Dilemma Zone Protection at An Isolated Signalized Intersection Using Dynamic Speed Guidance

Wenqing Chen / Department of Civil & Environmental Engineering

INTRODUCTION

Background
- Dilemma zone (DZ), a segment in the approach of the high-speed signalized intersection, is one of the most contributing factors for the traffic crashes.
- Current strategies for DZ protection are passive, which may have the following drawbacks: (1) cause aggressive deceleration; (2) overwhelming idling time; and (3) drastic speed fluctuation.
- With the development of Intelligent Transportation System, the motorists can actively follow the system’s guidance to change their driving status reasonably, realizing DZ protection and optimization of speed profile.

Study Objectives
This study makes contributions to develop a dynamic speed guiding method that can effectively prevent the vehicle from dropping in the DZ (see Fig. 2) while minimizing travel time, speed fluctuation and idling time through the high-signalized intersection.

Methodology

Dynamic speed guiding model
The dynamic speed guiding model proposed in this study consists of two critical modules: (1) DZ protection and travel time minimization; (2) Minimization of speed fluctuation and idling time. The two modules are processed in a two-stage model, whose architecture is illustrated in Fig. 4. The Dynamic Programming and Multi-objectives Mixed Integer Programming algorithms are used in Stage I and Stage II, respectively.

Guidance execution and status tracking
When the optimal speed profile is acquired, the system shall send it as a command to the motorist, and keep tracking if the motorist obeys the command. If the motorist disobeys the command, the system will go back to the beginning and redo the guidance.

Case study
Selection of study site
This study selects the intersection of US 40 (Pulaski Hwy) and Red Toad Road as the study site. Its aerial view is shown in Figure 6. The pre-design survey findings are summarized in Tab. 1.

Conclusions

Analytic results
The results are summarized in Tab. 2.

Table 2

<table>
<thead>
<tr>
<th>Scenario Number</th>
<th>With guidance</th>
<th>Without guidance</th>
<th>Idling Time (s)</th>
<th>Speed Fluctuation Duration (s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 Decleration</td>
<td>30</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>2</td>
<td>10 Decleration</td>
<td>30</td>
<td>0</td>
<td>14</td>
</tr>
<tr>
<td>3</td>
<td>20 Acceleration</td>
<td>20</td>
<td>0</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>20 Acceleration</td>
<td>22</td>
<td>0</td>
<td>15</td>
</tr>
</tbody>
</table>

Vehicular trajectories with and without guidance in various scenarios are depicted in Fig. 8.

Compared with the situation without guidance, vehicle with the guiding method can avoid DZ and passes the intersection without idling. In addition, travel time, idling time and speed fluctuation duration with or without control under both scenarios are analyzed, indicating the validity and effectiveness of the proposed guiding method.

Sensitivity analysis
The study conducts the sensitivity analysis towards the dynamic speed guiding method. The DZ guiding area selected as the research object. The results are depicted in Figs. 9 and 10.

The results indicate that the travel time of higher speed vehicle almost maintains the same under various scope guiding area, while of lower speed rises with the increase of guiding scope. For the speed fluctuation duration, the lower speed of vehicle seems to be stable while the higher speed of vehicle reflects a rising trend with the increase of the guiding scope.