reckless or wicked drivers could knock them down. Traffic signals are now used throughout the world, at intersections to reduce conflicts to a minimum by time-sharing of right of way. This not only reduces the capacity of the intersection, but also greatly enhances safety. Research shows that there are about 64 potential conflict points at a four – leg intersections with two way traffic flows at which all crossing and merging movements are permitted. The essence of traffic control is to reduce this number of potential conflicts from 64 to zero, [1]. When two or more traffic flows are competing for the same road space at a junction, some form of control or set of rules is needed to minimise delays and the risk of accidents. Due to the fluctuating nature of electricity supply and at times total black outs experienced in some developing cities, operation of traffic signals has become an onerous task. This paper is aimed at bringing to the public knowledge, the need for a Sensor-Based Intelligent Traffic Light Control System to enhance free flow of traffic on our major road junctions (roundabout). The delays and irregular control of traffic caused by manual time allocation control usually leads to traffic jams and road blocks, which has overall effect on our economy. A pre-empted control sequence using sensors such as an infrared or laser sensor is necessary to avoid such traffic congestion situations.

2.0. Review of Related Literature

i. Causes of Traffic Congestion

Study has shown that poor driving habit is the most significant cause of traffic congestion in Nigerian urban cities. Other major causes of traffic congestion include: poor road network, inadequate road capacity, poor traffic control/management, lack of parking facilities, poor parking habits, poor drainage, presence of heavy vehicles,

poorly designed junctions/roundabouts, etc.. These tend to agree with earlier findings from a number of studies, (17, and 15).

According to (20), the poor planning of transportation system in Nigeria has led to over dependence in motor vehicles resulting in too many vehicles with its accompanied problems including traffic congestion. This problem of poor planning/design and management has been supported by many papers presented during the NSE conference, (19 and 18).

ii. The Dangers of Traffic Congestion

The resultant effect of traffic congestion are numerous and can be classified into three major problems; Accidents, Environmental pollution, and Economic loss.

- **Accident**: - As the density of traffic increases, vehicles spend increasing amount of time in close proximity to one another, which increases the risk of accident. When large numbers of vehicles get caught up in traffic jams, accident may occur due to conflict from the impatient drivers competing for right of way. Road accidents can lead to loss of lives and resources alike.
- **Environmental Pollution**: - Any time that traffic congestion occurs, many competing and idling vehicles form a long queue, and vast levels of harmful emissions are being released into the atmosphere, consequently polluting the environments, which causes health hazards. At present, there are more than 30 million vehicles in UK, and all these cars emit about 30 tonnes of carbon dioxide (CO_2) into the atmosphere yearly; that is 1 tonne of CO_2 per car per year. If this situation is true of UK, then the amount of CO_2 per vehicle per year could be same or even more considering the conditions of cars being used Nigeria which mainly are already used and shipped "TOKUMBO" cars, [2]. It has been predicted that with rate of gas emissions from traffic related problem, it is expected to be the largest single contributor of EU greenhouse gas emissions. Hence overtaking both power generation and industrial combustion in the UK, possibly the most congested country in Europe. This prediction is of course a relative one to Nigerian situation. Nigeria is as well the most populous nation in Africa, and it follows that before long, harmful gas emission from traffic related matters will have been more compared to that of power generation and industrial activities combined together, (5).
- **Economic Loss:** - Due to traffic congestion, economic and commercial activities as well suffer either through extra cost of fuel usage and maintenance cost or from cost incurred due to loss of man-hour, delayed delivery or reception of goods. As a result of the above problems, there is urgent need to pay attention to traffic congestion problems on our motorways particularly at cross roads or junction.

iii. Traffic Congestion in London

The effect of traffic congestion, traffic jam and environmental when analysed, can be seen to have tremendous impact upon our existence. A research done on one of the roundabouts in London shows that of 500 accidents at conventional roundabouts; one-vehicle accidents, 22 % were caused by vehicles entering the roundabout, 20% by those on roundabout and 7% by those leaving. For two-vehicle accidents, 8% were caused by both vehicles entering, 17% by one entering and one on it, 3% by one entering and one leaving, 17% by both on the roundabout, 11% by one on the roundabout and one leaving and 2% by both leaving. The priority rule 'Give way to the vehicle from the right' was found to have reduced accidents by about 40%, (25). In a 4-way intersection/roundabout; these have been found to be more dangerous than the 3-way junctions. A careful study shows that 'YIELD' signs can be an effective way of reducing accidents at low volume on the intersections, (8).

