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Mathematical Model For Minimize The Arrival Waiting Time Of Cyclic Signal System

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ABSTRACT: This paper describes the method of optimizing the efficient green signal time for interruption vehicle queue on the crossroad signal controlled junction, provided the service in sequential, vehicle service flow considered in multilane and queue parameters are described by the Poisson Process. In this paper proposed a mathematical modeling in dynamic signal time and main objective of this chapter provides the maximum service flow in various approaches of traffic signal lights to calculate the total waiting time. Queueing theory very helpful to obtain waiting time and gives the explicit solution of the problem of minimizing interruption at the crossroad junction.

1. INTRODUCTION

General theory of traffic signals focuses on the assessment of delays and increasing queue length and that result can be adoption form a signal control strategy at the individual crossroad junction, as well as on a series junction point. The queue traffic delay performance measures enter into the resolve of crossroad level of service, in the assessment of the sufficiency of lane lengths, and in the view of fuel consumption and emissions. The following material emphasizes the theory of descriptive models of traffic flow as opposed to prescriptive model is that a better accepting of the interaction between supply and traffic at traffic signals is a requirement to the formulation of optimal signal control strategies. Performance assessment is based on assumptions on the subject of traffic signal parameter (arrival and service). In general, at present interruption models at cross roads are described in terms of a deterministic and stochastic component to reflect both the flowing and random properties of traffic flow. The deterministic module of traffic is founded on the fluid theory of traffic in which demand and service are treated as continuous variables described by flow rates which vary over the time and space domain. The stochastic component of interruptions is founded on steady state queueing theory which defines the traffic parameter (service and arrival) distribution. In a suitable queueing models are used to communicate the resulting distribution of the performance actions. But the theory of unsignalized junction area is representative of a purely stochastic move toward to be formative traffic performance. Models which integrate both deterministic and stochastic components of routine traffic are very attractive in the traffic area signals since they can be functional to a wide range of traffic intensities, as well as to various types of signal control. They are approximations of more tentatively accurate models, in which interruption terms that are numerically insignificant to the final result have been dropped. Because of their effortlessness they have established greater awareness since the original work by Webster (1958) and have been integrated in various crossroad control and analysis tools throughout the world. This chapter traces the development of interruption and queue length models for traffic signals. Chronologically language, near the beginning model efforts in this area listening carefully on the adjustment of steady state queueing theory to analysis the random component of interruptions and queues at crossroad junctions. This approach was valid as the common flow rate does not exceed the common capacity rate. In this case, steady state balance equation is achieved and expectations of interruption queues are finite and therefore can be predictable by the theory. The traffic parameter assumptions made surplus of steady state queueing models were developed in the text. As traffic flow rate move toward or exceed the facility rate, as a minimum for a finite duration period, the hypothesis of steady state models are desecrated from the time when a state of stochastic equilibrium cannot be achieved. In comeback to need for improved assessment of routine traffic in both under and oversaturated situation, and the lack of a tentatively thorough move towards to the problem, other methods were pursued. The required time dependent behavior has been adopted in different capacity in the foreign country. An additional restriction of steady state queueing hypothesis of confident types of arrival process at the signal, whereas the valid case of an isolated signal, in this consideration does not replicate the impact of adjoining signals and be in charge of which may change the model and number of arrival at a downstream signal. Therefore routine traffic system signal will be different significantly from that at a remote signal. For example, traffic management signal will be likely to minimize the interruption and the arrival process will be unusual signal (red and green) for each phase. The levels of skill advantage are rather than unresponsive due to the spreading of platoons connecting signals. The metering reflects the finite capacity of the vital junction which tends to abbreviate the arrival process of the next signal. This approach in which these controls affect the routine traffic system is quite varied and therefore difficult to the