Traffic Actuated Signal System Design for Heterogeneous traffic on urban roads-A Review.

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Abstract: *Urbanization leads to increase in traffic problem day by day.Congestion due to traffic affects nominal capacity of existing infrastructure. With the time, there is increase in population and vehicle ownership along with socio economic development leads to degradation of infrastructure specifically roads. At signalized intersection real time data collection helps in design of cycle length with optimum delay. At signalized intersection on busy urban roads, more waiting and queue formation is observed. This paper focuses on review of traffic actuated signal system. It is a detector base system for green time for the phase as per traffic volume and queue formation on that phase at signalized intersection. Full-actuated control implies that all approaches have their own detectors. The basic operating principle is that when one phase starts to turn green, it is given a minimum green time. Then the green time is extended by a pre-set unit extension, unless the detected headway is greater than the pre-set gap threshold or the green duration exceeds the pre-set Maximum green time. A well-designed actuated control plan that responds appropriately to traffic demand can significantly reduce fixed delay of trip maker. It is a boon to environment to reduce air pollution and saving in fuel consumption due to idealing of vehicle in queue at signalized intersection.*

Keywords: Delay, Green time, Real time data, S*ignalized intersection, Traffic* Actuated Signal, Queue

1. INTRODUCTION

1.1) Traffic Signals

Traffic signals are the control devices which alternately direct the traffic to stop and proceed at intersections using red and green traffic light signal automatically.

The signals are classified into the following types:

- Traffic Control Signals
- Fixed time signals
- Manually operated signals
- Traffic actuated (automatic) signals
- Pedestrian signals
- Special traffic signals

1.2) Traffic Actuated Signals

1.2.1 Basic Principles

Vehicle-Actuated Signals require actuation by a vehicle on one or more approaches in order for certain phases or traffic movements to be serviced. They are equipped with detectors and the necessary control logic to respond to the demands placed on them. Vehicle-actuated control uses information on current demands and operations, obtained from detectors within the intersection, to alter one or more aspects of the signal timing on a cycle- by-cycle basis. Timing of the signals is controlled by traffic demand. Actuated controllers may be programmed to accommodate:

- Variable phase sequences (e.g., optional protected LT phases)
- Variable green times for each phase
- Variable cycle length, caused by variable green times

Such variability allows the signal to allocate green time based on current demands and operations. A proper clearance interval between the green & the red phases is also ensured.

1.2.2 Types of Actuated Control

There are three basic types of actuated control, each using signal controllers that are somewhat different in their design:

1. Semi-Actuated Control
2. Full-Actuated Control
3. Volume-Density Control Especially effective at multiple phase intersections.

- **Semi-Actuated Control**

This type of controller is used at intersections where a major street having relatively uniform Flow is crossed by a minor street with low volumes. Detectors are placed only on the minor street. The green is on the major street at all times unless a call on the side street is noted. The number and duration of side-street green is limited by the signal timing and can be restricted to times that do not interfere with progressive signal-timing patterns along the major street.

- **Full-Actuated Control**

This type of controller is used at the intersections of streets or roads with relatively equal volumes, but where the traffic distribution is varying. In full actuated operation, all lanes of all approaches are monitored by detectors. The phase sequence, green allocations, and cycle Length are all subjected to variation. This form of control is effective for both two-phase and Multi-phase operations and can accommodate optional phases.

- **Volume-Density Control**

Volume-density control is basically the same as full actuated control with additional demand-responsive features. It is designed for intersections of major traffic flows having considerable unpredictable fluctuations.

1.2.3 Detection for Actuated Signalization

The various types of detectors used for detection of vehicles are as following:

- Inductive loop detectors
- Magnetometer detectors
- Magnetic detectors
- Pressure-sensitive detectors
- Radar detectors
- Sonic detectors
- Micro loop detectors etc.