According to British industrial researching organization, about 5.5 billion pounds are lost yearly to traffic related problems in UK (i.e. traffic jams, congestions, and accidents etc). If this figures referred above are true for UK, it could be much more in Nigeria where virtually nothing has been done to tackle traffic related problems. Emission of toxic gases from vehicle exhausts are on the increase, the environment are been polluted on daily basis, (4). In fact, in UK, it is estimated that about one tonne of carbon dioxide, one of the major contributor to global warming and depletion of ozone layers is been emitted per vehicle per year.

iv. Traffic Congestion in Nigeria

Traffic congestion in commercial cities in Nigeria has been of great concern for every well-meaning Nigerian who craves for infrastructural development and maintenance. Many urban cities in Nigeria are bedevilled with traffic congestion which tends to defy various remedial measures adopted by different governments over the years. Journey times from one point to another within a town have remained unreliable and residents have continued to face disturbing inconveniences in transportation. These are accompanied by noise and air pollution and the high costs associated with burning of fuels from stationary vehicles. The contributions of road transportation to environmental degradation in urban cities of Nigeria have been highlighted by (23). The problem is no longer limited to traditional cities such as Lagos, Ibadan, Benin-City, Port Harcourt, Abuja, Kano, and Kaduna, (22). Virtually every state capital city in Nigeria today faces the problem of traffic congestion, (21). For example, Calabar city which was not previously associated with traffic congestion is now facing considerable traffic congestion on many of its urban roads, particularly when the schools are in session. Although many researchers have conducted studies on traffic congestion and delays in Nigeria, most of these studies concentrate on specific cities such as Lagos (17 and 15).

Research carried out Lagos state, one of the most populated states in Nigeria, which is well known for traffic congestion due to the population explosion and urban migration shows that there increase in traffic density especially during the early hours of (6:00am – 9:00am) and late hours of (3:00pm – 7:00pm) peak hours, (12). In some cases, road traffic congestion is being experienced throughout the day from 8:00am – 9:00pm which can even extend into the dead of the night on occasions. It is also not uncommon for commuters to spend more than two hours enroute to work, school, market, hospital etc. or back home even when to and fro distance is not much, (10). According to (12), the situation has become so common that it even appears that traffic hold-ups are becoming acceptable excuses for late attendance to work or even formal and informal meetings. This malady is the same in most Nigerian cities and has been causing people a lot of concern, (14). It is posing formidable challenges to both state governments, Local government Councils, researchers and particularly the city residents.

3.0 Advancement in Traffic Control Measures

Many methods have been employed with the hope of solving this menace of traffic congestion, including variable speed limits, widening and channelization of roads at road intersections, construction of roundabouts and of course manual method of control traffic wardens). All these methods have done little in improving traffic situation on our roadways. The use of traffic wardens to replace existing but non-functional traffic signals is a welcome idea.

In America and other developed countries like Denmark, England, Australia and Norway, analysis has shown that variable speed limits have been deployed and it had proved to be effective, though analysis of traffic flow, speed and accidents had not so far demonstrated over all benefits relative to cost. And where there is, it is possible to relate these specifically to variable speed limits as other factors have also changed at the cost of the operation, (26).

Where as in UK, variable speed limits approach are already in use, even the need for computerized vehicles are being considered, in Nigeria there are few automated traffic control lights visible only in major cities Abuja, Lagos, Port Harcourt Calabar, etc . Unfortunately, traffic congestion has not been eliminated or at least reduced significantly.

4.0 Traffic Control Using Traffic Light

The traffic light, also known as traffic signal, stop light, traffic lamp, stop-and-go lights, or semaphore, is a signalling device positioned at a road intersection, pedestrian crossing, or other location, (1).

Traffic lights for vehicles usually contain three lamps: red, yellow (officially amber), and green. In some systems, a flashing yellow means that a motorist may go ahead with care if the road is clear, giving way to pedestrians and to other road vehicles that may have priority. A flashing red is treated as a regular stop sign, (1).

The use of these colours is thought to originate from nautical right-of-way. Usually, the red light contains some orange in its hue, and the green light contains some blue, to provide some support for people with red-green colour blindness. In UK, traffic lights typically have a white reflective border which enables colour blind users, during the hours of darkness, to distinguish the lights from other similarly-coloured street or automobile lights, and to allow them to distinguish the lights by vertical position (top/middle/bottom), (1).

In most countries like UK, New Zealand and Canada the sequence is green (go), amber (prepare to stop or go), and red (stop). In some systems, however, just before red changes to green, both red and amber are lit. It is customary for drivers to select neutral and/or use the handbrake at red lights; the additional phase is intended to give the driver time to select first gear or release the handbrake before the light turns green, but in practice it is treated as an invitation to go before the green light is showing. See figure 1 below.

Figure 1: Samples of traffic lights, (1).

In Russia, Austria, Israel, and parts of Mexico, the green light flashes for a few seconds before the amber light comes on. It is used in Serbia and the United States to mark places where greater attention is needed (dangerous crossings, sharp curves etc.). In British Columbia, Canada, a flashing amber light means "drive with

caution" and is frequently combined with a flashing red light (meaning "stop") at four-way intersections. Nigerian case is similar for where traffic light is used to control traffic. The research question is always, how effective are these traffic lights or even wardens in controlling traffic?, (7).

