NIPES

Journal of Science and Technology Research

Journal homepage: www.nipesjournals.org.ng

Intelligent Transportation System Simulation for Traffic Management in Urban Transportation Planning Process

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Article Info

***Keywords*:**
Intelligent Transportation System (ITS), Simulation of Urban Mobility (SUMO), Traffic, Urban Transportation.

Received 31 March 2021
Revised 06 April 2021
Accepted 07 April 2021
Available online 02 August 2021

https://doi.org/10.37933/nipes/3.2.2021.23

https://nipesjournals.org.ng

Abstract

Traffic management in recent times has faced numerous challenges such as a steady increase in the traffic volume annually, traffic jams, etc. However, in previous years; this problem has been solved by the construction of more transportation infrastructure (such as increasing the number of lanes) but in the phase of the world's energy crisis and limited land resources, this method has proven to be ineffective and costly in the long term. Hence the need for a more robust approach/method of traffic management which is "The Intelligent Transportation System" as captured in this study.This study evaluates the role played by Intelligent Transportation System in developed countries in solving problems in Traffic Management, Enforcement, and other related issues. Traffic conditions with the aid of Simulation of Urban Mobility (SUMO) software, an ideal condition was compared and contrasted with the prevailing traffic condition in Benin City (Akpakpava axis specifically) gotten from daily traffic count conducted during this research in terms of average travel time, average travel speed, vehicle waiting time, fuel consumption, and also emission of pollutant into the environment. From the analysis using Simulation of Urban Mobility (SUMO) software, it was discovered that Intelligent Transportation System (ITS) is indeed very effective and useful in traffic management in terms of its reduction of the average travel time by 20.57 %, vehicle waiting time (which equates to reduced fuel consumption) by 69.01%. Also, ITS with the aid of SUMO has shown that Carbon II Oxide from vehicles will be reduced by 31.05%, Carbon IV Oxide by 13.30%, Hydrocarbons by 21.14%, Oxides of Nitrogen by 11.56%, and Motor Vehicle pollutant by 14.71%. The study provides recommendations and implementation strategies for the deployment of Intelligent Transportation System in light of these challenges to improve traffic conditions.

1. Introduction

Roads and highways are important in society as they form the crux of infrastructure that aids in the movement of people, goods, and services from one point to another. The performance of road networks is a factor in the socio-economic development of a place and it serves as a connector for other means of transportation. As for a fact, we know road maintenance and improvements improve the efficiencies of our roads, but in recent time the current traditional traffic management is insufficient in dealing with the problems posed by the steady increase in traffic volume. In recent times, problems in traffic management which have been faced all over the world are been combated by a new innovation, which is the Intelligent Transportation System. According to the former United Nations Secretary-General Ban Ki-moon, technology has always been central in the development of transportation throughout history [1]. Recent advancement in information communication technology has given us a window of opportunity to transform traffic management in ways that previously would have been inconceivable. So, therefore, these problems in traffic management have been faced all over the world are been combated by a new innovation, The Intelligent Transportation System.

According to the Ministry of Information and Communications Royal Government of Bhutan [2], Intelligent Transportation System (ITS) is the use of computer and communication devices to combat the problems faced in Transport Management. They went further to state that Intelligent Transportation System (ITS) is the use of new and emerging technologies (or computers, sensors, communication technology, electronic devices, etc.) to improve safety, efficiency, effectiveness, accessibility, and sustainability of the transportation network with having to increase the capacity of the network of itself". In a broader view, the Asian development bank [3] defined Intelligent Transportation System (ITS) as a system that uses data processing and/or data communications to improve the safety and/or efficiency of surface transportation operation and/or maintenance, which includes all modes of surface transportation. The goal of Intelligent Transportation System (ITS) is to achieve traffic efficiency and safety by minimizing traffic problems.

Intelligent Transportation System application in traffic management is of numerous benefits. Some aspects of its common applications are Traffic control, Traffic signal control, Electronic Feel and Toll Collection (EFC) system probe car data collection, road management using probe car data, information provision services on roads, bus location, public Transport priority system (PTPS). Concerning the issue of the benefits and cost of Intelligent Transportation System, The Research and Innovative Technology Administration (RITA) of the United States of America has published a very large database on this subject. One renowned benefit of Intelligent Transportation System is the increase in mobility as better mobility improves the quality of lives of the people in the area and turns helps them be able to improve the economy of the nation by increasing productivity, another aspect is the environmental benefit as Intelligent Transportation System will help reduce travel time, optimize trips, reduce congestion which in turn translates to less time waste, less energy consumption, less pollution, and a reduction in other environmental impacts.