model in universal approach. Jianhua Guo et al [10] introduced a new method for area-wide traffic signal timing optimization under user equilibrium traffic. The optimization model was formulated as a multi-dimensional search problem aimed to achieve minimized product of the total travel time associated with urban street network and the variance of travel time for unit distance of travel. Gustav Nilsson _ Giacomo Como [5] focused on a class of dynamic feedback traffic signal control policies that are based on a generalized proportional allocation rule. Junchen Jin and Xiaoliang Ma [11] proposed a group-based signal control approach capable of making decisions based on its understanding of traffic conditions at the intersection level. Nasser R. Sabar et al [17] controlled the movement of traffic on urban streets by determined the appropriate signal timing settings. Proposed algorithm was based on the so-called combines the strengths of the genetic algorithm and local search in an adaptive manner. Mohammad Aslani et al [13] utilized RL (Reinforcement learning) algorithms to design adaptive traffic signal controllers called actor-critic adaptive traffic signal controllers (A-CATs controllers). Huajun Chai et al[7] captured the interaction between travellers' route choice and traffic signal control in a coherent framework. Ekinhan Eriskin et al[3] suggested a new method for designing traffic signal timing at oversaturated intersections was expressed "the elimination pairing system". An object function with vehicle delay and stop-start numbers has been generated. Total cost value has been calculated according to the object function. Obtained results were compared with Webster as a traditional traffic signal timing design method. Shailendra Tahilyani et.at.[20] developed a new lane bypass algorithm for route diversion given a result in smooth traffic flow on the urban road network. Genetic algorithms are utilized for the parameter optimization. Ishant Sharma and Dr. Pardeep K. Gupta[9] proposed to replace existed traffic signals with a system that are monitored the traffic flow automatically in traffic signal and sensors are fixed in which so the time feed are made dynamic and automatic by processed the live detection. Chandrasekhar.M et.al. [1] Suggested a system that implement image processing algorithm in real time traffic light control which will control the traffic light efficiently. Ramteke Mahesh K. et.al.[19] Proposed FPGA (Field Programmable Gate Array) controller based on Neuro-Fuzzy system thought provided effective solution for Traffic Control. It can used to minimize drawbacks of the conventional traffic controllers with the accuracy of provided variation in green cycle intervals based on the heavy traffic loads that changed at every lane in a four leg intersection. Naren Athmaraman and Srivathsan Soundararajan [16] introduced an adaptive predictive signal control system that performed real time queue length estimation and employed an efficient signal coordination algorithm with APTTCA-based system. Pavan Kumar and Dr. M. Kamala kumara [21] studied adaptive traffic control systems with VANET, Focused on reliable traffic prediction approaches and various types of adaptive traffic control algorithms also proposed a mobile crowd sensing technology to support dynamic route choices for drivers to avoid congestion. Suggested crowd sourcing can be one of the best options for Adaptive traffic control system for India. Zheng [23](2004) has developed a function to convert queue length into green time for the mixed traffic condition from the observed clearance times of different types of vehicles in the queue with different positions. Using this function and detected queue length a procedure for adaptive traffic control signal (ATCS) is developed, which in turn adjusts the traffic signal control adaptively. [12] Kadiya and Varia (2010) have presented a methodology to coordinate the signals in two-way directions on the busy urban corridor. They have suggested two-phase plans and their suitability for the satisfactory coordination in odd and even phase differences between two signals. [14] Martin Anokye et al (2013) discuss the application of queuing theory to vehicle traffic at signalized intersection using a case study of Kumasi Ashati Region Ghana.[15]Mala et al (2016) focus on the minimalism of traffic congestion by using queuing theory. Chao et al.[2] (2009) and Quddus et al.[18] (2010) argue that the level of traffic congestion does not affect the severity of road crashes on the M25 motorway. The impact of traffic flow on the severity of crashes, however, showed an interesting result. Yannis et al [22] develop ordered logic models to provide insight into the human-factors' aspect of the introduction of advanced technologies to the sensitive segments of driver population.[6] Glen et al. (2003) show how congestion-reduction strategies can induce additional traffic as a result of economic benefits. [18] Qingyu et al. (2007) suggest a base for the implementation of urban road congestion pricing and other travel management strategies after analyzing the production mechanism of urban traffic congestion. They found that travelers overlook the negative externality of urban traffic congestion and join the congested queues.

