The Importance of Intergreen Time in Preventing Crash at Intersection

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Abstract: The improper design of traffic signal can be a cause of accident such as driver can not pass a large intersection because of insufficient of Intergreen time. Intergreen time is duration time of the clearance part of the phase corresponding to the period between the phase change point and the beginning of the green display for the next phase. In Thailand, design guideline suggests that Intergreen time is the minimal time that the accident will not be occurred and the least time is 4 seconds. However, the comparison study with international design guidelines from Germany, Hungary and China; their guidelines consist of description and formula to determine the Intergreen time clearly. The Intergreen time depends on multi factors such as distance, design vehicle and speed. This paper describes the comparison the intergreen time among four countries.

Key Words: Intergreen time, road accident, traffic signal design

1. INTRODUCTION

The road accident is the important problem in Thailand, it has negative affected in Thailand such as economic, social and health etc. From accident statistic report in Bangkok metropolitan, accident occurred 50,521 and red-light running was 2,418 (Metropolitan Police Bureau, Royal Thai Police, 2006). Red light running can be a deliberate decision by a driver, or the result of an inability to halt safely due to the amber dilemma (Menzies, Adonijah and Alan Nicholson, 2003). Harb, Rami et al (2006) red-light running is a complex problem and occurred from many causes, FHWA studied road accidents in 31 intersections, 306 cases in three states, they found that the distribution causes of red light running was as follows:

- 40% the driver did not see the signal or its indication
- 25% the driver tried to beat the yellow-signal indication
- 12% the driver mistook the signal indication and reported they had a green-signal indication
- 8% the driver intentionally violated the signal
• 6% the driver were unable to bring their vehicle to a stop in time due to vehicle defects or environmental conditions
• 4% the driver followed another vehicle into the intersection and did not look at the signal indication
• 3% the driver were confused by another signal at the intersection or at a closely spaced intersection
• 2% the driver were varied in their cause

From the above analysis, 8% of the crashes, resulting from intentionally violated the signal and other crashes may be possibly related to insufficient sight distance to the traffic light, vehicle deficiency and human deficiency etc.

So, some solutions for decrease road crash caused from red-light running such as CCTV, intersection information providing by ITS, flash light, time counter and designing of suitable intergreen time for each intersection etc.

Designing of intersection consider traffic volume, delayed time, capacity and density etc; however, it should consider road safety also such as intergreen time. Intergreen time is period time of the clearance part of phase corresponding to the period between the phase change point and the beginning of the green display for the next phase.

Authors found that Thailand highways design guideline lack of regarding the detailed intergreen time design. They only identified that a number of intergreen time should be at least 4 seconds. However, authors compared Thailand guideline with German, Hungarian and Chinese guidelines that these countries have in-depth considering the intergreen time. This paper presents the comparison of intergreen time and evaluates an accident case study in Thailand about intergreen time design.

2. DESIGNING OF INTERGREEN TIME IN GERMANY

Dahl A (2008) studied traffic control at signalized intersection for determining the intergreen time \( (t_f) \), a formula consist of three parts such as Crossing time \( (t_{cr}) \), clearance time \( (t_r) \) and entering time \( (t_e) \). Equation 1 shows a simple form of intergreen time and equation 2 shows a detailed form.

\[
t_f = t_{cr} + t_r - t_e
\]

\[
 t_f = t_{cr} + \frac{s_c + l_v - s_e}{v_c}
\]

Where

\( t_f \) = Intergreen time [s]
\( t_{cr} \) = Crossing time [s]
\( s_c \) = Clearing traffic stream [m]
\( l_v \) = Clearing vehicle [m]
\( v_c \) = Clearing vehicle [m/s]
\( s_e \) = Entering traffic stream [m]
\[ v_e = \text{Entering vehicle [m/s]} \]

Where value of \( t_{cr}, s_c, l_v \) and \( v_e \) depend on type of crossing time and clearance time, which can be classified in 6 types such as:

- Figure 1: Clearing of straight-ahead moving vehicles
- Figure 2: Clearing of turning vehicles
- Figure 3: Clearing of trams or buses - no stop before the intersection
- Figure 4: Clearing of trams or buses - stopping before the intersection
- Figure 5: Clearing of cyclists
- Figure 6: Clearing of pedestrians

Which entering time \( (s_e \text{ and } v_e) \) can be finding from table 1. From table 1 shows \( s_e \text{ and } v_e \) for total category for an example when designer wants to design intergreen time for motorized vehicles, the design speed is 40 km/h and equation \( t_e = \frac{3.6 \cdot s_e}{40} \).

