AN APPROACH TO REDUCE TIE-UPS BY SPEED ADAPTATION AT SAG/TUNNEL SECTIONS ON EXPRESSWAYS

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1. STUDY BACKGROUND

- Definition of tie-up in Japan
  Vehicle operational speed is less than 40km/h, or repetitive stop-and-go operations over an excessive distance, traveling more than 1 km and during more than 15 minutes.

- Primary tie-up section definition
  The subject sections have experienced either prime bottlenecks more than 5 times annually, maximum tie-up length averaging 2 km or more, or more than 30 instances of tie-up annually.

In Japan about 50% of the traffic tie-ups on inter-urban expressways occur at the sag/tunnel sections.

- Proportion of primary tie-up sections by road structures on expressways (inter-urban) in Japan (2002)

A total number = 221 sections
2. TIE-UPS FORMING MECHANISM AT SAG/TUNNEL SECTION

A driver is sometimes unaware of the topographical change from descending to ascending, leading to deceleration. When vehicles are operating in high density, this results in a closing distance with the vehicle ahead, and the following driver brakes to keep an appropriate space.

This impact ripples over the following vehicles, and eventually tie-ups form.

A driver is often subject to a feeling of oppression due to the tunnel structure and tends to decelerate.

Tie-up mechanism at sag section

At tunnel approaching section
3. HYPOTHESIS FOR DISPERSION OF TIE-UPS

- Generally vehicles operate in the overtaking lane while avoiding low speed vehicles on the main lane as the traffic volume increases.
  - Vehicles concentrating in the overtaking lane form a highly dense traffic operation causing congestion in these sections!

Also tie-up formed in a main lane

Tie-up formed in an overtaking lane

When traffic demands converge into an overtaking lane

Being unaware of deceleration at sag section, or due to depressed feeling toward tunnel inside

HYPOTHESIS

- The unbiased lane use resists the formation of tie-ups.
- Speed adaptation control that decelerates vehicle operation creates a disincentive to changing lanes to an overtaking lane, and balanced use is achieved over all lanes.
This study focused on the impact of balanced lane use and dispersion of tie-ups by speed adaptation control (ISA).

A traffic simulator, SIPA (Smart Infrastructure Performance Analyzer) was used to calculate the impact.
The frequently congested sag/tunnel sections between Otsuki and Hachioji are observed.

- About 51,000 vehicles/day are observed in this section.

### Subject Field for Simulation

**Kobotoke Tunnel on the Chuo-Expressway**

- **Otsuki Interchange**
- **Otsuki JCT**
- **Saruhashi Bus Stop**
- **Nakanohashi**
- **Around Uenohara Interchange**
- **Kobotoke Tunnel**
- **Around Moto-hachioji Bus Stop**
- **Hachioji Toll Barrier**

#### Number of tie-ups around the Kobotoke tunnel (2002, Inbound)

<table>
<thead>
<tr>
<th>Bottleneck location</th>
<th>Iwadono Tunnel</th>
<th>Saruhashi Bus Stop</th>
<th>Nakanohashi</th>
<th>Around Uenohara Interchange</th>
<th>Kobotoke Tunnel</th>
<th>Around Moto-hachioji Bus Stop</th>
<th>Hachioji Toll Barrier</th>
</tr>
</thead>
<tbody>
<tr>
<td>KP</td>
<td>67.7</td>
<td>65.5</td>
<td>61.9</td>
<td>48.7</td>
<td>40.4</td>
<td>30.3</td>
<td>25.8</td>
</tr>
<tr>
<td>No. of tie-ups</td>
<td>9</td>
<td>27</td>
<td>37</td>
<td>7</td>
<td>7</td>
<td>7</td>
<td>15</td>
</tr>
<tr>
<td>Note</td>
<td>The lane-doubling to the extended 6 service lanes has dispersed tie-ups</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
The subject section is the inbound 30 km extension around the Kobotoke tunnel.
7. SIMULATION CONDITIONS
VALUE AND TIMING TO CONTROL SPEED

- The Q-V graph in the section around Kobotoke tunnel reads 3200 vehicles/h of traffic volume.
  - The trigger value to start control is set to 2400 vehicles/h, taking the safe side.
  - The set speed is 80 km/h, taking account of a speed restriction in the subject section.

