Innovative ITS Technologies for Reducing Traffic Impacts at Bangkok Intersections

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Traffic flow at urban intersections in Bangkok is characterized by long queues and drivers' frustration which has led to road accidents caused by drivers' disobedience of traffic signals. This paper describes the development of two innovative ITS technologies to improve traffic flow and to remedy traffic accidents at intersections. The first ITS technology is an Adaptive Traffic Signalization System that uses CCTV cameras, telecommunication wiring and wireless system, and image sensing software to detect vehicles on each approach of an intersection; the number of vehicles passing a Virtual Loop is then used to set the amber and the all red times, at the same time, this vehicle data is sent to servers at the control room which calculate the adaptive cycle times, optimum phasing, as well as the offset times. The second ITS technology is used to track lane changing and speeding of vehicles when approaching the intersections. In addition, the fuel consumption of vehicles and the applied VMS –Variable Message Signs will be taken into consideration.

Key Words : *ITS, Adaptive Traffic Signalization System, Virtual Loop, Vehicle Tracking*

1. INTRODUCTION

Congestion, and the resulting wasteful fuel consumption, and accident at urban intersections are the three common traffic impacts found in Bangkok. The causes of the long delays are engineering in nature and therefore can be addressed by applying appropriate engineering solution. While congestion and wasteful fuel consumption are perennial problems in most big cities, its negative influence has increased several impacts such as, the rising road user cost, the higher level of emission and pollution, and the risk of accidents in Bangkok. The technologies were developed and tested at two intersections in Bangkok (1). There are two phases of crash data:

(a) Crash Data during 2005 -2008, they were used to analyze the causes of accidents at intersections. The two pilot Bangkok intersections had been identified as black spot since there were more than 5 accidents per year (2). It was found that the major causes of accidents were drivers' disobedience of traffic laws and malfunction of the equipments. The authors‘ Intelligent Technology Systems (ITS) technology has been applied to mitigate the traffic impacts at these intersections. In case of the before situation, the two signalised intersections, which are 460 meter apart were controlled by the Fixed Time System (Designed and Built from the Factory).

(b) Crash Data during 2009 -2011, major accidents are caused by speeding and dangerous changing lane maneuver and the number of accidents are 3 per year.

2. THE APPLIED ITS TECHNOLOGY

The Technology is divided into *two main parts* as follows:

(a) The Adaptive Traffic Signalization and Application to Red Light Running:

(1) Calculated Optimum Cycle Times and Phasing under the Fixed Times System. The calculated cycle times and phasing at intersections as produced by SIDRA(3) and Synchro(4) were input as the optimum cycle times and phasing of the 3 and 4- leg pilot intersections. Before running the software, PCU (Passenger Car Unit) is defined by the researchers as follows:

$$PCU_x = [q_{pc-x/(WL)}] / [q_{x-x/(WL)}] \quad (1a)$$

where PCUx is PCU for x vehicle, q_{pc-x} is traffic flow rate of passenger car following passenger car or passenger car following other types of vehicles, q_{x-x} is traffic flow rate of other types of vehicles following other types of vehicles and WL is lane width per direction. Therefore, the results of PCU are 1.00 for Passenger Car, 0.70 for Motorcycle, 2.07 for Light Truck, 3.16 for Bus, and 3.82 for Truck. Moreover, the outputs for cycle times and number of phases are 150 seconds and 3 phases for the 3- leg and 90 seconds and 2 phases for the 4- leg intersection respectively.

(2) Synchronization of Traffic Light. The offset times between the 3 and 4- leg intersections (local people prefer driving under these phases) are calculated using the method of ARRB –Australian Road Research Board (4,5). The offset time within 460 meters is 34 seconds under the speed of 60 km/hr.

(3) The Classified Traffic Count and the 'Virtual Loop'Traffic Detector based on Image Sensing Technique. Referring to open source coding in the developed software (6); passing vehicles are detected and counted when they pass through a rectangular box or virtual loop. The process of the system starts from the collected VDO –Streaming at Analog Cameras and the VDO is compressed by MPEG4 encoder so as to send the images to Servers by routers. Morevoer, the noise reduction and image enhancement techniques, tracking vehicles on the foreground / background (FG/BG) detection by the deleted images between FG and BG (refer to: Fig. 1) are taken into account. In case of Virtual Loop Detector, there are two functions as described below.

Fig. 1 FG and BG and vehicles on FG detection technique

The classified vehicles – software. It is based on the process of motion techniques. Therefore, the process can distinguish between static and dynamic objects such as, electrical poles, and traffic signs, etc. The collected data are checked and rechecked with the prototypes of vehicles (sizes – width and length) prerecorded in a server. However, the Length and Height of vehicles will cause small error in the classified results and will need adjustments.

The traffic detector. The developed software for image sensing calculates and evaluates the frame by frame of images. Therefore, the triggered vehicles are detected when passing the virtual loops and they are sent as signalized data to a traffic controller.

