Simulation Model for Public Transport Vehicles for Towns: Case of Nakuru Town, Kenya

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Abstract: ***Nakuru town is the capital of Nakuru County in Kenya, and lies about 1850m above sea level. It has an estimated of 307,990 inhabitants making it the largest urban centre in Kenya. The road network in this country and within Nakuru Town is crammed. The roads accessing Nakuru Town are narrow, to be able to cater for the increased number of motorists. There are no designated pathways for cyclists and motorbikes. This leads to increased traffic congestion. Mass transit and non-motorized transport were not considered in the design of the roads of this town thus making traffic flow being slow. This leads to poor economic growth. Traffic congestion in this town is a menace. There are slow speeds and access to amenities becomes difficult. This initiative tends to initiate the upgrading of public transport systems, implementing improved non-motorized transport infrastructure (bicycle and walkways), and apply travel demand management for instance, Parking reforms and other supporting policies. In this study, simulated traffic flow and speeds was used as a way of decongesting the town. We proposed the use of larger capacity public service vehicles, and introduction of a secondary bus terminus. The sole purpose for traffic flow management to avoid congestion is to get drivers and passengers to their destinations faster and safer. Drivers should have exact route information and arrival times this achieved by building, a view of traffic flow over entire road network. The system proposed has the model of the road network used by public service vehicles and their various routes. This information is helpful for traffic flow management. Alternate routes will be easier to locate, since the view of the current position and other adjacent routes are made available. The case study for the above research was Nakuru town, and a total of 147 bus stops within the town were examined and mapped onto a road network map. This information was used together with vehicle speeds and counts collected via GPS (Global Positioning System) devices manually, so as to be able to enable the simulation of public transport. The tool that was used for simulation was SUMO, and RStudio was used for analysis purposes of the various results obtained from the simulation.***

Keywords: Simulation, SUMO, RStudio, JOSM, GPS, GTFS

1. Introduction

Traffic simulation models are computer models where the movements of individual vehicles travelling around road networks are determined by using car following and gap acceptance rules. They are becoming increasingly popular for the evaluation and development of road traffic management and control systems. The researcher set out in this study to create General Transit Feed Specification (GTFS) for the town, and further use the data to visualize public transport routes, and finally simulate traffic flow using vehicle speeds on the said routes. In recent years, simulation models have been increasingly used to help studies of a wide range of transport systems, LRT Priority System Development [1]

2. Simulation Algorithms for Traffic Control

An algorithm for alleviating traffic flow instabilities which could be implemented by a variation of the adaptive cruise-control systems that are an option on many of current vehicles has been presented by [2]. This is done using a car with an adaptive cruise control using sensors, such as radar or laser rangefinders, to monitor the speed and distance of the car in front of it. That way, the driver does not have to turn the cruise control off when there is traffic congestion. The car will automatically slow when it needs to and return to its programmed speed when possible. He reiterates that, a car equipped with the said system would also use sensor information about the distance and velocity of the car behind it, thus referring to the system to having bilateral control. Instabilities arise, because variations in velocity are magnified as they pass through a lane of traffic.

An adaptive control algorithm as an important strategy to manage traffic at an intersection has been proposed by [3]. These are improvements of vehicle actuated signal control, where explicitly strategies are formulated to compute the signal timing considering the current traffic state obtained from sensors. However, field evaluation of these strategies is cumbersome and expensive and hence simulators which model traffic system can be a good alternative. The main challenge was a good interface between the signal control system and the traffic simulators. The signal control system needed the state of the junction in terms of vehicle occupancy at every instant. On the other hand, traffic simulator needs information on whether the signal state has changed. This two way communication required an efficient interface which is similar to client-server architecture. The simulator acted as the server where as the adaptive control strategy act like client. He proposed an efficient interface to couple adaptive control strategy and traffic simulator. This interface mediates between traffic control system and traffic simulator and provides online interaction to simulation from the control strategy. This interface facilitates pure procedural routines to communicate and is written in C language along with Python/C API. Additionally, a module to estimate the vehicular delay due to the control strategy is developed. This delay is estimated by defining effective length of queue, which is provided as a user input. This interface is tested using SUMO (Simulation for Urban Mobility). The traffic control strategy is analogous to the HCM vehicle actuated traffic control except that there is a queue prediction model which computes upper limits on the maximum green time. An isolated four arm junction having four phases is simulated for various flow conditions. The simulator supplied the state of the downstream detector to the traffic control algorithm at every simulation step and the control algorithm determines the signal time strategies (phase termination, green extension, and maximum green time).

These strategies communicated to the simulator. These communications were facilitated by the proposed interface. The average stopped delay was computed as the performance parameter. The interface was also coupled with another traffic simulator VISSIM (Visual Simulator) and the results compared. This interface justified the concept of reusability by the evaluation of number of control strategy.