Q-V graph around Kobotoke tunnel and a timing of speed control

Bottleneck Capacity: 3200 vehicles/h
Applied timing of speed control: 2400 vehicles/h
8. SIMULATION CONDITIONS
SIMULATION CASES

- Two specific days are selected to simulate tie-ups in different scales.

<table>
<thead>
<tr>
<th>Case 1</th>
<th>Date</th>
<th>Maximum tie-up length (Tie-up duration)</th>
<th>Traffic volume (Commercial vehicle ratios)</th>
<th>Length of a speed control applied section</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 2\textsuperscript{nd} Thursday 2002</td>
<td>4.6 km (2 hours and 30 minutes, (17:15\sim19:45))</td>
<td>5,123 vehicles /two hours* (8.4%)</td>
<td>2 km</td>
<td></td>
</tr>
<tr>
<td>Case 2</td>
<td>July 27\textsuperscript{th} Saturday 2002</td>
<td>9.4 km (3 hours and 40 minutes, (16:45\sim20:25))</td>
<td>5,504 vehicles /two hours* (8.3%)</td>
<td>5 km</td>
</tr>
</tbody>
</table>

* In Two hours between 15:00 and 17:00 before tie-ups
9. OUTLINE OF SIPA
Smart Infrastructure Performance Analyzer

- The traffic simulator, SIPA has been developed by NILIM in order to measure the performance and effectiveness of ITS such as VICS, ETC and AHS.

- SIPA employs a ‘vehicular modeling’ to emulate vehicle start, halt, following operation, lane changes and so on.
Case 1 shows the complete tie-up dissipation.
Case 2 does not show tie-up dissipation due to larger traffic demand compared to Case 1.
12. IMPACT OF SPEED CONTROL
SHIFT OF LANE USE RATE AND TRAFFIC CAPACITY

Case 1

Case 2

Passenger car equivalent supposed to be 2.0

Shifts of lane use rate and traffic capacity by each cases

- The control section of 2km scored about 50% of overtaking lane use to achieve parity lane use.
- This 2 km control section proves the potential to increase traffic capacity by 5% to 7%.
13. IMPACT OF SPEED CONTROL
SHIFT IN TRAVEL TIME

Case 1

Calculating subject distance is 4.6 km of the current tie-up forming section

Shifts of total travel time (Speed control applied section: 2 km)

- Case 1 results in a travel time reduction by 60%.
- Case 2 does not show tie-up dissipation; however, travel time is reduced by 13%.

Case 2

Calculating subject distance is a 10 km section, including the current tie-up forming section
14. IMPACT OF SPEED CONTROL DIFFERENCE BY LENGTH OF APPLIED SECTION

Case 2

- **Applied section=2km**
- **Applied section=5km**
- **Applied section=10km**

<table>
<thead>
<tr>
<th>Applied section</th>
<th>Total travel time (vehicle x hour)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2km</td>
<td>Speed control is not applied</td>
</tr>
<tr>
<td></td>
<td>Speed control is applied</td>
</tr>
<tr>
<td>5km</td>
<td>Speed control is not applied</td>
</tr>
<tr>
<td></td>
<td>Speed control is applied</td>
</tr>
<tr>
<td>10km</td>
<td>Speed control is not applied</td>
</tr>
<tr>
<td></td>
<td>Speed control is applied</td>
</tr>
</tbody>
</table>

Calculating subject distance=10km from Kobotoke tunnel (Including the current tie-up forming section)

**Shifts of total travel time by the length of applied section**

- Along the extended control section, the travel time loss increases when speed control is applied over the non-tie-ups section in the course of tie-ups generation, extending and dissipation.
- Consequently, even if the control section is extended more, more additional benefits cannot be reaped.
15. CONCLUSION

- The outcome in this study proved that unbiased lane use is effective for tie-up dissipation at sag/tunnel sections.
- Further, a speed adaptation control is effective to achieve balanced use among lanes.
- An effective impact come out from an appropriate extension of a speed control section.

The following items are challenges to overcome toward system introduction:

- Further study on a position to apply speed adaptations, distance, speed restriction and timing, etc according to characteristics of control sections and time of day
- An examination of the safe, economical, and effective tools to control speed
- Consensus building among users

Thank you.