(4) Algorithm for Calculation of Cycle Times and Phasing. The movements at the 3-leg intersection are in 6 directions, 2 movements of left turn directions are free flow. In case of the 4- leg intersection, there are 10 directions and two of them are left turn –free flow or un-prohibited. The normal Phases and Offset Phase are presented in the following parts (refer to: Fig. 2).

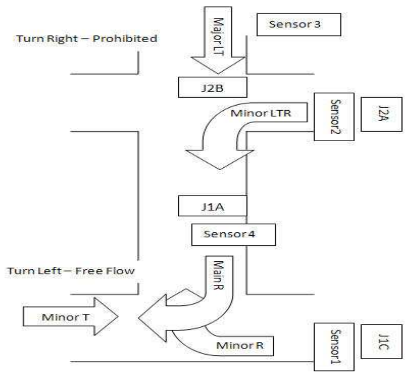

Fig. 2 Sensors or virtual loops – locations and Phasings

Normal Phase Algorithm. There are 3 phases at the 3- leg intersection and cycle times are varied based on the traffic volumes at different period of times. During peak hour, headways of vehicles passing through the virtual loop are within 5 seconds and the characteristic of traffic flow is steady state –steady flow therefore, the cycle times is extended up to maximum green times of J1-A,B, and C (from calculation of SIDRA and Synchro). In case of the 4- leg intersection, phases J2-A and B are also the same as the J1A, B, and C's concepts.

Additional Algorithm (Offset or Green Wave Concept). The offset times -phase or green wave –phase are proposed for the vehicles passing from one intersection to the other intersection such as, the group of direction flow of J2-B phase and J1-A phase, the group of J1-C Phase and J2-B, and the group of J2-A and J1-A. The offset times were as mentioned before and were calculated based on the method of ARRB –Australian Road Research Board (4). In the case of J2-B and J2-A to J1-A direction, 34 seconds of offset times was taken into consideration and it was subtracted with the amber and all red times (7 seconds). Therefore, 27 seconds of offset times is proposed for the green wave phase. As for J1-C to J2-B direction, the 28 seconds comes from the difference values of 34 seconds (offset times) and 6 seconds (3 seconds -amber times and 3 seconds –all red times).

(b) Lane Changing Model: Coordinate (x,y) is evaluated from the pixels frame by frame in the avi.file, however, the process of angle and length calibration is taken into consideration. The calculation of speed depends on the time-frame. Moreover, the reference points of coordinates (x_1,y_1) and (x_2,y_2) (refer to Fig. 3) are marked as the standard length (1 meter) in the software. The VDO frames are applied with the Blob functions and the first and last frames are checked for the positions and length**.** In case of time frame, the absolute values of (t_2-t_1) which are more than threshold values (checking status of moving vehicle) are taken into account.

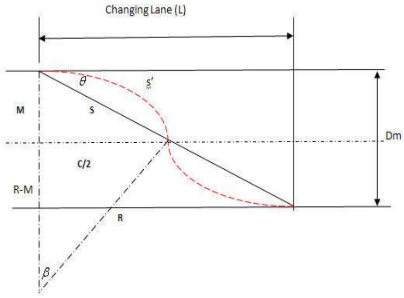

Fig. 3 The Changing Lane Path of Vehicle

Fuel Consumption Model

In addition, the fuel consumption model was taken into consideration. There are three models of popular passenger cars in Thailand with engine capacity 1.6 L, 1.8 L, 2.0 L. For the pilot study the testing length is 3 km., the speed data were collected from zero to 80 kph., and the fuel consumption (L/100 km.) was measured and displayed by the speedometer .

3. RESULTS OF THE APPLICATION OF THE NEW ITS CONCEPTS.

Traffic data collected since September 2008 (real time) were evaluated using statistical methods. There are presented in three parts. The first is the traffic factors of traffic signalization and lane changing model equations, the second, the results of traffic accidents and traffic indicators for the mitigation of problems, and the third, the fuel consumption model**.**

(a) The evaluated traffic factors equations:

(1) In case of Traffic Signalization. The following equations were derived from the collected field data.

$$v = 1.16115 \times \lambda - \frac{1.36164}{\cos(125.776\,\lambda)} \tag{1a}$$

$$g_e = 12.7998 \times (52.923 \times e^{0.0056\,\lambda}) - 635.59 \tag{1b}$$

Where v is the average speed (kph), g_e is the Effective Green Time (seconds), λ is the arrival rate defined as (PCU/min). The correlation coefficients for both equations were 0.901 and 0.799, respectively.

