Sustainable Transportation: Use of Intelligent Transport Systems

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Abstract

In a fast-paced urbanized culture, sustainable transportation still remains a major challenge. Quick and smooth mobility of people and goods with the possibility of regulating traffic congestion is important for every public transportation user. Urban population in developing nations like Kenya is expected to double by the year 2050 and balancing supply and demand of the urban transport system will be a major issue.

This paper aims to review different intelligent transport systems that can be used to reduce the traffic congestion in Nairobi. This would be done by analyzing historical data to gain performance insights and understand the behavior of traffic at intersections and traffic lanes. Using a software this data would then be stored and co-analyzed with real time data to predict traffic volumes and traffic flow. This data obtained would then be used to control traffic signal's timing based on the changing patterns of vehicles arriving at an intersection. Use of Active Traffic Management to monitor and adjust roadway operations over time can ensure dynamic strategies are deployed to optimize performance of traffic operations and enhance safety.

If policymakers and legislators establish clear goals, link them to regulatory frameworks with elements of transport planning they can ensure that this new mobility will improve access to new opportunities and development. Efficient transportation will therefore ensure sustainable development of cities.

Key Terms: Intelligent Transport System, Sustainable Transportation, Traffic Congestion, Smooth mobility, Active Traffic Management

1. Introduction

1.1 Background Study

Due to an increased surge in ownership of private vehicles, traffic congestion in Nairobi has increased drastically. This shows polices put in place have not been implemented effectively. If policymakers and legislators implement proposed policies across the board, it would balance demand on urban traffic and ease mobility. Traffic congestion can be defined as the state where a road's vehicle flow demand exceeds the road's capacity. Congestion is characterized by reduced free-flow speeds, decreased vehicle spacing, increased time travel and increased driver discomfort. Traditional methods of curbing traffic congestion include addition of traffic lanes, junction improvements, grade separations, and bus and carpool lanes. However, to set up these kinds of infrastructure an enormous amount of capital is required. This has led to innovation of intelligent transport systems (ITS) which require less capital to implement and more sustainable to reduce congestion.

Why ITS?

ITS provides real time simulation and control of traffic networks. As a result of increased congestion

In the city air pollution and fuel consumption has increased, efficiency in travel time has reduced, thus Proposed ITS systems will help in surveillance of roadways and enhance sustainability. (Senlai Zhu, 2019)

Figure 1: Intelligent transportation systems: http://www.lta.gov.sg/content/ltaweb/en/roads-and-motoring/managingtraffic-and-congestion/intelligent-transportsystems/SmartMobility2030.html

1.2 Problem Statement

Nairobi's ever increasing population of private cars has led to a rapid increase in traffic congestion. Despite measures by the city council to increase parking fees to discourage use of private cars, the convenience brought about by private cars is still unmatched by public transport. This has led to research of new ways to tackle traffic congestion by use of disruptive technology in a bid to provide smooth mobility and sustainable transportation.

1.3 Research Objective

To achieve a sustainable, safe and clean transportation system by reducing traffic congestion.

1.4 Literature Review

a. Adaptive traffic signal control

A review on intelligent traffic control system for traffic congestion shows that traffic congestion is as a result of an increase in the number of vehicles on the road. This results into wastage of time, energy and environmental pollution. To reduce traffic congestion, the traditional traffic lights put in place with a pre-determined red and green phase are not sufficient. This is due to change of traffic densities during the peak hours of the day. This is why City planners, urban designers are opting for intelligent systems to automate the traffic lights based on the density of vehicles on the road. This was to be done by incorporation of traffic sensors at intersections to monitor traffic density and tackle congestion depending on the nature of the traffic. (Pallavi A. Mandhare, 2018)