[4] in their study "Intelligent Transportation System" identified the various problems and classified them into three main groups: Lack of traffic management; Homeland security system and vehicle operations; and Vehicle to Vehicle coordination and implementation of new technologies. Lack of traffic management as indicated in the study is the current lack of an appropriate system that can handle a large mass of traffic efficiently; the study proposed the introduction of a 'properly programmed system' with GIS, GPS, remote sensing, and a digitalized and centrally controlled. Homeland security system is the security and surveillance of the highway and the study proposed creating a system capable of keeping track of all vehicles on the road by providing them with a digital identity where every vehicle could be identified in real-time in the blink of an eye. [4] in the study also discusses the demerits of Intelligent Transportation System such as failure of the system will lead to stoppage of vehicular movement, vehicles, and passenger data security. The study by Palmer et al, further discusses the need for social acceptance of Intelligent Transportation System and the need to make a top priority the education of the public about this new technology while quashing rumors.

[5] in their study on "Intelligent Transportation System for developing countries conducted a survey that determines the traditional methods of traffic management such as traffic lights, traffic signs,

traffic police officers, and roundabout were no longer sufficient for traffic management. In the study, the benefits of ITS technologies were extensively discussed and the study went further to discuss the various world leaders in ITS technology made of most developed countries like Japan, South Korea, Singapore, United States, Australia, and United Kingdom.

The ITS infrastructures in traffic management are bound to reap benefits. According to the Executive Summary, U.S. Department of Transportation [6], Intelligent Transportation System (ITS) infrastructures has generated an overall cost to benefit ratio of 1: 5.7 on average for all the metropolis included in the study. The same study found out that in the top 75 most congested cities, the cost to benefit ratio were even higher, having a value of 1: 88.1. From the above study by the U.S. Department of Transportation, we can see the immerse benefits there is to reap from the implementation of ITS infrastructures especially in cities facing challenges of traffic congestion.

From the review of existing literature, it was discovered that studies into Intelligent Transportation System are quite extensive for developed countries like Japan, South Korea, Singapore, United States, Australia, and United Kingdom with each a having National or Regional Intelligent Transportation System framework or architecture. In developing countries excluding India studies into Intelligent Transportation System is very limited.

From the review of existing literature, studies conducted on Intelligent Transportation System were for Lagos State, Enugu State, and Niger State. No study has been conducted on Intelligent Transportation System for Edo State or Benin City Metropolis in particular.

2. Methodology

Traffic Simulation was done with the aid of 'Simulation of Urban Mobility (SUMO). Simulation of Urban Mobility (SUMO) is a traffic simulation software that is also non-proprietary and available since 2001. It is a microscopic and multi-modal traffic simulation software package designed in such a way that it is capable of handling large network [7].

Simulation of Urban Mobility (SUMO) is capable of addressing large simulation networks on purely a microscopic level with each vehicle in the network modeled explicitly with its own route and movement through the network.

SUMO acts not only as a traffic simulator but as a collection of programs with the capacity to allow used to generate/import network and thereafter determine the traffic demand. It uses NETEDIT to create network or import them from Open Street Map. After network has been successfully created with the aid of 'randomTrips', " DUAROUTER", or "DFROUTER" traffic demand and route of each individual vehicle can be created [8].

Krajzewicz et al. [9] in their paper titled "Second Generation of Pollutant Emission Model for SUMO" showed recent development in modelling and inclusion of emission model into microscopic traffic simulation which allows for a better understanding of the effects of the various proposed solution on the environment. The paper went further counteracting the common believe smoother traffic will result in lesser emission with the GLOSA (Green Light Optimal Speed Advisory) application. This showed the need for traffic emission model on all proposed systems. Sumo over the span of nearly two decades has been used in a variety of national and international research projects and works. A summary of its application includes but is not limited to: Traffic light evaluation, Route choice and rerouting, Evaluation of traffic surveillance method, Simulation of vehicular communication, and Traffic forecast.