The vast majority of actuated signal installations use inductive loops for detection purpose. Now, the type of detection is of greater importance than the specific detection device(s) used. There are two types of detection that influence the design and timing of actuated controllers:

1. Passage or Point Detection: - In this type of detection, only the fact that the detector has been disturbed is noted. The detector is installed at a point even though the detector unit itself may involve a short length. It is the most common form of detection.

2. Presence or Area Detection: - In this type of detection, a significant length (or area) of an approach lane is included in the detection zone. Entries and exits of vehicles into and out of the detection zone are remembered. Thus, the number of vehicles stored in the detection zone is known. It is provided by using a long induction loop, or a series of point detectors. These are generally used in conjunction with volume-density controllers.

1.2.4 Actuated Control Features

Regardless of the controller type, virtually all actuated controllers offer the same basic functions, although the methodology for implementing them may vary by type and manufacturer. For each actuated phase, the following basic features must be set on the controller:

- **Minimum Green Time**

  Each actuated phase has a minimum green time, which serves as the smallest amount of green time that may be allocated to a phase when it is initiated. Minimum green times must be set for each phase in an actuated signalization, including the non-actuated phase of a semi-actuated controller. The minimum green timing on an actuated phase is based on the type and location of detectors.

- **Unit Extension**

  This time actually serves three different purposes:

  1. It represents the maximum gap between actuation at a single detector required to retain the green.
  2. It is the amount of time added to the green phase when an additional actuation is received within the unit extension, U. It must be of sufficient length to allow a vehicle to travel from the detector to the STOP line.

In terms of signal operation, it serves as both the minimum allowable gap to retain a green signal and as the amount of green time added when an additional actuation is detected within the minimum allowable gap. The unit extension is selected with two criteria in mind:

- The unit extension should be long enough such that a subsequent vehicle operating indense traffic at a safe headway will be able to retain a green signal (assuming the maximum green has not yet been reached).
- The unit extension should not be so long that straggling vehicles may retain the green or that excessive time is added to the green (beyond what one vehicle reasonably requires to cross the STOP line on green).

The Traffic Detector Handbook recommends that a unit extension of 3.0 s be used where approach speeds are equal to or less
than 30 mile per hour, and that 3.5 s be used at higher approach speeds. For all types of controllers, however, the unit extension must be equal to or more than the passage time.

- **Recall Switch**

  Each actuated phase has a recall switch. The recall switches determine what happens to the signal when there is no demand. Normally, one recall switch is placed in the on position, while all others are turned off. In this case, when there is no demand present, the green returns to the phase with its recall switch on. If no recall switch is in the on position, the green remains on the phase that had the last" call. "Demand exists; one phase continues to move to the next at the expiration of the minimum green.

1.2.5 Operating Principle

The operation of an actuated phase based on the three critical settings minimum green, maximum green, and unit or vehicle extension. When the green is initiated for a phase, it will be at least as long as the minimum green period. The controller divides the minimum green into an initial portion and a portion equal to one unit extension. If an additional call is received during the initial portion of the minimum green, no time is added to the phase, as there is sufficient time within the minimum green to cross the STOP line (yellow and all-red intervals take care of clearing the intersection). If a call is received during the last U seconds (Unit Extension) of the minimum green, U seconds of green are added to the phase. Thereafter, every time an additional call is received during a unit extension of U seconds, an additional period of U seconds is added to the green. Note that the additional periods of U seconds are added from the time of the actuation or call. They are not added to the end of the previous unit extension, as this would accumulate unused green times within each unit extension and include them in the total green period. The green is terminated in one of two ways:

1. A unit extension of U seconds expires without an additional actuation,
2. The maximum green is reached.

The maximum green begins timing out when a call on a competing phase is noted. During the most congested periods of flow, however, it may be assumed that demand exists more or less continuously on all phases. The maximum green, therefore, begins timing out at the beginning of the green period in such a situation. Now-a-days, in India, detectors are placed mostly at stop lines. In that case, the green times for phases are primarily determined by arrival headway. The Green time is extended until the gap between two vehicles becomes equal to or greater thanthe pre-determined threshold value. Generally threshold of 4 seconds is considered

