Traffic Management using Moving Light Guide System

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Speed control of Drivers using Dynamic Blink Control of the Light-Emitting Devices

Optic Flow under the Presentation of Vection Stimuli and Phototaxis
Vection

• Perception of self-motion by visual sensation systems (Vection)

The scenes are input into the driver’s retina as a motion-like optic flow. (arrows)
Phototaxis

Photo taxis generally refer to the phenomenon such that insects or cells, etc., move directionally in response to the stimulus of light and not to human behavior.

Result of Field Experiment on Shin-Tomei Expressway

Vehicle Initial Speed: 120km/h (over-limit speed)

Relative Speed:
- 0km/h
- -120km/h
- -240km/h

Daytime:
- Phototaxis
- Vection

Night:
- Phototaxis
- Vection
Result of Field Experiment on Shin-Tomei Expressway

Vehicle Initial Speed: 60km/h (lower speed)

Relative Speed
- 0km/h
- -60km/h

Daytime

Night
Expected Effects of the devices

• Reduce speed
  – Make over-speed vehicle speed down
  – Prevent accident caused by over-speed

• Keep speed at desirable level
  – Homogenization of speed
  – Form homogeneous platoon
  – Raise capacity and prevent flow from breaking down

• Pull up the vehicle from bottleneck
  – Raise throughput from bottleneck in case of congestion
  – Eliminate congestion rapidly
Uri-Tunnel, Tomei-Expressway

Tokyo Aqua Tunnel

Metropolitan Expressway (MEX)

Hanshin Expressway (HEX), Route 3
Locations of Installation (Tokyo Megalopolis Area)
Locations of Installation

(Kobe)
- Hanshin Expressway
- Shimizu Connection Road (mainly speed reduction)

(Tohoku)
- Rifu-JCT
- Adatara-SA
- Fukushima-TN

(Shizuoka)
- Uri-TN
- Okitsu
Effects : flow rate before breakdown

• Before Breakdown
  – +3.2% Peak 15min flow rate (Aquq-TN, E-Nexco) (Endo, M. et al. (2015))
  – +8.6-16.3% 15min flow rate before congestion (Uri-TN, C-Nexco) (Kameoka et al. (2014))
  – It might be effect on delaying occurrence of breakdown (HEX) (Masumoto et al. (2017))

3〜15% increase of flow rate before breakdown
Effects: During Congestion

- **Vehicle Speed**
  - Vehicle speed: +9km/h (37%) (Aquq-TN, E-Nexco, Endo, M. et al. (2015))
  - Vehicle speed: +0.5-1.0km/h (sangen-jaya, MEX, Kobayashi et al. (2015))
  - Vehicle speed: +4-9km/h (Fukushima-TN, E-Nexco, Kamata et al. (2013))
  - Decreased Low speed Vehicles (Fukae sag, HEX, Masumoto et al. (2017))

Increase of vehicle speed can be observed (especially low speed vehicles)
Effects : During Congestion

• Throughput
  - +10% (Fukushima-TN), +8.3% (Rifu JCT) (E-Nexco, Kamata et al.(2013))
  - +0.6% (Aquq-TN), E-Nexco, Endo et al.(2015))
  - +2.4% (sangen-jaya), +1.1% (Ogi-Ohashi), +0.7% (Senju-Shinbashi), +3.0% (Ogi-Ohashi) (MEX, Endo, S. et al.(2015))
  - +6.0%-16.5% (Uri TN, C-Nexco, Kameoka et al.(2014))
  - +4.3-7.3% (Fukae sag, HEX, Masumoto et al.(2017))

0-15% increase of throughput during congestion
Example: Tokyo Bay Aqua Tunnel

Flow Demand: Similar pattern

Total Flow: 28,300/day

Total Flow: 28,800/day

Congestion

Endo, M. et al. (2015)
Example: Uri TN, C-Nexco
(Throughput During Congestion)

W/O Light  
With Light (grouped by various Operations)

Kameoka et al. (2014)
Example: Hanshin Exp (Adaptive Control)

Masumoto et al. (2017)
Factors to decide the effect of moving light?

• Hardwares
  – Installation side
    • Single side (cruising / overtaking lane) / double sides
  – Distance of installation section
  – Color, Shape, Brightness, interval of lights
Factors to decide the effect of moving light?

- Operations
  - Lighting Pattern
  - Moving Speed

Vehicle Speed: $V$ km/h
Factors to decide the effect of moving light?