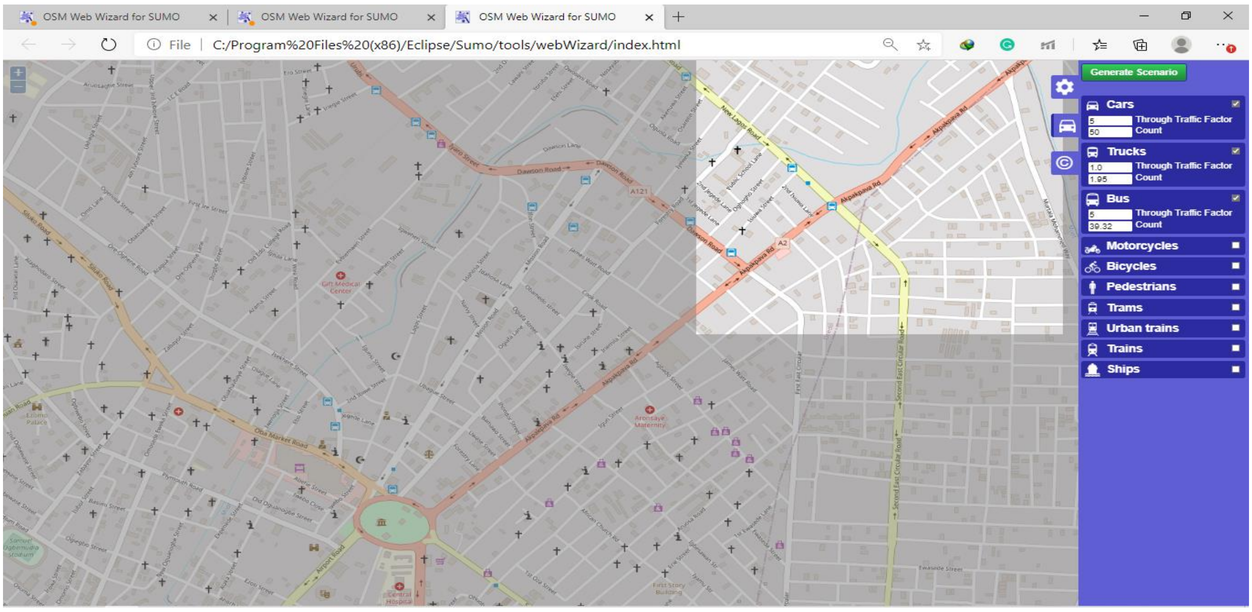

Figure 1- Open Street Map to Be Exported

There were two scenarios during this study: one representing the current traffic management system and the other the proposed traffic management system. The study area was at the intersection of Akpakpava Road and Second East Circular Road, Benin City located at 6°20'39" N 5°38'11" E at an elevation of 84 m. The true map of the area was imported from Open Street Map as seen in Figure 1. Traffic demand was generated via Open Street Map with the following values (Derived from actual road traffic count) and simulation run for 3600 seconds. Scenario A where the centrally placed traffic light represents the current traffic control mechanism with a cycle time of 180 seconds as shown in Figure 2 which is static predetermined.

