The First Adaptive Traffic Controller in Bangkok: The Intelligent Intersections Project

Oravit HEMACHUDHA
Deputy Director-General
Traffic and Transportation Department
Bangkok Metropolitan Administration
44 Vibhavadi Rangsit Road
Din Daeng, Bangkok 10400, Thailand
Fax: +62-354-1201
E-mail: oravit@hotmail.com

Prapas LUEANGSIRINAPHA
Chief of Traffic Signal Section
Traffic and Transportation Department
Bangkok Metropolitan Administration
44 Vibhavadi Rangsit Road
Din Daeng, Bangkok 10400, Thailand
Fax: +662-354-1234-5
E-mail: prapas2205@yahoo.com

Kittipon MOONJUD
Electrical Engineer
Traffic Engineering Office
Traffic and Transportation Department
Bangkok Metropolitan Administration
44 Vibhavadi Rangsit Road
Din Daeng, Bangkok 10400, Thailand
Fax: +662-354-1234-5
E-mail: tongs_93@hotmail.com

Sitisak SANGTHONG
Electrical Engineer
Traffic Engineering Office
Traffic and Transportation Department
Bangkok Metropolitan Administration
44 Vibhavadi Rangsit Road
Din Daeng, Bangkok 10400, Thailand
Fax: +662-354-1234-5
E-mail: sangthong_sit@hotmail.com

Bhornpravas YAMPRASERT
Electrical Engineer
Traffic Engineering Office
Traffic and Transportation Department
Bangkok Metropolitan Administration
44 Vibhavadi Rangsit Road
Din Daeng, Bangkok 10400, Thailand
Fax: +662-354-1234-5
E-mail: phanumas@bangkok.go.th

Panumas UNHASUT
Software Engineer
Genius Traffic System Co.,Ltd.
226/27-29 Phaholyothin Road
Samsennai, Phayathai
Bangkok 10400, Thailand
Fax: +662-615-2441
E-mail: panumas@gets.co.th

Boonya TANTIPANICHAPHAN
Executive Director
Genius Traffic System Co.,Ltd.
226/27-29 Phaholyothin Road
Samsennai, Phayathai
Bangkok 10400, Thailand
Fax: +662-615-2441
E-mail: boonya@gets.co.th

Sutat NANTHASRIVIWAT
Civil Engineer
Traffic and Transportation Department
44 Vibhavadirangsit Road
Dindaeng, Bangkok 10400
Fax: +662-354-1230
MP: +668 483 5610
E-mail: nansutat@hotmail.com

Abstract: More than 500 signalized intersections have been introduced in Bangkok. By law, the traffic management is under the Royal Police Office which will be transferred to the local governments while installation and maintenance of traffic control devices (traffic signs, marking, signals) is under the local governments. Pre-timed controllers with different time plan of the day have been set and fine tuned for each intersection during off-peak periods. During peak periods, the Police Command Center with hand-radio reporting and CCTV with
experienced policeman at each intersection controller assigns the phasing for each leg of the intersection. Complaints arise at isolated intersections where drivers have to stop without incoming traffic from other directions. Adaptive traffic controllers with additional detectors to detect intersection blockage with Fuzzy Logic Algorithm have been installed at 5 isolated intersections in Bangkok. Favorable results on operation were observed and value of time saving of at least 1,000,000 Baht per year per intersection was estimated.

**Key Words:** adaptive traffic control, value of time saving, signalized intersection

1. INTRODUCTION

The Intelligent Intersections Project is a traffic lights controlling system for single intersection that can process and change the traffic signal timing according to traffic conditions at certain time period in real-time. The detectors detect the in–out traffic volumes and send traffic data to a computer in the controller cabinet at the intersection to calculate the optimal signal timing for each phase of the intersection. In other words, the system has an ability to detect and adjust the appropriate timing for the traffic conditions at any time of day. The adaptive traffic controller Intersections are different from traditional pre-timed intersections which cannot adjust the signal timing to the actual traffic conditions. The conceptual diagram is shown in Figure 1.

**Traditional System (Fixed-Time)** is a one-way communication with fixed signal timing. No real-time traffic data is considered for processing, which is inflexible and inconsistent with the phase duration and the instant traffic conditions.

**The new system (Adaptive)** is equipped with the detectors to measure real-time traffic volume and vehicle occupancy. The system has the processing computer to analyze and decide an appropriate timing for each leg in accordance with the actual traffic conditions in each phase of the intersection.
2. EXPECTED CAPABILITY

This traffic adaptive controller system has been designed with the following capabilities.