- **Before breakdown**
  - Duration of light, lighting pattern and total distance (MEX) (Endo, S. et al. (2017))
  - Light Speed (+10km/h from average speed (=50km/h) has better effect) (Aqua Line) (Endo, M. et al. (2015))
  - Adaptive Control of Light Speed (upstream: same as average vehicle speed, downstream: +5km/h-10km/h) (HEX) (Masumoto et al. (2017))

**Key Factors**
- Total distance (longer)
- Light Speed (average speed + $\alpha$)
Factors to decide the effect of moving light?

- **During Congestion**
  - Upstream distance from bottleneck (MEX) (Endo, S. et al. (2017))
  - Upstream distance from bottleneck (long distance: increase throughput, short distance: minus effect, extension to downstream: no increase) (Uri TN, C-Nexco) (Kameoka, et al. (2014))
  - Distance (200m: no effect, extension to 1000m: increase throughput) (Fukushima TN, E-Nexco) (Kamata et al. (2013))
  - Light Speed (+10km/h from average speed (=50km/h) has better effect) (Aqua Line, E-Nexco) (Endo, M. et al. (2015))
  - Light Speed (70km/h has an effect) (Sangen-jaya, MEX) (Kobayashi, et al. (2015))
  - Light Speed (100km/h near bottleneck has better effect than 80, 60) (Uri TN, C-Nexco) (Kameoka, et al. (2014))
  - Adaptive Control of Light Speed (upstream: same as average vehicle speed, downstream: +5km/h-10km/h) (HEX) (Masumoto et al. (2017))

**Key Factors**
- Total distance (Upstream longer)
- Light Speed(average speed + α?)
  - (much higher speed?) Different effect
How Drivers Drive?

Before Breakdown
Leading Vehicle Speed: around 80km/h
Light Speed: 75km/h, 85km/h

During Congestion
Vehicle Speed: congested flow -> 80km/h
Light Speed: 50km/h

Car Following Behavior
Acceleration from Congestion

Driving Simulator Experiment
Driving Simulator (UC-Win Road)
Car Following Behavior
(Before Breakdown)

Desired Spacing [m]

<table>
<thead>
<tr>
<th>Light Speed</th>
<th>85km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=</td>
<td>Leading Speed + $\alpha$</td>
</tr>
<tr>
<td>Desired Spacing getting smaller</td>
<td></td>
</tr>
<tr>
<td>Variation getting smaller</td>
<td></td>
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</tbody>
</table>

Drivers tend to follow the leading vehicle with homogeneous spacing.
Acceleration from Bottleneck

- Running Speed [m/s]
- Headway [s]
- Position [m]
- Moving Light
- Leading Vehicle
- No Light
- With Light
- Velocity
- Position
- Acceleration
Headway Distribution
(1000m: End of Light Section)

Drivers’ tend to follow the leading vehicles with less delay

Headway getting shorter
Operation Strategy (image)

Before Congestion

- Keep a speed / Homogenization of desired spacing

During Congestion

- Raise a speed without delay at the bottleneck
Conclusion
- toward the era of connected and automated driving -

• Now : less connected and automated vehicle
  – Similar effect as “Variable Speed Limit” but unconscious way

• Near Future: mixed condition
  – Normal vehicles may have negative effects
  – The system still have a effect of “pacemaker”, showing appropriate speed level that will be realized for connected and automated vehicles.

• Future : all connected and automated vehicle
  – No need for these system
Thank you for your attention!
Related Publications
[in English]


• Yamamoto et al.(2011), “ATTENTION-ATTRACTING FACILITIES UTILIZING PHOTOTAXIS (PERCEPTION OF SELF-MOTION INDUCED BY VISUAL STIMULI)”, 18th World Congress on Intelligent Transportation Systems, Orlando.

• Yamamoto et al.(2012), “Verification of Decline in the Drivers Concentration Due to the Control of Light-emitting Equipment”, 19th World Congress on Intelligent Transportation Systems, Vienna.
Related Publications
[in Japanese-1]

• Kameoka et al. (2015) "Verification of Traffic Congestion Relief in Case of Traffic Congestion Induced by Dynamic Blink Control of Light-Emitting Devices Installed on Road Shoulder", Expressways and Automobiles, Vol.58, No.2, pp.28-36. [in Japanese]

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Related Publications
[in Japanese-2]


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