2. INTERRUPTION MODELS AT INACCESSIBLE SIGNALS

Previously conformed the interruption models include both deterministic and stochastic components of routine traffic. The following assumption are predictable to the deterministic component as follows: (i) Consider the initial queue length is zero to beginning the green phase (ii) consistent arrival flow rate (q) right through the cycle (iii) consistent service rate at the dispersion flow rate (S) at the same time as a queue is present, and at the arrival rate when the queue vanishes (d) the limitation of signal capacity is more than the arrival pattern, it defined as the manufacture consumption of move towards diffusion flow rate (S) and is efficient for the ratio of green cycle (g/c). The portion of efficient green time is where as flows are continued at the level of diffusion flow rate and it's consider the initial time set-up is zero for the green signal time min and permission the end time period. The routine traffic measure can be draw from the average interruption per vehicle (total delay divided by the total cyclic arrivals) and stopped the number of arriving vehicle (Q_s), the number of vehicle reach the queue level in maximum ($Q_{\max}$) and the average queue length (Q_{avg}). The routine traffic model of this type is appropriate to low flow capacity ratio. Since the hypothesis made initial case is zero and most of the queue end is not violated, if the queue cyclic time is failure then increase the traffic intensity ratio. But some cycles will start occurrence an overflow vehicle queue does not release from the prior cycle length. This happening occurs at random depending on which cycle happens to experience higher than capacity flow rates. The incidences of an initial queue cause an additional interruption which must be measured in the assessment of traffic performance. The interruption based models on queue theory have been functional to the account for this effect. The effect of stochastic queueing model minimal comparison of oversaturation queue sizes. Consequently, a fluid theory behavior may be suitable to the use of highly oversaturated crossroad junction. So interruption model remove the gaps that are relevant to the rang of traffic flow and numerically close to the signal capacity. In view of real world signals are time to function within the area, the value of time dependent models are of exacting significance for this different situation. Such cases managing the vehicle control neither the green time nor the queue length in advance. In partly determined the green length parameters controller such as optimized the green times in the rate of arrival process. In the simplest case of total green time is away from it minimum such as (i) arriving vehicle time beyond the unit extension controller (U) (ii) does not reached the maximum green time.

3. WAITING TIME FOR INTERRUPTION MODEL

The models characterize based traffic interruptions based on statistical distribution of queueing parameters. Because of its fully theoretical model and considered the consistent valid assumptions. The next section describe the how to predictable the interruption model including the essential data requirements. The average interruption model fixed the time signal and very first derived by Beckman (1956) with the hypothesis of arrival process consider in binomial and deterministic the departure rate and the Fig(i) mathematical diagram as follows:

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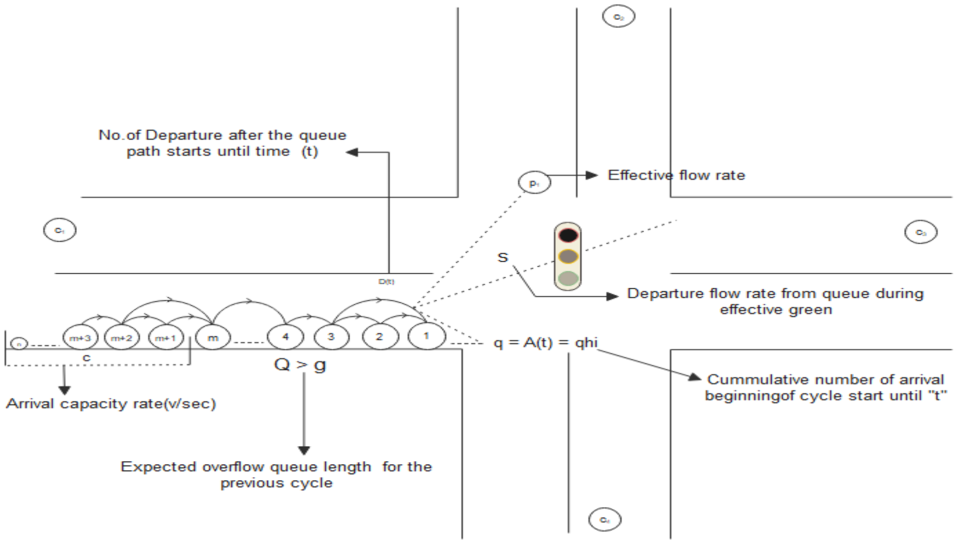

Fig:4.1 Mathematical Model for Interruption traffic management system

$$d = \frac{c-g}{c(1-p/S)}\left[\frac{Q_0}{q} + \frac{c-g+1}{2}\right] -------(3.1)$$

Where
c - length of signal cycle (sec)
g- Effective signal time for green
q -rate of traffic flow
S – Maximum service flow rate during the green signal time from queue
Q_0 - Queue length for previous cycle overflow rate.

Here used the overflow queue formula and limiting hypothesis reduce the real-time effectiveness. Analyzed the average interruption at the nearby signals to turning the vehicle crossing in a Poisson manner. Whatever its does not include the outcome of turners on other vehicle interruption. (1964) Darroch studied the arriving vehicle in single condensation at signal time are fixed. Considered the arrival pattern in Poisson process and index of distribution is

$$I = \frac{\text{var}(A)}{qh} ------(3.2)$$

Where q- Total arrival flow rate
h –length of interval
A_i – Number of arrivals in i^{th} the queue during the interval “h”

The service process can be provided by flexible and may comprise the attempt of a disparate flow by the addition queue length. The resultant model very difficult and they consist of the elements requiring for advance modeling such as queue overflow. McNeil (1968) derived the formula for average signal delay with the statement of arrival process in general and consistent service time. The following works express the total vehicle interruption during a signal cycle length as sum of four components.