2.1 Improve Suitable Signal Timing for Actual Traffic Volume

The computer takes the traffic condition information from the detectors to calculate and decides signal timing using Fuzzy Logic Algorithm. It can adjust the traffic signal timing in accordance with the volume of traffic on each leg of the intersection. The system will gradually and continuously increase or decrease signal durations in every time period of the traffic signal operations.

2.2 Reduce the Loss of Waiting Time

The new system reduces the loss of total waiting time (delay) at the intersection. The system detects the traffic volume and congestion in each leg, and shortens the green time of the low traffic volume leg(s) while adjusting efficient green time for other legs to achieve an efficient control of the traffic. Informing car drivers for reduced green time is done by flashing the countdown device.

2.3 Prevent Overflow at Intersection (Intersection Blockage)

In case of detecting intersection blockage or traffic overflow, the system shortens green time in that direction to prevent more accumulated blockage. Flashing of the countdown device is on to inform the drivers.

2.4 Manual Control Availability

The system can operate in the traditional mode in situation where traffic condition requires officers to resolve complicated problems.

2.5 System Stability

If the system detects irregular condition, or the processing computer does not work properly, the system will automatically revert to use the fixed time plan control.

2.6 Data Recording

The system can save data on traffic conditions and signal timing in both automatic and manual mode. The recorded data can be browsed back for further analysis and adjustments.

3. METHODOLOGY

This project (Phase 1) was conducted at 5 intersections in Bangkok:

1. Phokaew Intersection, Nawamin Road - Phokaew Road
2. Nimit Mai Intersection, Nimit Mai Road - Hatai Rat Road
3. King Kaew Intersection, Onnut Ladkrabang Road - King Kaew Road
4. Krungthepkreetha Intersection, Srinakarin Road
5. Thawonthawat Intersection, Patthanakarn – Soi Patthanakarn 25

as shown in Figure 2.
Installation of devices is shown in Figure 3 where two additional devices were installed:

1) **The detector for measuring traffic condition**: install induction coils under the road surface to detect traffic conditions by counting the number of vehicles that pass the device.

2) **The processing computer**: the computer system is used to process data received from the detectors and to decide the appropriate signal timing by using the Fuzzy Logic Algorithm to assign the cycle length and split in consistent with the traffic volume of each phase.
Leading Detector
Tailing Detector
Gridlock Detector

Location of Loop Detector

Loop Detector Configuration
The process of calculating traffic signal control consisted of:
1. Initial data was input in Transt-7F to obtain initial value of green times. Using loop detectors to detect traffic demand and sending traffic conditions to adaptive traffic control system to calculate phase duration.
2. The traffic information was processed to calculate the Degree of Saturation (DS) of each lane by using the Principle of Lane Group Capacity (HCM 2000) to consider the critical traffic demand for calculating the appropriate signal timing (Cycle Length) by the following formula.

\[
DS_i = \frac{g_i - n(e - t)}{g_i}
\]  

Where  
- \( DS_i \) = Degree of saturation  
- \( g_i \) = Allocated Green Time (sec.)  
- \( n \) = Number of vehicles (pcu.)  
- \( e \) = Actual space (sec.) = \( \sum e \)  
- \( t \) = Unavoidable space (sec.)  
- \( t = (3600/\text{max.Flow}) - \text{(occupancy at max. flow/100)} \)
3. Modify the DS with the Occupancy values (OCC) measured by Tailing Loop Detectors to account for the queuing and oversaturation condition.

\[
DS_{\text{modified},i} = DS_i \times OCC_i
\] (2)

Where \( DS_{\text{modified},i} \) = modified degree of saturation that accounts for oversaturation and queuing

\( OCC_i \) = occupancy ratio of the Tailing Detector measured over the recent 5 minutes (in percentage)

4. The system collects information on \( DS_{\text{modified}} \) and \( \triangle DS \) (the difference in DS from the two consecutive cycles). The system will calculate the average DS and \( \triangle DS \) over the three recent cycles, which are input for Fuzzy Logic Algorithm.

\[
DS = \frac{DS_{\text{tnow}} + DS_{\text{tnow-1}} + DS_{\text{tnow-2}}}{3}
\] (3)

\[
\triangle DS = \frac{\triangle DS_{\text{tnow}} + \triangle DS_{\text{tnow-1}} + \triangle DS_{\text{tnow-2}}}{3}
\] (4)

5. Rules of Fuzzy Logic as shown in Figure 4 were used to decide an increase or a decrease of the phase duration in the next cycle as follows:

5.1 IF \( DS = \text{low} \) AND \( \triangle DS = \text{decrease} \) THEN \( CR = \text{decrease} \)
5.2 IF \( DS = \text{low} \) AND \( \triangle DS = \text{same} \) THEN \( CR = \text{decrease} \)
5.3 IF \( DS = \text{low} \) AND \( \triangle DS = \text{increase} \) THEN \( CR = \text{same} (=1.00) \)
5.4 IF \( DS = \text{medium} \) AND \( \triangle DS = \text{decrease} \) THEN \( CR = \text{decrease} \)
5.5 IF \( DS = \text{medium} \) AND \( \triangle DS = \text{same} \) THEN \( CR = \text{same} (=1.00) \)
5.6 IF \( DS = \text{medium} \) AND \( \triangle DS = \text{increase} \) THEN \( CR = \text{increase} \)
5.7 IF \( DS = \text{high} \) AND \( \triangle DS = \text{decrease} \) THEN \( CR = \text{same} (=1.00) \)
5.8 IF \( DS = \text{high} \) AND \( \triangle DS = \text{same} \) THEN \( CR = \text{increase} \)
5.9 IF \( DS = \text{high} \) AND \( \triangle DS = \text{increase} \) THEN \( CR = \text{increase} \)

Where \( CR = \) critical ratio
6. The phase duration in the next cycle is computed from the critical ratio (CR) obtained in step 5 as follows.

\[ g_{i+1} = (CR) \times g_i \]  

Where \( g_{i+1} \) = allocated green time in the next cycle (sec.)
\( CR \) = critical length ratio
\( g_i \) = allocated green time of the existing cycle (sec.)

Note that when the cycle length attains the maximum value (180-200 sec.), splits were computed as proportions of the flow ratios from each phase.
4. RESULTS

The testing results on comparison between the traditional system (fixed-time) and the new system (adaptive) are shown in the Figure 5 (Nimit Mai Intersection) and Figure 6 (King Kaw Intersection).

Nimit Mai Intersection

**Fixed-Time System**

**Thursday 19 November 2009**

<table>
<thead>
<tr>
<th>Time</th>
<th>Leg A</th>
<th>Leg B</th>
<th>Leg C</th>
<th>Leg D</th>
<th>Intersection</th>
</tr>
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<tr>
<td>10.45 - 11.00</td>
<td>28.03</td>
<td>18.08</td>
<td>51.63</td>
<td>32.94</td>
<td>29.78</td>
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<tr>
<td>11.30 - 11.45</td>
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<td>20.43</td>
<td>31.42</td>
<td>38.82</td>
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</tr>
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<td>12.30 - 12.45</td>
<td>51.58</td>
<td>11.67</td>
<td>45.00</td>
<td>30.45</td>
<td>28.49</td>
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<td>13.00 - 13.15</td>
<td>54.15</td>
<td>15.00</td>
<td>35.94</td>
<td>19.58</td>
<td>24.30</td>
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**Friday 20 November 2009**

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<th>Intersection</th>
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<td>31.81</td>
<td>27.41</td>
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<td>11.30 - 11.45</td>
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<td>21.74</td>
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Average delay (Fixed Time) = 29.52 second/pcu
Adaptive System

Thursday 26 November 2009

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<th>Time</th>
<th>Average Delay (seconds/pcu)</th>
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<td>Leg A</td>
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<tr>
<td>10.45 - 11.00</td>
<td>46.10</td>
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<tr>
<td>11.30 - 11.45</td>
<td>22.88</td>
</tr>
<tr>
<td>12.30 - 12.45</td>
<td>32.58</td>
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<td>13.00 - 13.15</td>
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Friday 27 November 2009

<table>
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<td>47.59</td>
</tr>
<tr>
<td>13.00 - 13.15</td>
<td>32.81</td>
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</table>

Average delay (Adaptive) = 25.88 second/pcu

Average delay reduction = 3.64 second/pcu

Figure 5 Test results of Nimit Mai Intersection (12% delay decrease)
King Kaw Intersection

Average delay (Fixed Time) = 15.82 second/pcu

**Fixed-Time System**

**Tuesday 24 November 2009**

<table>
<thead>
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<th>Time</th>
<th>Leg A</th>
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<th>Leg C</th>
<th>Intersection</th>
</tr>
</thead>
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<td>16.22</td>
<td>14.58</td>
<td>16.61</td>
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<td>12.30 - 12.45</td>
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<td>15.22</td>
<td>19.10</td>
<td>16.53</td>
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<tr>
<td>13.00 - 13.15</td>
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**Wednesday 25 November 2009**