<table>
<thead>
<tr>
<th>Description</th>
<th>Assumption</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>motorised vehicles enter</td>
<td>$v_e = 40 \text{ km/h}$</td>
<td>$t_e = \frac{3.6 \cdot s_e}{40}$</td>
</tr>
<tr>
<td>public transport enter (no stop</td>
<td>$v_e = 20 \text{ km/h at the beginning}$, acceleration up to $v_e = \max v$; $a = \text{see case 4}$;</td>
<td>$t_e = \frac{3.6 \cdot s_e - \frac{2 \cdot s_e}{a}}{20}$ at $t_e \leq \frac{\max v}{3.6 \cdot a}$</td>
</tr>
<tr>
<td>before intersection)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>public transport enter (stop</td>
<td>$v_e = 0 \text{ km/h at the beginning}$, acceleration up to $v_e = \max v$; $a = \text{see case 4}$;</td>
<td>$t_e = \frac{2 \cdot s_e}{a}$ at $t_e \leq \frac{\max v}{3.6 \cdot a}$</td>
</tr>
<tr>
<td>before intersection)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cyclists jointly signalised with</td>
<td>not relevant due to their low start-up acceleration and speed</td>
<td></td>
</tr>
<tr>
<td>motorised traffic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>cyclists with separate signals</td>
<td>$v_e = 5 \text{ m/s}$</td>
<td>$t_e = \frac{s_e}{5}$</td>
</tr>
<tr>
<td>pedestrians (conflict area begins</td>
<td></td>
<td></td>
</tr>
<tr>
<td>directly at the lane edge)</td>
<td>$t_e = 0$</td>
<td></td>
</tr>
<tr>
<td>pedestrians (other cases)</td>
<td>$v_e = 1.5 \text{ m/s}$</td>
<td>$t_e = \frac{s_e}{1.5}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Description</th>
<th>Entering traffic streams</th>
<th>large intersections (max. 5 lanes per entrance)</th>
</tr>
</thead>
<tbody>
<tr>
<td>small intersections (max. 2 lanes per entrance)</td>
<td>vehicle, straight ahead moving + right turning</td>
<td>6 5 6 3 5 5 7 8 4 4 7 4 6 5 9</td>
</tr>
<tr>
<td></td>
<td>vehicle, left turning</td>
<td>7 6 6 3 5 5 8 9 7 10 7 9 5 10</td>
</tr>
<tr>
<td></td>
<td>public transport, no stop</td>
<td>8 7 7 4 6 6 9 9 6 8 5 7 6 10</td>
</tr>
<tr>
<td></td>
<td>public transport, stop</td>
<td>9 8 8 5 7 7 10 11 8 10 7 9 7 12</td>
</tr>
<tr>
<td></td>
<td>cyclist</td>
<td>8 7 7 4 - - - 13 10 12 9 - - -</td>
</tr>
<tr>
<td></td>
<td>pedestrian, entrance</td>
<td>7 7 7 7 - - - 12 12 12 12 - - -</td>
</tr>
<tr>
<td></td>
<td>pedestrian, exit</td>
<td>7 7 7 7 - - - 4 4 4 1 - - -</td>
</tr>
</tbody>
</table>

From table 2 shows reference of intergreen time value for intersection for each category, however designer should not use this value directly to design intersection but designer should determine intergreen time directly from above equations and consider the design criteria.

### 3. Designing of Intergreen Time in China

Hui, Xiong et al (2008) studied signalized intersection design in China and conclude intergreen time ($t_I$) formula that consists of:
\[ t_i = \frac{s_c}{v_0} + t_b \] (3)

Where
\[ t_i = \text{Intergreen time [s]} \]
\[ s_c = \text{Distance from stop line to conflict point of clearing traffic stream [m]} \]
\[ v_0 = \text{Running speed of clearing traffic stream [m/s]} \]
\[ t_b = \text{Stopping time [s]} \]

In addition, this manual suggests that if intergreen time is less than 3 second then designer should use amber time is 3 second but if intergreen time is more than 3 second then designer should use intergreen time is 3 second and add surplus time in red period.

4. DESIGNING OF INTERGREEN TIME IN HUNGARY

Boros, A (2008) studied traffic control at signalized intersection that Hungarian guideline suggest to use intergreen time equation as shows in equation 4.

\[ t_i = t_a + \frac{s_c + l_e}{v_c} + 1\cdot \frac{s_e}{v_e} \] (4)

Where
\[ t_i = \text{Intergreen time [s]} \]
\[ t_a = \text{Amber time [s]} \]
\[ s_c = \text{Distance from stop line to conflict point of clearing traffic stream [m]} \]
\[ l_e = \text{Clearing vehicle [m]} \]
\[ v_c = \text{Clearing vehicle [m/s]} \]
\[ s_e = \text{Distance from stop line to conflict point of entering traffic stream [m]} \]
\[ v_e = \text{Entering vehicle [m/s]} \]

Table 3 shows \( t_a, s_c, l_e, v_c, s_e \) and \( v_e \) for determine intergreen time which it defines all-red time is 2 second.