2. LITERATURE REVIEW

(Wenqiang Guo, 2007)This paper presents two approaches to optimize maximum green time estimation. One is single-objective adaptive model based on HCM delay formula minimizing intersection average delay; the other is multi-objective analytical model minimizing delay-and-stops in unsaturated conditions and maximizing capacity in saturated conditions. Single-objective model is effective to reduce vehicle delay while multi-objective model produces lower average number of stops and more intersection throughput in non-oversaturated conditions

(ZADE & DANDEKAR, 2012) This paper presents a Simulation of Fuzzy Traffic Controller design for controlling Green Light time for effective traffic flow. They have developed a system which reflects two fundamental aspects of traffic responsive signal control- the observation of on-going traffic situation around the intersection, and the control of the traffic signals in a manner appropriate to the observed situation. At constant value of traffic flow rate, green light extension time increases slowly with respect to traffic density. When density is kept constant and arrival (i.e. traffic flow rate) is increased slowly, the green light extension time also increases. However, when traffic flow rate become comparable or higher than traffic density, the green light extension time tends to increase, allowing higher number of vehicles to pass the junction.

(Jun, 2013)In this study an empirical study was conducted in Madrid and data were collected from the road of Hermanos Garcia Noblejas. The implemented effects and applicable condition of actuated signal control are studied by inspecting the field application and analyzing simulation results of the different intersections under actuated signal control and fixed time control. The simulation results include average queue, delay, emission CO, emission NOx, emission VOC, fuel consumption, vehicle number, mean number of stops per vehicles etc. At the small or medium sized crossings, whether coordinated control or semi-actuated control or fully-actuated control, using actuated signal control can reduce delays, emissions, increase capacity, so it is recommended to use the actuated signal control. At the small and T-shaped intersections, considering the pedestrian waiting time and the operation results of vehicles, the actuated signal control is also more recommended.

(Nageswara & Reddy, 2013)In this study An intelligent traffic light system had successfully been designed and developed. The sensors were interfaced with Lab VIEW integrated system. This interface is synchronized with the whole process of the traffic system. In the simulation one pair of lights was used to control traffic in the north-south direction, while the other pair controls the east-west direction. In order for the Traffic Signal Simulator to work intelligently, mathematical functions that can calculate the time needed for the green signal to illuminate based on the length of queue are developed. The length of queue is detected through the infrared object detectors by the presence of vehicles.

(Jha & Shukla, 2014)In this paper an intelligent traffic model and fuzzy logic traffic controller are developed to evaluate the performance of traffic controller under different pre-defined conditions for oleaginous flow of traffic. The maximum value of waiting time and vehicle queue length has to be selected by using proximity sensors as inputs to controller for the ameliorate control traffic flow at the intersection An intelligent traffic model and fuzzy logic traffic controller are developed to evaluate the performance of traffic controller under different pre-defined conditions for oleaginous flow of traffic. Additionally, this fuzzy logic traffic controller has emergency vehicle siren sensors which detect emergency vehicle movement like ambulance, fire brigade, Police Van etc. and gives maximum priority to him and pass preferred signal to it.

(Lee, Wong, & Li, 2015)In this study, they developed a real-time estimation approach for lane-based queue lengths. To determine the proportions of total traffic volume in each lane, the downstream arrivals for each cycle are estimated by using the Kalman filter, which is based on upstream arrivals and downstream discharges collected during the previous cycle. To develop the real-time estimation of lane-based queue lengths, the first step is to establish the discriminate models by logistic regression. These models identify the existence of residual queues in each lane at the start time of every cycle and prevent the cumulative errors induced by passage detectors or counting errors. The Kalman filter is an effective and efficient recursive process for time series analysis which is used in signal processing. To start the recursive process, the system variables, time update equations and measurement equations are set. The proportion of downstream arrivals, and the proportion of downstream discharges, are defined as the state variable and the measurement variable for cycle. In the simulations, seven models were examined, including the traditional conservation equation and the developed models that considered the discriminate models and the downstream arrivals as estimated by the Kalman filter. It was found that the calibrated discriminate models and the Kalman system parameters were effective. The proposed method performed well for the calibration set and for five different validation sets with 100 m, 200 m and 300 m upstream detectors. The results of the computer simulations showed that the real-time estimations of lane-based queue lengths based on the discriminate models and downstream arrivals as estimated by the Kalman filter outperformed the other methods. Moreover, the distance between the stop lines and the upstream detectors was an important factor for estimating the lane-based queue length, and 200 m upstream detectors were appropriate for the proposed method. This approach provided a sufficient capacity for queued vehicles and maintained a high accuracy of estimates