5.0 Discussion

Based on foregoing, computer controlled traffic system which will not suffer human setback and failure is being considered as a solution to traffic congestion problem; the use of which will significantly reduce these problems at least to the barest minimum. They assign the right of way to road users by the use of lights in standard colours (**Red, Amber and Green**), using a universal colour code (and a precise sequence, for those who are colour blind). When illuminated, the red light indicates stop; the amber indicates caution, either because it is about to turn green or is about to turn red (depending on the current colour status displayed) and the green light to proceed. There is something exotic about the traffic lights that "know" you are there -- the instant you pull up, they change! How do they detect your presence?

In October 1920, William Polts of the Detroit Police Department developed and installed a four-way directional signal with distinct Red, Yellow and Green light colour configuration at the intersection of Woodward Avenue and Saint Anthony. Charles Adler Jnr. in the year 1928, developed the first automated traffic controlled system and barely a year after; he went further to build the first pedestrian push button actuated traffic device, though electronic traffic control computers were first introduced in 1959.

In most cities in Nigeria, the ones installed in some major road intersections have their timing pre-programmed in the sense that they could be allocated say 5 minutes to each way not minding whether there is long or no queue at all on such way. This makes it imperative for Nigerians to agitate for automated traffic light control system that could be knowledge based, which will be able to acknowledge the side of the road that has more vehicles queuing up waiting for the traffic and subsequently allocate more time to such way/side as appropriate. This more sophisticated (intelligent) control systems use electronic detector loops, with sensors buried in the pavement to detect the presence of traffic at the light, and thus can avoid giving the green light to an empty road because they are pre-timed, to the detriment of the huge motorists who are in queue waiting for traffic on the other ways. A timer is frequently used as a backup in case the sensors fail. The intelligent traffic light control system should have human knowledge intent can detect which way the traffic density is higher using intelligent sensors and consequently allot time to such way as required.

This traffic light control system will consists of three main parts. The controller, (the brain of the traffic system) which consists of computer that controls the selection and timing of traffic movements in accordance to the varying demands of traffic signals as registered to it by sensor/switch, the signal visualization, (signal face) which comprises the signal head provided for controlling traffic in a single direction with one or more signal sections (made up of light emitting diodes (LED); red, yellow, or green lights) and the detector or sensor, the device that keeps track of the presence of vehicles. The manoeuvres among the three parts are to be programmed using adequate programming language.

The control Unit controls the action of the traffic lights by selecting the various lamps and passing out individual data one at a time according to the way vehicles are to be passed at the cross (+) junction (roundabout). When powered on, it sends signal to turn on or to turn off the transistor switch that corresponds to the particular traffic light that should be seen at the moment. The design of this unit could be achieved using an NPN transistor or the like to the output pins of the controller unit, which will enable a large current to be controlled by a small current and therefore use small current to control devices with heavier currents, such as DC lamps, etc, and also to enable the control circuit to be isolated from the controlled circuits. This enables low-power equipment such as a micro-computer to operate a high power device such as a DC lamp. Transistors are connected to the common emitter. The function of the transistor is to control or drive the DC lamps and acts as an electronic switch. The controlling current flows through the large number of turns of the coil of the relay so that it can produce a magnetic field strong enough to operate electrical contacts of the relay, which either cuts off the supply to the heating element or maintains it in operation, (4). The complete circuit diagram for the system can be shown as in figure 2 below.