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<td>15.95</td>
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<tr>
<td>12.30 - 12.45</td>
<td>16.45</td>
<td>14.69</td>
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<td>16.21</td>
</tr>
<tr>
<td>13.00 - 13.15</td>
<td>13.33</td>
<td>12.52</td>
<td>21.76</td>
<td>14.75</td>
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</table>
Adaptive System

Tuesday 17 November 2009

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<td>Leg A</td>
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<td>12.30 - 12.45</td>
<td>9.72</td>
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<tr>
<td>13.00 - 13.15</td>
<td>8.78</td>
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</table>

Wednesday 18 November 2009

<table>
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<tr>
<th>Time</th>
<th>Average Delay (seconds/pcu)</th>
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</thead>
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<td></td>
<td>Leg A</td>
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<td>10.45 - 11.00</td>
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<td>12.30 - 12.45</td>
<td>9.46</td>
</tr>
<tr>
<td>13.00 - 13.15</td>
<td>7.50</td>
</tr>
</tbody>
</table>

Average delay (Adaptive) = 11.14 second/pcu
Average delay reduction = 4.68 second/pcu

Figure 6 Test results of King Kaw Intersection (29% delay decrease)

From the test results, the following capabilities have been evaluated.
1. The system can gradually and continuously change the cycle time and splits according to the actual traffic volume at the test intersections.
2. The results on reduction of average waiting time (or delay) at the Nimit Mai Intersection and the King Kaw Intersection during the observed period of 10:45-13:15 hrs. are 3.63 seconds per pcu and 4.68 seconds per pcu, respectively.
3. Even though it may be argued that the test duration is only a short period, the study attempts to estimate the annual value of time saving of each intersection by applying the hour factor based on available traffic count data of 5% and 6%, and rounded hourly traffic
volume of 1,800 pcu and 1,600 pcu for Nimit Mai Intersection and King Kaw Intersection, respectively, and the savings are estimated as follows.

a. Delay reduction per day = 36.3 pcu-hours per day (3.63 seconds per pcu × 1,800 pcu per hr × 5% hour factor ÷ 3,600) for Nimit Mai Intersection.

b. Delay reduction per day = 34.7 pcu-hours per day (4.68 seconds per pcu × 1,600 pcu per hr ÷ 6% hour factor ÷ 3,600) for King Kaw Intersection.

c. Estimated value of time at 77.84 Baht/pcu-hour obtained from a study of The Expressway Authority of Thailand show a rough saving of approximately 2,826 Baht per day for Nimit Mai Intersection and 2,698 Baht per day for King Kaw Intersecton.

d. Finally, the annual value of time saving is 1,031,4901, Baht and 984,935 Baht for Nimit Mai Intersection and King Kaw Intersection, respectively.

4. Intersection blockage was tested and the system can perform successfully.

5. Overriding the system with manual control has been tested successfully

6. Failure of the system was tested and successfully satisfied.

7. Recording and retrieving of data was successfully performed as shown in Figure 7

Traffic Controller Configuration
The Intelligent Intersections Project was submitted and awarded as the local innovation and local public services in Bangkok at the Local Innovation Awards 2010 announced as:

- The technology is being used for traffic control.
- The travel time delay is reduced.
- The monetary reduction about 1 million Baht per year per intersection.
- The ability to work well with the low volumes intersection.
- The invention is practical.

The award was given by Prime Minister on September 17, 2010 at the Santi Maitri Building, Government House as shown in Figure 8.
Figure 8 Director of Traffic and Transportation Department received award from Thai Prime Minister Abhisit Vejjajiva

Bangkok Metropolitans Administration is now undertaking the Intelligent Intersections Project Phase 2 for installation of this system at 23 intersections in fiscal year of 2011.

4. CONCLUSION

The first adaptive traffic controller of the Intelligent Intersection Project Phase I has proved for success. More application to alleviate traffic congestion in Bangkok is waiting ahead for the well-being of the Bangkok citizen.

ACKNOWLEDGEMENTS

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Ebrahim Bagheri, Department of Computer Science, University of New Brunswick, Fredericton, Canada Mehdi Feizi, School of Business and Economics, Goethe University Frankfurt, Germany Faezeh Ensan, Department of Computer Science, University of New Brunswick, Fredericton, Canada Farid Behnia, Computer Department of Imam Reza University, Iran: A NOVEL FUZZY CONTROL MODEL OF TRAFFIC LIGHT TIMING AT AN URBAN INTERSECTION