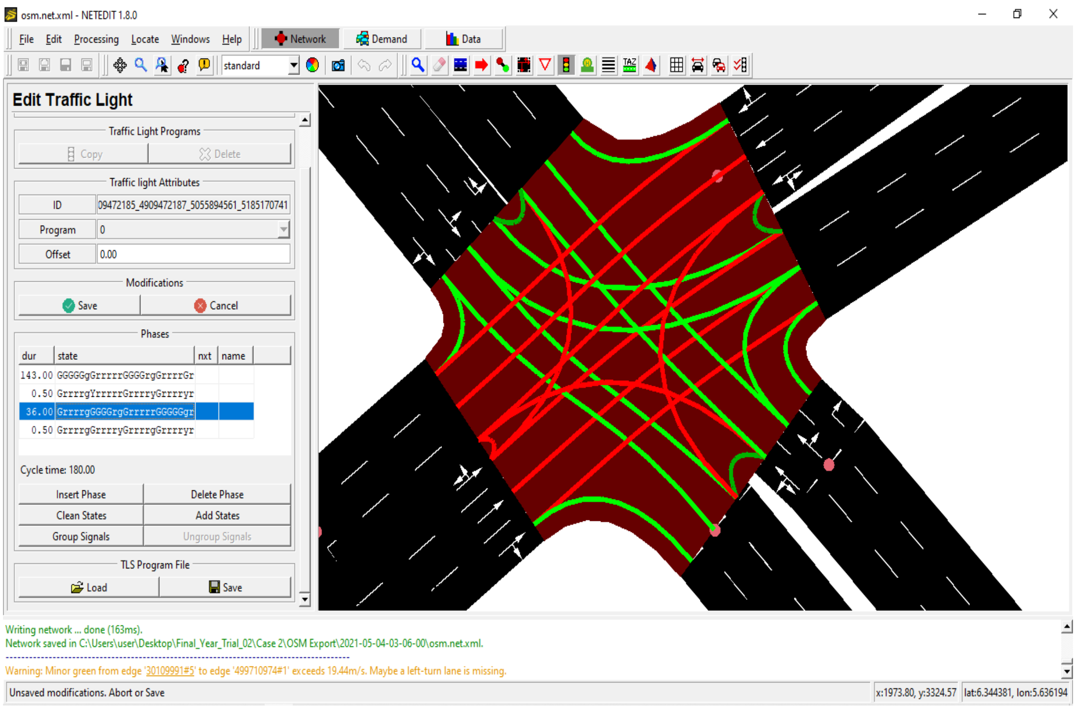

Figure 2- Scenario A in NET EDIT

Scenario B where the centrally placed traffic light represents the proposed traffic control mechanism represented by actuated traffic lighting which response bass on the output of the induction loop sensors placed on the highway.

To evaluate both scenarios using Simulation of Urban Mobility (SUMO), the road network from the study area was imported from Open Street Map with the aid of 'OSM Web Wizard' program and the traffic count gotten from manual counting according to Table 1 was inputted into the OSM Web Wizard program demand generation panel as show in Figure 2 to generate the traffic demand. Road network exported from Open Street Map was further postprocessed with Netedit software program to ensure it was an exact replica of the road network and other transportation infrastructure. The simulation for each scenario was run for 3600 seconds with a delay of 20 milliseconds.