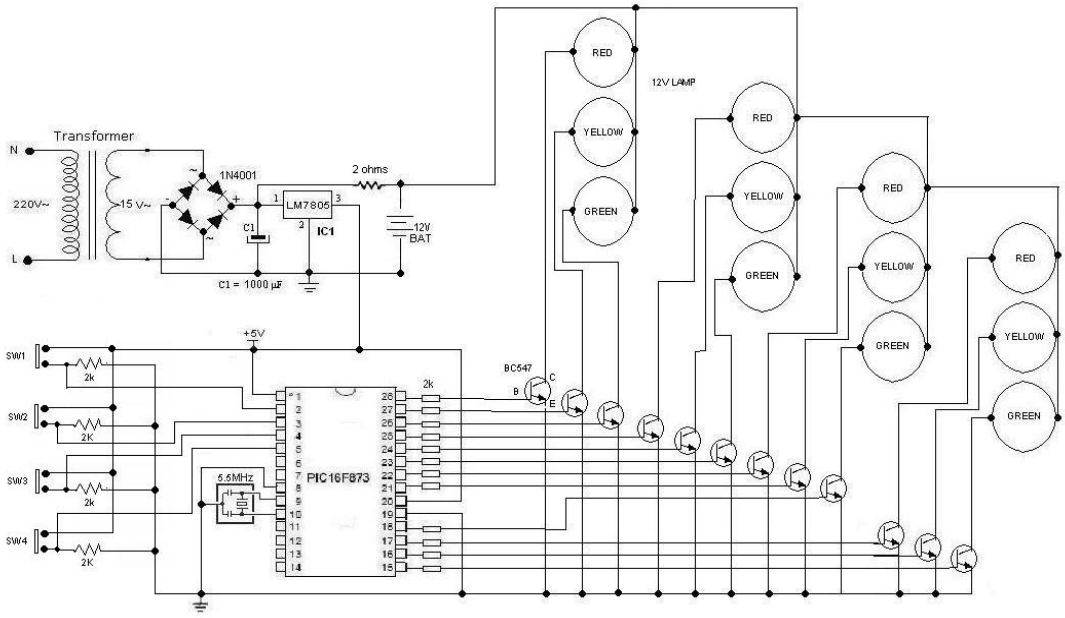

Figure 2: Circuit Diagram the intelligent traffic control system.

The system circuit diagram shown above consists mainly of a PIC (Peripheral Interface Controller), transistors, capacitors and resistors.

6. 0 Intelligent Traffic Control System Using Sensors

More sophisticated (Intelligent) control systems use electronic detector loops, where sensors are buried in the pavement to detect the presence of traffic waiting at the light, and thus can avoid giving the green light to an empty road while motorists on a different route are stopped. A timer is frequently used as a backup in case the sensors fail; an additional problem here is that they may fail to detect motorcycles or bicycles and cause them to wait indefinitely (or at least until a detectable vehicle also comes to wait for the light). The sensor loops typically work in the same fashion as metal detectors; small vehicles or those with low metal content may fail to be detected, (2).

Though there are many sensors that are available such as Inductive sensor, Infrared sensor, Image or Video sensor, Inductive sensor, Intelligent sensor, RADAR, Transducer, etc, Infrared sensors is recommended for this project. The layout of the sensors can serially be done one after the other with one sensor meant to be about 5m away from each other. This layering of the sensors will be done in such a way that up to 100m of the four cross roads are covered with the detector. The sensor task is to detect the presence of vehicles. It is functioning continuously by giving a logic 0 when there are no vehicles and logic 1 when there are vehicles present. Therefore, they can detect the queue of cars to the length of 100m as they are being placed. Each detector has a JST connector housing slot and three crimped wires to use in the JST connector. The connectors are plugged into the appropriate housing slot and into the detector and with light emitting diodes been used to show the traffic light changing according to the program output by the computer. In each lane, there are three LEDs according to traffic lights colours which consist of RED, YELLOW and GREEN. Therefore, when the green LED is ON, then the red LED will be OFF and vice-versa. The input and output ports are connected to sensors and LEDs.

A single 3-lamp traffic light is considered as a finite state machine. It has three states, Red, Yellow, and Green, which are also the outputs. A single input for the traffic light is defined, with values 0 for no change and 1 for change. This input is connected to the output of a countdown timer, which outputs a 1 when it reaches zero.

The program will check first the condition of the sensors, whether they are triggered or not. The total number of sensors triggered will be used in the mathematical function to calculate the appropriate timing for the green signal to illuminate. After the green signal finishes the illumination timing, the yellow signal will illuminate for 2 seconds and then finally the red signal will illuminate for 5 seconds. After that, the traffic signal will wait for 1 second before it goes to the next lane condition. If the green light in the traffic model does not illuminate, the system goes into default since there is no input into the system. Each time a vehicle blocks the sensor at a certain distance, the sensor is triggered and this will inform the controller (computer) via the DB 25 that there is a vehicle in the specific lane.

7.0 Conclusion

This study has brought into focus the issue of traffic congestion in major urban cities of Nigeria. The main

causes of congestion have been considered indicating that poor driving habits, poor road network, inadequate road capacity, and lack of parking facilities are the greatest causes of traffic congestion in Nigeria. The research also shows that cities like Lagos, Port Harcourt and Abuja are most affected by traffic congestion, among other major cities in Nigeria. Several efforts and mechanisms already put in place to reduce this menace have not proven enough solution to the problem of traffic congestion in Nigerian roads. The research also highlighted some remedies to improve traffic congestion in Nigeria to include good road network, encouragement of mass transport system, proper traffic planning/management, regular road maintenance, construction of interchanges and regular education of road users are among the recommendations to reduce traffic congestions. Because, the current traffic control system can be influenced by so many factors, the research highlighted the need for an intelligent traffic light control system with human knowledge which can detect which way the traffic density is higher using intelligent sensors and consequently allot time to such way as required without allowing the human influence the decision.

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