EXPANDING FAST EMERGENCY VEHICLE PREEMPTION SYSTEM IN TOKYO

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INTRODUCTION

The Fast Emergency Vehicle Preemption Systems (hereinafter referred to as the FAST) is a system which assists police cars as well as ambulances on an emergency run by giving them traffic signal priority along their path.

The Tokyo Metropolitan Police Department (hereinafter referred to as the MPD) has implemented various methods including a car location system which enables to know the situation of the police cars’ activities easily since the improvement of the police response time to emergency calls leads to the improvement in the arrest rate. The Tokyo Fire Department as well has implemented measures to improve its response time to emergency calls since the quick transport to hospital by ambulance greatly influences the resuscitation rate and others.

For the purpose of improving police response time to emergency calls and preventing police cars from getting involved in accidents while on an emergency run, the MPD started operating the FAST from 2001. The system in the initial trial stage had a limited coverage over the selected geographical area, with only 137 subject intersections involved. The MPD plans to expand the geographic areas to be controlled by the FAST throughout Tokyo and to increase the number of the subject vehicles significantly starting from 2011.

SYSTEM CONFIGURATION

The FAST is built as a part of the Traffic Control System and consists of in-car devices mounted on emergency vehicles and overhead infrared beacons installed along the roads (as shown in Picture 1).
When a police car or an ambulance on an emergency run passes immediately beneath the infrared beacon, the in-car device reports the passage data to the Traffic Control System via infrared beacon to perform traffic signal preemption (as shown in Figure 1).

![Picture 1. Infrared Beacon](image)

**Figure 1. System Configuration**

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**IMPLEMENTATION PLAN**

**GEOGRAPHIC AREAS TO BE IMPLEMENTED**

As of today infrared beacons, which provide traffic information to the public vehicle, are installed at 1,900 locations in Tokyo. Making effective use of such existing infrared beacons for the FAST will enable expansion of the geographic areas to be controlled without introducing new dedicated infrared beacon units, and then, the MPD plans to effectively use the existing units installed at 1,506 locations during the period between 2011 and 2013 (as shown in Table 1). These units at 1,506 locations will be reused to control approx. 3,000 intersections under the FAST.

For reference, in Tokyo traffic signals are installed at about 15,000 locations, of which those at 8,000 locations are controlled by Traffic Control System. Figure 2 shows 1,109 intersections adapted to the FAST by 2011.

![Figure 2](image)

**Figure 2** FAST-enabled intersections (in 2011)

<table>
<thead>
<tr>
<th>Legend</th>
</tr>
</thead>
<tbody>
<tr>
<td>FAST-enabled intersections</td>
</tr>
</tbody>
</table>
INSTALLATION OF IN-CAR DEVICES

Police Cars
When the existing car location system is updated for police cars, the FAST function is also mounted to the updated car location system. So the FAST will also be enabled for such cars without installing any dedicated in-car devices additionally. The FAST will be enabled for most of the police cars (i.e. 1,267 cars) on patrol in Tokyo during the period between 2012 and 2014.

Ambulances
The Tokyo Fire Department plans to install in-car devices in all ambulances (i.e. 237 cars) in Tokyo during the period between 2011 and 2012.

<table>
<thead>
<tr>
<th>Subject Vehicles (in units)</th>
<th>Year 2011</th>
<th>Year 2012</th>
<th>Year 2013</th>
<th>Year 2014</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Police Car</td>
<td>(24)</td>
<td>600</td>
<td>573</td>
<td>94</td>
<td>1,267</td>
</tr>
<tr>
<td>Ambulance</td>
<td>79</td>
<td>158</td>
<td>–</td>
<td>–</td>
<td>237</td>
</tr>
<tr>
<td>Infrared Beacon (in units)</td>
<td>566</td>
<td>470</td>
<td>470</td>
<td>–</td>
<td>1,506</td>
</tr>
<tr>
<td>FAST-Enabled Traffic Signals (in locations)</td>
<td>1,109 Under study</td>
<td>Under study</td>
<td>–</td>
<td>Approx. 3,000</td>
<td></td>
</tr>
</tbody>
</table>

The figure in ( ) shows the status as of FY2001

Table 1. Current Implementation Status and Future Plan

FAST PREEMPTION METHOD

FAST TRAFFIC SIGNAL PREEMPTION OVERVIEW
In the FAST, when an overhead infrared beacon at an egress point of an intersection detects an emergency vehicle on an emergency run (with its red light flashing and siren blaring), its travel time to each intersection in the downstream is estimated to perform traffic signal preemption such as extending the green time of traffic signals.

Parameters such as maximum extension time are predefined as traffic signal behaviors such as green time extension. Signaling duration in

Figure 3. FAST Traffic Signal Preemption Overview
seconds is instructed for different behaviors such as “green time extension”, “red time reduction”, “green time reduction in the previous cycle”, and “no action” within the range specified by such parameters (as shown in Figure 3). In case of “no action”, the emergency vehicle may either cross an intersection on green without traffic signal preemption or inevitably encounter an intersection on red. Parameters such as maximum extension time configured for each traffic signal are designed based on the distance between the infrared beacon and the traffic signal. Green time extension is more effective for a traffic signal which is located relatively close to the infrared beacon while red time reduction is more effective for a traffic signal which is located relatively far from the infrared beacon. Up to six intersections along the road are controlled by the data reported by one infrared beacon.