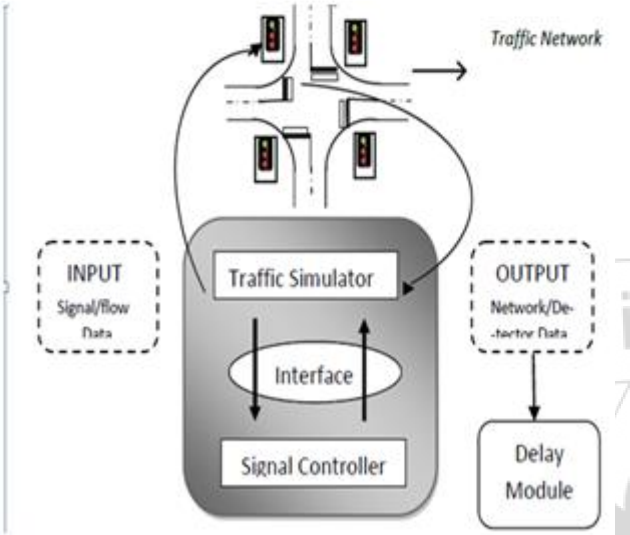

Figure 1: Architecture of the interface which couples signal controller and traffic simulator **(source [3])**

Use of digital cameras which are able to observe traffic and gain real information, including the length of jams on a street or trajectories of vehicles is presented by [8]. Besides developing these systems themselves, another goal was to invent mechanisms which use such information for traffic optimization. To show the capability of improving traffic flow, he implemented an agent based algorithm for traffic lights control within the microscopic road traffic simulation SUMO.The agent based traffic lights control algorithm is first presented. The main idea was that each traffic light was trying to solve the jams in his front by itself. To achieve this, he looked into the incoming lanes and measures the jam lengths on these lanes. If at one of these lanes the jam gets longer, this lane green for a longer time. Beside these assumptions, several parameters prevented the system from oscillating and from adapting too fast or too strong. This was done by increasing the green phase’s duration only if a jam is longer than a threshold. Furthermore, the jam has to occur for a certain amount of time. These are further boundaries for the duration of the phase beside the standard value given at the beginning; a phase must not be longer or shorter than predefined thresholds. The whole algorithm shown below is beside the advantage to be very simple, the agent based traffic lights logic can be set on top of existing traffic lights and tries to adapt them to the current traffic amount.

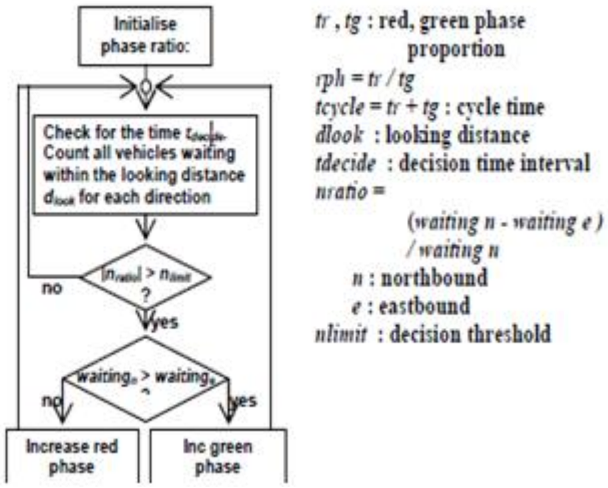

Figure 2: Traffic lights control algorithm **(source [8])**

3. Application of Simulation in Public Transport

In a traffic simulation study, [9] presents a review of some traffic simulation software applications, their features and characteristics as well as the issues these applications face. The use of SUMO open software which was used in this study to simulate public transport is discussed. Some algorithmic ideas underpinning data structural approaches and quantifiable metrics that can be applied to simulated model systems are also introduced in their study. SUMO is a simulation package that can be used to achieve the objective of traffic flow simulation. It enables the possibility to simulate how a given traffic demand moves through large road networks. This is an open source tool and a microscopic road traffic simulation package that supports different types of transportation vehicles. Every vehicle has its own route and moves individually through the network. It supports traffic lights and is space continuous and time discrete (default duration of each time step is one second). SUMO has three main modules, that which reads the input information, processes the simulation, gathers results and produces output files. It has an optional graphical interface called SUMO-GUI; NETCONVERT, a tool to simplify the creation of SUMO networks from a list of edges. It reads the input data (from GPS device), computes the input for SUMO and writes the results into various output formats, such as XML, CSV or VISUM-networks. It is also responsible for creating traffic light phases; DUALROUTER, a command line application that, given the departure time, origin and destination, computes the routes through the network itself using the Dijkstra routing algorithm.

4. Research Methodology

Research Design

The study adopted experimental research design

In this study, the researcher used various software namely JOSM (Java Open Street Maps) for editing the road network as downloaded from Open Street Maps, and also mapping of bus stops and routes onto the road network as extracted from the GPS device.

Further, for the simulation aspect SUMO was used together with vehicle speeds and counts collected manually through the device to simulate public transport traffic flow.