Increased congestion in the city of Iran with limited budgets to increase roadway infrastructure, made transportation authorities to recognize the need of increasing the roadway capacity to get the largest output out of their current transportation facilities. Since delay times often occur at intersections the need of an intelligent control system with ability to control the growing traffic was necessary. This system optimized fuel consumption as well as reduced environmental pollution. They found out that the adaptive traffic control system consistently reduced travel times and average delay on stopped and approaching vehicles. (Saeed Samadi, 2012)

b. Use of CCTV to monitor road conditions

A closer look at the integration of active traffic management schemes in the USA shows that its main aim is to reduce traffic congestion and improve journey time reliability. This was done by utilization of vehicle detection 'loops' which are set beneath the road surface at regular intervals and a network of CCTV cameras to detect traffic density and speed. Active traffic management is aimed at maximizing efficiency of already established transportation facilities throughout the day both under recurrent and non-recurrent congestion conditions. A study conducted to quantify the impact of temporary shoulder use to control traffic operations showed significant environmental, operational and economic use of the road due to temporary use of the left shoulder lane within an ATM environment. (Dr. Virginia P. Sisiopiku, 2009)

Active traffic Management majorly banks on comprehensive automated systems to monitor and regulate roadway operations over time depending on traffic conditions that change with time. Due to this automation, dynamic strategies can be deployed to optimize performance of traffic operations and enhance safety. As a result of dynamic response as a result of continuous monitoring, and coordination of systems, Active Traffic Management provides a holistic approach to manage transportation facilities. (Sisiopiku, 2012)

2. Methods

2.1 Optimization of traffic-light management

This is done by use of adaptive traffic signal control. This is the process by which a traffic signal's timing is adjusted continuously based on the changing patterns of vehicles arriving at an intersection. Based on anticipated arrivals, the traffic signal provide green time to each intersection approach. With the changing patterns of vehicle arrivals from one cycle to another, the duration of green time allocated for each approach changes. Adaptive Traffic signal Control (ATSC) is therefore used as an intelligent transport system to reduce delay in flow of traffic in traffic congested areas. This extends the lifespan of the existing road by minimizing the need of adding the capacity of the road through more traffic lanes. Reduced traffic congestion increases the fuel efficiency of vehicles thus reducing vehicle emission. This helps in creating sustainable transport. (Astarita, 2017)

Surveys are usually conducted before and after to evaluate traffic flow within a given road section. The total travel and delay times are monitored and the major delay types are determined. These studies are used to compare practical conditions of the road before and after improvement and then optimizing the controlling parameters. After studies are usually hypothetical and done with aid of statistical techniques. Total travel time and average delay time of vehicles traversing a given road are used as the measure of effectiveness of this system at a signalized intersection. Case studies should be carried out during peak hours. That is during the morning and evening period and non-peak times I necessary. These traffic studies should be conducted in appropriate weather conditions as studies done bad weather conditions lead to unacceptable results.

Travel time in the roads of interest ending at specific intersections is usually found by use of a probe vehicle that is similar in behavior to the vehicles on the road. It should stop and move as other vehicles do. This is to ensure correct simulation of the actual traffic on the road. The following parameters are recorded in specific forms.

- Travel time (TT): time within which probe vehicle travels from start of route to the end.
- Delay time (DT): Time during which the probe vehicle stops due to reduced speeds or bottlenecks.
- Running Time (RT): Total time taken by the probe vehicle

$$RT = TT - D$$

- Running Speed (RS): Average speed of probe vehicle during motion

$$RS = \frac{distance}{RT}$$

ATSC works on real time data to be able to function. Traffic sensors along road intersections collect data to optimize and update signal timing settings. This data is then evaluated, analyzed and new signal timing improvements are developed. The updates are then implemented. This process is repeated continuously using a software. The ATSC shares this information with each other and make necessary adjustments to the timing schedules to make sure traffic is running smoothly. Traditional timings of signals repeats this process every 3 to 5 years. Traditional signal timing relied on historical traffic data collected manually. This did not account for the day to day unpredictable traffic demands. This caused it to be time-consuming which led to frustrated drivers, complaints from customers, increased delays and excess human consumption.

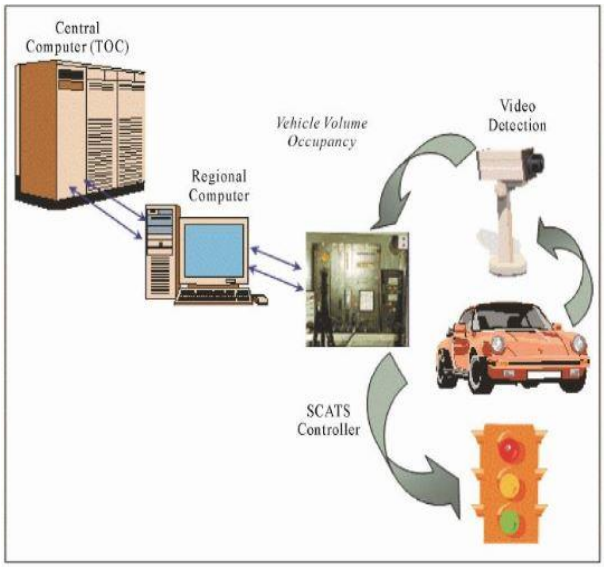

Figure 2: How SCATS works. Source: (Saeed Samadi, 2012)