<table>
<thead>
<tr>
<th>Variables</th>
<th>vehicle</th>
<th>cyclists</th>
<th>pedestrians</th>
</tr>
</thead>
<tbody>
<tr>
<td>( t_a )</td>
<td>(&lt;50 \text{ km/h} = 3 \text{ sec}) (&gt;50 \text{ km/h} = 5 \text{ sec})</td>
<td>3 sec</td>
<td>0 sec</td>
</tr>
<tr>
<td>( s_c )</td>
<td>between stop marking lane and farther edge of conflict zone + 6 m</td>
<td>distance between stop marking lane and farther edge of conflict zone + 3 m</td>
<td>length of pedestrian crossing</td>
</tr>
<tr>
<td>( v_c )</td>
<td>(\leq 10.0 \text{ m/s})</td>
<td>(\leq 2.5 \text{ m/s})</td>
<td>(\leq 1.5 \text{ m/s})</td>
</tr>
<tr>
<td>( s_e )</td>
<td>distance between stop marking lane and closer edge of conflict zone</td>
<td>distance between stop marking lane and closer edge of conflict zone</td>
<td>0 m</td>
</tr>
<tr>
<td>( v_e )</td>
<td>travel speed</td>
<td>11.1 m/s</td>
<td>1.5 m/s</td>
</tr>
</tbody>
</table>
5. DESIGNING OF INTERGREEN TIME IN THAILAND

Thailand Department of Highways (2007) presents the Intersection, Interchange and Tunnel Design Guideline that designing of intergreen time should be at least 4 second and explain for special intersection which designer consider that accident can be occurred that designer should consider and add intergreen time for road safety. And guideline also explains that intergreen time should provide sufficient time for road safety, however intergreen time should not so high until affect a delayed intersection time.

6. CASE STUDY: ACCIDENT BETWEEN A TRUCK AND A MOTORCYCLE

An accident occurred at Songkhla Province in Thailand as shows in figure 7 and it shows both directions of motorcycle and truck. An accident occurred on September 14, 2006, a truck driver tried to cross an intersection while he saw amber signal and at the same time a motorcycle rider followed front vehicles. Thereby, a truck driver attacked a motorcycle.

An intersection is a four-lane arterial highway (main road) and a four-lane collector highway (minor road). A truck driver drove his vehicle on minor highway and a distance between stop-line to conflict point was 42 meter. A motorcycle rider rode her vehicle on arterial highway and a distance between stop-line to conflict point was 23 meter. An amber time was 4 second and all-red was 1 second.

Authors determine intergreen time from four methods and it shows in table 4.

<table>
<thead>
<tr>
<th>Countries</th>
<th>Intergreen time (second)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hungary</td>
<td>8.05</td>
</tr>
<tr>
<td>Germany</td>
<td>6.45</td>
</tr>
<tr>
<td>China</td>
<td>6.06</td>
</tr>
<tr>
<td>Thailand</td>
<td>5</td>
</tr>
</tbody>
</table>

From table 4, Intergreen time of German guideline is 6.45 and intergreen time of Chinese guideline is 6.06 second. When compare values between German and Chinese guidelines, it looks closely because both guidelines consider vehicle length, distance between stop-line to conflict point and travel speed.
Intergreen time of Hungarian guideline is 8.05 second and it is the highest value because it adds special value of components in term of time and distance in intergreen time equation.

Intergreen time of Thailand guideline is 5 second that it consists of 4 second of amber time and 1 second of all-red time. It is the lowest value because this intersection was designed without regarding of road geometry and vehicle type such as distance between stop-line to conflict point.

From this accident, a truck driver tried to cross this intersection when he saw an amber time but this intersection is large and it was insufficient intergreen time. Thereby, a truck driver could not cross this intersection and crashed a motorcycle.

7. Conclusion and further research

Authors studied and compared designing of signalized intersection among four countries that signalized intersection guideline of Thailand does not have detail of intergreen time design. It suggests simple design of the lowest intergreen time should be at least 4 second and this time should be the shortest time that an accident may not occurred. However, German, Hungarian and Chinese guidelines consider 3 basic variables that are 1) amber time, crossing time and stopping time 2) clearance time and 3) entering time.

For further research, authors will determine related factors of intergreen time which appropriate for highways in Thailand such as driver’s behavior of Thai motorcycle, responding time and size and distance of signal signs etc. Next, authors will model Thai intergreen time and evaluate our model in SIDRA in term of safety and delayed time. Authors expect that new intergreen time model may improve our road accident problem in Thailand.

8. REFERENCES


Taneerananon, Pichai (2006) In-depth accident investigation report case no. 4: accident between truck and motorcycle at Sanambinnok Intersection, Hat Yai, Songkla, Thailand.