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$$W_k = \sum_{i=1}^{4} w_{k_i} ------(3.3)$$

where w_{k_i} - total interruption vehicle waiting time during k phase for the i^th direction.

w_{k_1}- Represents the total interruption vehicle experience in the green phase and $w_{k_2}, w_{k_3} \& w_{k_4}$ - Represents the total interruption vehicle experience in the red phase.

Therefore

$$(w_{k1}) = \left(\sum_{t=0}^{c_1=c-g} Q_0\right) + \left(\sum_{t=0}^{c_1=c-g} A(t)\right)$$

$$= Q_0\, c_1 + \left(\sum_{t=0}^{c_1=c-g} A(t)\right)$$

$$= Q_0\, c_1 + (A(0) + A(1) + A(2) + ...A(c_1))) \quad ---------(3.4)$$

$$= Q_0\, c_1 + q\left[\frac{(c_1)^{n+1} - 1}{c_1 - 1}\right] \quad h > 1$$

Where A(t)- Represents the cumulative arrival a time "t", Q(t) – Represents the total vehicle queue at a time "t".

Similarly, Remaining values are calculated as follows:

$$W_{k_2} = \sum_{y=C_1}^{C_1+C_2} Q(t),\ W_{k_3} = \sum_{t=C_1+C_2}^{C_1+C_2+C_3} Q(t),\ W_{k_k} = \sum_{t=C_1+C_2+C_3}^{C} Q(t)$$

The expectation in equation (4.3), we get

$$E(w_{k1}) = C_1 Q(0) + q\left[\frac{(c_1)^{n+1} - 1}{h - 1}\right] \quad h > 1 ----- (3.5)$$

In a paper (1) introduced the effective service lane and using the result can be assumed that the service flow rate k_i in each direction and is defined as:

$$E(V_i) = S\frac{k_i}{q}$$

In this case the departure rate does not equal to S. So service rates are varying for each case. If the traffic signal is infinite, let us define the random variable V_1 as the total interruption vehicle experience during this phase. Therefore, the busy period, total waiting time can be considered Q(t) with Poisson arrival of strength "q", consistent service time ($1/s_i$) and initial system state $Q(t_0)$.

Therefore

$$E(V_1) = \frac{E(Q(t_0))}{2S_1\left(1 - \frac{q}{S_1}\right)^2} + \frac{E(Q^2(t_0))}{2S_1\left(1 - \frac{q}{S_1}\right)} ----- (3.6)$$

Now w_{k_1} can be expressed in the form of V_1:

$$E(w_{k_1}) = E(V_1 / Q(t = c_1) - E(V_1 / Q(t = 0))$$

Where $E[Q(c-g)-Q(0)] = 2E(A(c-g)) = q(c-g)$

$$E[Q^2(c-g)-Q^2(0)] = 2E(A(c-g))E(Q_0)+E(A^2(c-g))$$
$$= 2q(c-g)Q_0 + q^2(c-g)^2 + q(c-g)I$$

and it follows that

$$E(w_{k_1}) = \frac{E(Q(c_1)-Q(0))}{2S_1\left(1-\frac{q}{S_1}\right)^2} + \frac{E(Q^2(c_1))-E(Q^2(0))}{2S_1\left(1-\frac{q}{S_1}\right)^2} --------(3.7)$$

Similarly for the remaining phases

Here $A(c_{k_i})$ is equal to the number of arriving vehicle, Average service rate at the ith direction is $S_i c_i$ and Surplus service flow rate of each direction

$P_i = q_i - E(s_i)$.