3. Results and Discussion

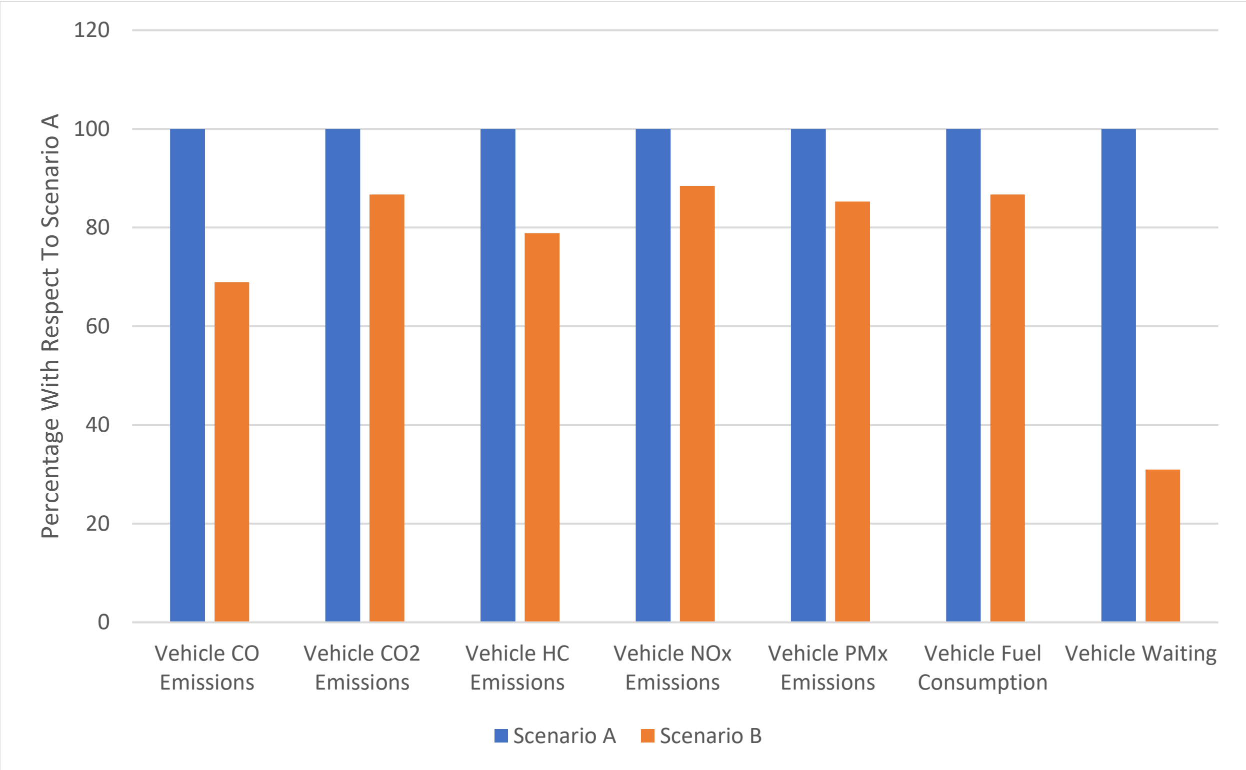

Figure 3- Comparison of Scenario Outputs

From simulation as seen in Figure 3, scenario B results in 31.05 % less Carbon II Oxide to be emitted than scenario A; scenario B results in 13.30 % less Carbon IV Oxide to be emitted than scenario A, scenario B results in 21.14 % less Hydrocarbon to be emitted than scenario A, scenario B results in 11.56 % less Nitrogen Oxides to be emitted than scenario A, scenario B results in 14.71 % less Motor Vehicle Pollutant to be emitted than scenario A, scenario B results in the consumption of 13.32 % less Fuel than scenario A, and scenario B results in 69.01 % decrease in waiting time in comparison to Scenario A.

Average travel time of vehicles passing the study area is calculated as:

$$TT = \frac{1}{n}\sum_{i=1}^{n}(tt_i) \quad (1)$$

Where:

TT = Average travel time

tt_i = Time travel of vehicle i passing study area

n = Number of vehicles

From simulation, Scenario A has an average travel time of 190.4729 seconds while Scenario B has an average travel time of 151.2886 seconds. Scenario B results in 20.57% reduction in the average travel time.

Average travel speed of vehicles passing the study area is calculated as:

$$VV = \frac{1}{n}\sum_{i=1}^{n}(v_i) \quad (2)$$

Where:

VV = Average travel time

v_i = Time travel of vehicle i passing study area

n = Number of vehicles

From simulation, Scenario A has an average travel speed of 19.4686 m/s while Scenario B has an average travel speed of 19.7890 m/s. Scenario B results in 1.6457 % reduction in the average travel speed.

In this study, we have shown the impact of the current challenges on the community at large a such as the increased demand/pressure on the already stressed traffic infrastructure which has led to an increase in waiting time, travel time, emission of harmful substances into the environment fuel and energy consumption. From the study, there have been laid sufficient points stating the fact that Intelligent Transportation System is capable of mitigating these challenges currently been faced by traffic management. It showed how with Intelligent Transportation System, transportation infrastructure can be better optimized to make the most out of them. So rather than focusing on improving the capacity of transport infrastructure, we can make better use of what we have.

4. Conclusion

This study from its review of existing literature and observation identified the challenges faced by the current Traffic Management System and how Intelligent Transportation System has helped solved similar problems in developed countries. This study with the aid of Simulation of Urban Mobility (SUMO) examined the effect of Intelligent Transportation System implementation in the form of Actuated traffic signal lighting on traffic flow characteristics which provided a drastic reduction in waiting time by 69.01% and fuel consumption by 13.32%. The study revealed how Intelligent Transportation System can be an effective tool in the current energy tool been faced in the world in that it increases the efficiency in the use of land and energy resources. The study went a step further to show how Intelligent Transportation System reduce the emission of harmful substances into the environment which would be a useful tool in stemming the tide against climate change.

Findings of the study suggested the following measures be taken: setting up of a working committee to conduct feasibility and cost study into the deployment of Intelligent Transportation System, the inclusion of the private sector in all aspects of the deployment and use of Intelligent Transportation System technology, provision of suitable legislative laws and the education not the populace on the need for Intelligent Transportation System.

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