Development of a Mathematical Model for Traffic Light Control

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***Abstract*— the invention of traffic lights has helped to reduce traffic congestion on highways and eased mode of transportation. However, the ever-increasing volume of vehicles has given rise to conflicts, accidents and pollution due to emission from the vehicles. Traffic light switching control could either be pre-timed (Static) or Actuated (Adaptive). In this paper, a comparative study of mathematical models is done to determine the better switching technique for vehicles at an intersection at various levels of saturation and which reduces conflicts and accidents on the highway. For the static time, Webster's method for the signal design was used to determine the total cycle length of the signal and the approach in the allocation of green-time in a cycle. The adaptive model uses sensors in connection with the control unit to determine the cycle length and also allocate the green and red time depending on the queue length and arrival rate on each of the phases at the intersection. Both models were simulated side by side with simulation of urban mobility (SUMO) programme using python language. Results obtained indicated that the developed adaptive time switching scheme is better in almost all level of saturations as it took less time for the vehicles to exit the intersection and reduced the occurrence of conflicts and accidents at the intersection.**

***Keywords*— Traffic Control, Mathematical Modelling, Intersection, Arrival rate, Queuing Length, SUMO**

I. INTRODUCTION

The problems of urban transportation are mainly traffic congestions along intersections. Overcrowding and congestions with vehicles of all type, creating lots of traffic problems and pollutions from the emissions of the vehicles. This makes the cities slowly but surely unhealthy. Here in Nigeria, the problem could be down to several factors, ranging from poor town planning and its implementation, to poorly constructed motorways and even poor drivers. As the population of a country increase, citizens migrate to the urban cities and create traffic problems because the cities often were not planned to accommodate such a large number of individuals. Road travel has become an inherently risky activity in cities, traffic jams can take lots of useful hours of the day from the average driver, accidents that may lead to loss of life and also loss of property is another risk driver's face daily on the highways.

Traffic signals are used to aid traffic operation and manage urban roadway intersections. The capacity of the urban road network mainly depends on the capacity of the traffic signals. Traffic Signals are signaling devices located at road intersections, pedestrian crossings, and other locations to control flows of traffic. They are an important element of traffic control devices. Installing traffic signals has numerous calculations to prevent traffic hazards at the intersection.

II. LITERATURE REVIEW

Various optimisation techniques have been used to optimise traffic flow and control, [1] developed optimal steady state-state control for isolated traffic intersections, using a discrete-event max plus model for green light switching. Emphasis was placed on shorting queuing length by evaluating arrival and departure times at the intersection. The optimal switching sequence can be computed for the steady-state problem with constant cycle length by solving an LP problem analytically. Similarly, [2] developed two strategies aimed toward real time-optimal control for traffic flow. Optimal "on-off" laws based on bilinear control problem with binary constraints. First of all Lyapunov function method is used and gives out a feedback law for setting on-off signal laws at the traffic intersection. The second strategy uses an optimization method for binary optimisation problems where it is a real variable optimisation in which the binary constraint is treated by the exact penalty method. The method is tested to solve the traffic control problem but it should be widely applicable to other models formulated as 0–1 integer optimal control problems. Both methods are tested and compared, and the tests demonstrate that the both methods provide very effective and efficient traffic control laws.

Shifting focus to queue length [3] developed a model that showed the evolution of the queue lengths in each lane as a function of time. It was shown that for a class of objective functions, an optimal light switching scheme can be obtained efficiently. After creating the model simulations with examples were done to show the merits of the model. The major advantage of this model is that the green-amber-red cycle is allowed to vary from one cycle to another. Going further [4] derived methods to optimize performance measures such as average or worst case waiting times and queue lengths for a switched system with linear dynamics subject to saturation, quantitative properties of the system were considered and it was advised that other techniques of interest in qualitative properties such as, safety should be used. Also, suggestion was given for future research if the extension of the results obtained to networks of dependent queues, i.e., a situation where the outputs of some queues will be connected the inputs of some other queues. If a moving horizon strategy in combination with a decentralized control solution, it can apply still the approach given and use measurements from one queue to predict the arrival rates at

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