(2) In case of Lane Changing. The equations below were formulated from the collected real time data.

$$M = \max\left[0.454652 + \frac{0.269666 \times v}{\operatorname{atan}(\lambda)},\quad 8.20255\right] \tag{2a}$$

$$L = 2 \times \frac{\sqrt{(V_f \times \frac{1000}{3600})^2}}{9.81(0.025+0.15)} \times D_m \times \cos(\frac{\theta}{180} \times 3.14592) \tag{2b}$$

$$V_f = 0.0572063 \times \theta + 1.33585 \times L + \sin(L) + \frac{0.0694052 \times \theta}{L} \tag{2c}$$

$$SSD = 0.0896671 \times V_f^2 \tag{2d}$$

$$ASL > ACLL > \mathrm{SSD} \tag{2e}$$

Where M is the Average Spacing, L is the Average Length of Changing Lane, λ is the Arrival *Rate* defined as (PCU/sec), V_f is the Final Speed, θ is the Angle of Changing lane, ASL is Average Sapcing Length, ACLL is Average Changing Lane Length, SSD is the Stoping Sight Distance. The correlation coefficients for the equations are 1.00, 0.997, 0.997, and 0.995, respectively.

(3) In case of Fuel Consumption. The following equations were derived from the recorded field data:

y = 21.94 + -0.2699*x + -0.05226*x^2 + 0.002685*x^3 + -5.401e-5*x^4 + 5.069e-7*x^5 + -1.843e-9*x^6 (3a)

y = 2.195 + 14/max(0.6139, 0.08073*x) (3b)

$$y = 19.21 + 0.1414*\max(x, 65.12) + -0.66/\tanh(x - 14.64) - \max(1.713 + \mathrm{sqrt}(0.1338 + x), \min(x, 23.4)-2.121) \quad (3c)$$

Where y is the Fuel Consumption (L/100 km.) and x is Speed (km/hr). The correlation coefficients for the equations are 0.984, 0.982, and 0.992, respectively.

(b) Impact of the New ITS Technology:

From the collected data, it is seen that the existing speed of vehicle approaching an intersection is more than 45 kph. This has led to the increase of number of accidents in the risky areas, 100 m from the stop line. The obseverved traffic situation and number accidents,and the car fuel consumption before and after application of the ITS technology are described in the next section.

(1) The observed traffic indicators. Before the application of the ITS technology, queue lenght at the 3 and 4- leg intersections are 420 and 890 metres respectively. After the application, queue lenght are 0 – 125 and 0 – 155 metres, respectively as shown in Figure 4.

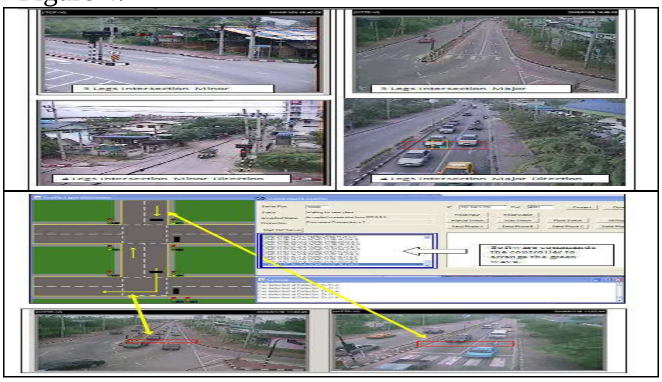

Fig. 4 Traffic Synchronization and Decreased Queue Length

(2) The observed number of accidents. The number of major accidents between 2005 and 2008 are red light running, after application of the ITS technologies, the major accidents decrease substantislly. However, in 2009,the major causes of traffic accidents were speeding and dangerous lane changing. For Example, there were two crashes during 3:15 pm to 3:50 pm on Monday 7th June 2009. This was caused by the fact that the drivers were in a hurry to pick up their children at schools. So, they swiftly changed lane to find the nearest space to the stop line during the red period. The number of speeding and lane changing accidents have decreased during the year 2009 to 2010. The situation regarding the number vehicles which change lane dangerously before and after the deployment of VMS is that the number of changing lane vehicles without VMS was 47 vehicle/ hour, with VMS but without warning message, 29 vehicles /hour, and with VMS and the “FINE 500 THB” message, 20 vehicle/hour. Therefore,it is clear that the number of changing lane and speeding vehicles decrease drastically with the installation of VMS with the warning message. Moreover, it can be seen that trend in the number of accidents has declined substantially.

(3) The observed fuel consumption. The car fuel consumption before and after situations are 12.906, 11.867 L/100 KM per PCU/90 MINS for engine> 2000 cc and 10.276, 8.968 L/100 KM per PCU/90 MINS for engine < 2000 cc.

4. CONCLUSIONS

The main causes of the problems are red light running, speeding, poor lane changing behavior, and drunk driving. Several policies were formulated to remedy the situation. The installation of the new system including the traffic synchronization, vehicle lane changing and speeding model, VMS and new software has been shown to be effective in reducing the number of these traffic violations especially, the number of red light running, speeding and poor lane changing vehicle has dropped significantly resulting in the decreasing number of crashes at the intersections. In addition, the car fuel consumption shows significant reduction of around 10% after the ITS implementation. As a consequence, the quality of life of Thai drivers are better.

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