4.1 Data source and collection

Data that was used for this study was from a GPS device which basically picked waypoints, or rather bus stops as the public vehicles were on transit until they reached their specified bus stages or destinations. Since the GPS device only picks/collects points in coordinate form (latitude and longitude), a notebook was used in recording the various points and route names so as to later change them with the ones picked by the device during analysis.

This data collected referred to as GTFS data includes the tracks used by the vehicle to reach its destination and also waypoints/bus stops.

4.2 Data analysis

JOSM tool was used for the plotting of bus stops onto the road network for Nakuru Town downloaded from open street maps. The road network as viewed on JOSM included removal of unwanted parts not needed for the simulation such as power lines.

Figure 3: Nakuru Town road network and bus stops (source author)

Simulation of Urban Mobility (SUMO) was used for the simulation of public transport given the road network and various vehicle speeds. Figure 4 shows the simulation results of a roundabout entering Nakuru town and the road network converted into SUMO file [5][6][7][9]

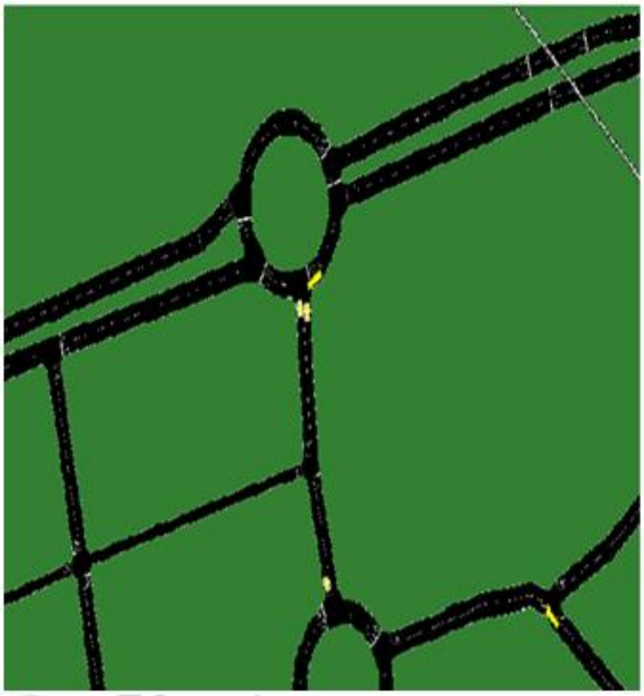

Figure 4: Nakuru road network converted into SUMO file (Roundabout entering Nakuru town) (source author)

4.3 Results and discussions

The results for this study were from comparison done from simulation output using SUMO and actual data collected from the ground. RStudio is the tool that was used to do this comparison after the various vehicle speeds and vehicle counts were tabulated as shown in tables 1, 2, and 3 below.

Table 1: Vehicle counts for 14-seater public service vehicles as per Thursday 28/08/2014 (source author data)

Time interval	6.10-7.45 am	12.30-1.30 pm	6.30-7.45 pm	Calculated speeds
Terminus inbound	129	112	47	10.81
Terminus outbound	53	43	108	6.73
Town inbound	134	57	35	8.05
Town outbound	77	83	59	16.88

Table 2: Vehicle counts for 14-seater public service vehicles as per Friday 29/08/2014 (source author data)

Time interval	6.10-7.45 am	12.30-1.30	6.30-7.45 pm	Calculated speeds
Terminus inbound	111	88	76	10.33
Terminus outbound	41	52	116	6.89
Town inbound	117	62	49	8.12
Town outbound	69	73	63	15.80

Table 3: Vehicle counts and speeds as simulated by SUMO (source author data)

Variables	*Vehicle counts*	*Simulated speeds*
Terminus inbound	294	11.04
Terminus outbound	215	7.09
Town inbound	236	8.41
Town outbound	216	16.65

The use of induction loop detectors was used at various congestion hot spots to be able to get the vehicle counts at those areas. This points are namely stage inbound to signify entering the stage, stage outbound to show those vehicles going out of the stage terminus. The other points are town inbound signifying those vehicles entering town, and town outbound showing those vehicles going out of town.

From the above results a hypothesis was formulated, all means of the vehicles speeds are all the same. The anova test and kruskal test were used for hypothesis testing of the results. The results above show that in terms of speeds of the different public service vehicles, when combined in pair's amount to the same, and both anova and kruskal tests helped us to accept our hypothesis of all means are the same. This further made the researcher see it fit to combine the different public service vehicles instead of having one type plying through the town. This for example can be the combination of 14-seater and 25-seater,14-seater and 33-seater, and 25-seater with 33-seater vehicles.

5. Conclusions

This research concentrated on a simulation model for public transport that would be implemented on the public service vehicles to assist drivers and other users. It was found that inclusion of other large capacity vehicles could yield good results as traffic control management is concerned. Introducing 25-seater public transport vehicles gradually together with reducing the number of 14-seater vehicles will be of great use in reduction of traffic congestion at the terminus.

Future work will see that the dilapidated traffic lights around the town get fixed and thus further incorporated in this simulation model.

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