(Ali Gholami, 2016)In this study a simple method to obtain turning volumes from signal information in actuated non-coordinated traffic signals without using loop detector data is proposed. Regression and the adaptive neural fuzzy inference system (ANFIS) were used to build models to obtain turning volumes. The accuracy of models is defined in terms of mean absolute percent error (MAPE). At first a simulation model is built in VISSIM with different volume inputs. Then, based on this simulation a data set is produced which contains green times in each cycle during the simulation period and their corresponding volume. A model is developed for each phase/turning movement based on this data set and if errors of these models are acceptable, they can be used for future count estimation. For modeling, regression and ANFIS are used. Results show that during peak hours there is a high correlation between actuated green time and volumes at the major street. Minor street green terminates after gap out, or maximum green.

(Moghimi, Safikhani, Kamga, & Hao., 2018) In this study the behavior of the signal's cycle length under different levels of demand was analyzed, and, based on sample autocorrelation functions (ACFs), a well-known family of time series called autoregressive integrated moving average (ARIMA) was chosen for model fitting and prediction. In these model, they tried to capture the linear dependence (covariance) structure among the data points through time, and then use it to forecast the new points in the future

(Xiubin Bruce Wanga, 2018)In this paper they have studied green extension of a two-phased vehicle actuated signal at an isolated intersection between two one-way streets. The green phase is extended by a preset time interval, referred to as critical gap, from the time of a vehicle actuation at an advance detector. The green phase switches if there is no arrival during the critical gap. A signal cycle goes with a green time t_L for the major approach, followed by an All-Red interval δs, and sequentially followed by a green interval ts for the minor approach before another All-Red interval δL, where= $\delta s+ \delta L$. The cycle repeats itself onwards.

(Wu, et al., 2018)This paper proposes a mathematical model to optimize the unit extension in fully actuated signal controls that operate at an isolated intersection with two phases. The contribution of this paper is more on the understanding of the rational basis for the choice of unit extension than on the optimal values obtained. When a green phase starts, it is allocated a minimum green time. Before the expiration of the minimum green time, a unit extension is added. If a new actuation occurs before the expiration of the previous unit extension, another unit extension will be added. Otherwise, the current phase stops extension of green time if actuation on the current phase's approach does not occur or if the accumulated green time exceeds the maximum green time. The accumulated green time is counted from the actuation of the competing phase. The consideration of minimum and maximum green times indicates that our model is suitable when traffic flow is not very light or very high.

3. CONCLUSION

From the literature review following observations has been concluded.
For the evaluation of intersection,

- Fuel consumption and emission is considered.
- Delay as per queue length, and volume is considered.
- Number of phase and type of phasing at signalized intersection is considered.
- Waiting time for movement through intersection for pedestrian is considered.

At the complicated intersections at which the traffic flow is more than 4000veh/hr, that intersection is either cruciform or multiple roads intersect with the arterial roads, and there are more than three phases, it is better to use the fixed time control.

At the small or medium sized crossings, It is recommended to use the actuated signal control(whether coordinated control or semi-actuated control or fully-actuated control) Use of actuated signal control can reduce delay, emissions, and increase capacity.

At the small and T-shaped intersections, considering the pedestrian waiting time and the operation results of Vehicles, the actuated signal control is also more recommended.

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