In any general arrival and departure Process

$Q(c) = Q_0 + A - c + \Delta c$

$Q(c)$ = Vehicle queue at the end of cycle

$Q(0)$ = Vehicle queue at the beginning of cycle

A = Number of arrival during cycle

C = Maximum Possible number of departure during green

Δc = reserve capacity in cycle equal to $(c - Q(0) - A)$, if $Q(0) + A < c$ zero, otherwise $E(\Delta c) = E(c - A)$

Then $E(Q(c_1) - A(c_1) - (Q(0) - A(0)) + S_1 c_1 = 0$

$$E(Q(c_1) - Q(0)) = -S_1 c_1 + E(A(c_1) - A(0)) = -S_1 c_1 + c_1(q - s_1) = c_1 P_1$$
$$E(Q(c_1)) = c_1 P_1 + Q_0$$

Similarly, $E(Q(c_1+c_2) - A(c_1+c_2)) - (Q(c_1) - A(c_1)) = -S_2 c_2 + qc_2 = c_2(q - s_2) = c_2 P_2$

$$E(Q(c_1+c_2)) = c_2 P_2 + c_1 P_1 + Q_0$$
$$E(Q(c_1+c_2+c_3) - A(c_1+c_2+c_3)) - (Q(c_1+c_2) - A(c_1+c_2)) = c_3 P_3$$
$$E(Q(c_1+c_2+c_3)) = c_3 P_3 + c_2 P_2 + c_1 P_1 + Q_0$$

$$E(Q(c) - A(c)) - (Q(c_1+c_2+c_3) - A(c_1+c_2+c_3)) = c_4 P_4$$
$$E(Q(c)) = c_4 P_4 + c_3 P_3 + c_2 P_2 + c_1 P_1 + Q_0$$

Thus

$$E(Q^2(c_1+c_2)) - E(Q^2(c_1)) = 2E(Q(c_1+c_2) - Q(c_1) * E(Q(c_1)) + E(Q(c_1+c_2) - Q(c_1))^2$$

Using the above value finally we get

$$E(Q^2(c_1+c_2)) - E(Q^2(c_1)) = 2c_2 P_2 * (Q_0 + c_1 P_1) + P_2^2 c_2^2 + qc_2$$
$$E(Q^2(c_1+c_2+c_3)) - E(Q^2(c_1+c_2)) = 2c_3 P_3 * (Q_0 + c_1 P_1 + c_2 P_2) + P_3^2 c_3^2 + qc_3$$
$$E(Q^2(c)) - E(Q^2(c_1+c_2+c_3)) = 2c_4 P_4 * (Q_0 + c_1 P_1 + c_2 P_2 + c_3 P_3) + P_4^2 c_4^2 + qc_4$$

From the above equation as follows

$$E(w_{k_1}) = \frac{E(Q(c_1)) - Q(0))}{2S_1\left(1-\frac{q}{S_1}\right)^2} + \frac{E(Q^2(c_1)) - E(Q^2(0))}{2S_1\left(1-\frac{q}{S_1}\right)} = c_1Q_0 + \frac{P_1\left((c_1)^{n+1}-1\right)^2}{2(c_1-1)} + \frac{c_1S_1}{2P_1}$$

$$E(w_{k_2}) = \frac{P_2\left((c_2)^{n+1}-1\right)^2}{2(c_2-1)} + c_2(Q_0 + P_1c_1) + \frac{c_2}{2}$$

$$E(w_{k_3}) = \frac{P_3\left((c_3)^{n+1}-1\right)^2}{2(c_3-1)} + c_3(Q_0 + P_1c_1 + P_2c_2) + \frac{c_3}{2}$$

$$E(w_{k_3}) = \frac{P_4\left((c_4)^{n+1}-1\right)^2}{2(c_4-1)} + c_4(Q_0 + P_1c_1 + P_2c_2 + P_3c_3) + \frac{c_4}{2}$$

We are simplifying and calculating the all the values. In this case Initial phase value and maximum service flow rate is zero

$$E(w_{k_1}) = c_1Q_0 + \frac{P_1\left((c_1)^{n+1}-1\right)^2}{2(c_1-1)} + \frac{c_1S_1}{2P_1} = c_1Q_0 + q\left(\frac{(c_1)^{n+1}-1}{c_1-1}\right) - - - - - (3.8)$$

So, we finished that the calculations are not differing.
Using the remaining equation, we obtain the interruption queue vehicle total waiting time is

$$E(W) = E(w_{k_1}) + E(w_{k_2}) + E(w_{k_3}) + E(w_{k_4}) \quad - - - - - (3.9)$$

In this model very simple and do not take into financial credit. Because initially not immediate to the moving vehicle after the transform of traffic light phase, but it is satisfactory to solve the problem of optimizing with the beloved capacity.

4. CONCLUSION

In this chapter, we proposed a mathematical modelling traffic light signal restricted to the cross road intersection of traffic flow in queueing theory. Effective number of lane discussed in interruption model and reduces the minimization of average total failure time on the traffic signal controlled in junction area and it's show that the methods of queueing theory to helpful to obtain the explicit formula delays encountered when crossing the intersection.

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