Adaptive traffic signal control methods are based on timing parameters such as phase split, cycle length an duration of each phase adapt which are based on the traffic operations present and traffic fluctuations in order to reduce total traffic delay at intersections.

2.2 Active Traffic Management

This involves use of monitoring systems with closed circuit cameras. The main aim of Active Traffic Management is to create more reliable travel times by reducing traffic congestion. This is done by providing drivers with more reliable information that has been analyzed using real time data and help transport authorities to respond more quickly incidents.

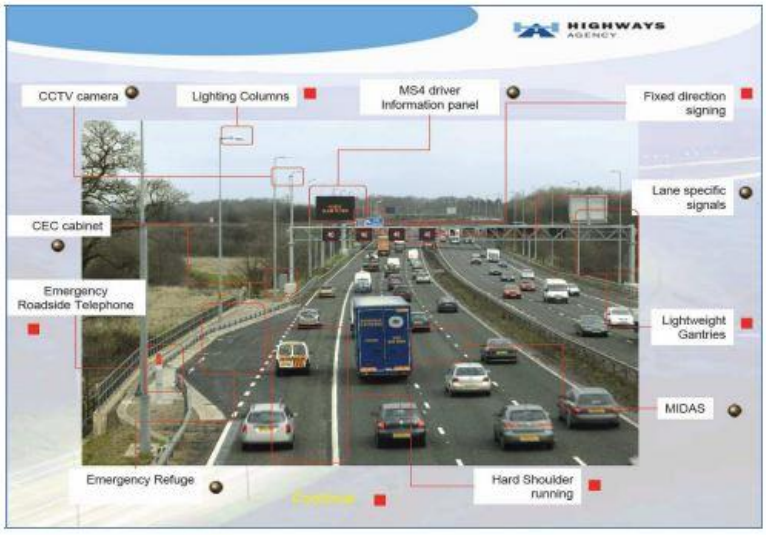

Figure 3: Traffic Devices and Strategies in M24 UK (Stone et al., 2007)

3. Discussion

Intelligent Transport Systems are necessary as the world evolves around us. They maximize the road infrastructure therefore reducing the need to build additional highway lanes. Application of real-time data to traffic lights improve traffic flow and reduce traffic delays by up to 40% reducing time travel by 25 % and cutting fuel consumption by 10 % and cutting gas emissions by 22% (Radwan, 2015) Use of ITS enables transportation agencies in the government to collect real time data which is required to improve transport infrastructure making it the centerpiece required to reform surface transportation and hold the ones who provide the facilities accountable.

By improving the performance of traffic operations on the road, ITS has ensured smooth and convenient mobility of driver, increased environmental benefits

Advantages of ITS

- Ensures safety at all times of day by giving priority to the most susceptible users
- Increases efficiency of transportation facilities
- By regulating traffic congestion, ITS encourages sustainability. Carbon emissions are reduced and environmental pollution decreases
- Efficient transportation facilities attract investors and individuals, this leads to an increase in the economic development of a town

4. Conclusion

This paper proposes two ways of reducing traffic congestion by use of intelligent transport systems. This methods include use of adaptive traffic signal control to reduce total traffic delay at intersections and Use of active traffic management which synchronizes real time data obtained by vehicle 'loop' detectors and CCTV cameras to tackle congestion by making best use of existing road space while improving current safety standards. (Senlai Zhu, 2019)

Case studies carried out on adaptive traffic signal control show they significantly reduce traffic delay at intersections both at peak and non-peak periods. Intersections with low and high volume to capacity ratios are the main areas of interest for studies to be carried out. Actual data collection and traffic forecasts were not considered in the proposed method and additional research is required to achieve accurate results. (Senlai Zhu, 2019)

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