EXAMPLE OF THE FAST TRAFFIC SIGNAL PREEMPTION
Figure 4 shows that based on the report of an ambulance on an emergency run from the infrared beacon installed at the egress point of Suginami Kuyakushimae intersection on the Tokyo Prefectural Road Nakasugi-dori, it is assumed that the ambulance was allowed to cross six intersections on green.

The result from Intersection A shows that green time was extended by 15 seconds to allow the vehicle to cross it on green.

![Figure 4. Example of Traffic Signal Preemption](image)

EFFECTIVENESS MEASUREMENTS
For all 79 ambulances updated during 2011, all the data of the passage vehicles on an emergency run which the infrared beacons installed in the downstream of the intersections reported, were
extracted in order to validate the effectiveness.

**TRAFFIC SIGNAL PREEMPTION ACTIVATION RATE**

Table 2 shows the traffic signal preemption records during one week between March 28th and April 3rd.

On a daily average basis, ambulances on an emergency run were detected by infrared beacons installed at about 500 locations and FAST-based preemption was performed at about 200 intersections.

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Emergency Vehicles detection (Number of Infrared Beacon)</td>
<td>564</td>
<td>487</td>
<td>435</td>
<td>527</td>
<td>534</td>
<td>617</td>
<td>584</td>
<td>509</td>
<td>535</td>
</tr>
<tr>
<td>Number of FAST-enabled intersections</td>
<td>249</td>
<td>180</td>
<td>181</td>
<td>191</td>
<td>189</td>
<td>243</td>
<td>257</td>
<td>198</td>
<td>213</td>
</tr>
<tr>
<td>Activation Rate</td>
<td>44.1%</td>
<td>37.0%</td>
<td>41.6%</td>
<td>36.2%</td>
<td>35.4%</td>
<td>39.4%</td>
<td>44.0%</td>
<td>38.9%</td>
<td>39.8%</td>
</tr>
</tbody>
</table>

**Table 2. Status of Traffic Signal Preemption by the FAST**

- FAST-based preemption activation means either one of the following was performed, i.e. green time extension, red time reduction, or green time reduction in the previous cycle.

**AVERAGE TRAVEL SPEED**

Table 3 shows the average speed before and after the system implementation in the subject areas where the system was implemented. The average speed has improved by approx. 1.5km/h after the implementation of the system.

<table>
<thead>
<tr>
<th></th>
<th>Period</th>
<th>Ave. Speed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before the Implementation</td>
<td>2011/02/28-03/06</td>
<td>40.1km/h</td>
</tr>
<tr>
<td>After the Implementation</td>
<td>2011/03/23-04/03</td>
<td>41.6km/h</td>
</tr>
</tbody>
</table>

**Table 3. Average Travel Speed Comparison Before and After the System Implementation**
VERIFICATION OF EFFECTIVENESS IN REDUCING AVERAGE STOP TIMES

The counts of vehicles crossing the intersection on red (hereinafter referred to as crossing on red) were compared between with and without system implementation.

The counts of vehicles crossing on red derived from the simulation result of FAST-based preemption by calculating the average speed based on the time records of the FAST-enabled emergency vehicle passing the start and end points (as shown in Figure 6).

Verification Period
From Monday, 28 March 2011 to Sunday, 3 April 2011
From Monday, 30 May 2011 to Sunday, 5 June 2011
From Monday, 6 June 2011 to Sunday, 12 June 2011

Results
Out of 7,858 intersections, 1823 intersections were crossed on red with FAST preemption activated during the period between 6 June 2011 and 12 June 2011, indicating a decrease by approx. 15 points from 3,011 intersections crossed on red with FAST preemption inactivated (as shown in Table 5).

Similar trend was observed from the data averaged over 3 weeks.
### CHALLENGES

The FAST-based traffic signal preemption requires configuration of the predicted arrival time since the FAST preemption method is designed to predict the arrival time of the emergency vehicle at each intersection to allow the vehicle to cross it on green as much as possible. When the system predicts that the vehicle can cross the intersection during green time or determines that the vehicle cannot cross it on green anyway even with traffic signal preemption activated, the FAST preemption will not be activated.

Figure 7 shows the case, in which the FAST preemption was determined to be “unnecessary”. In reality, however, the emergency vehicle crossed the intersection earlier than the predicted passage time at the intersection. Therefore, the vehicle had to cross the intersection on red.

![Figure 7. FAST-Controlled Signal Light Colors and Driving Route of Emergency Vehicle](image)

*Table 5. Comparison of Crossing on Red between with and without FAST Preemption Activated*

<table>
<thead>
<tr>
<th></th>
<th>Number of intersections crossed</th>
<th>Red crossing rate without FAST</th>
<th>Red crossing rate with FAST</th>
<th>Effectiveness</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011/03/28–2011/04/03</td>
<td>8152</td>
<td>3139</td>
<td>1898</td>
<td>1241</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38.5%</td>
<td>23.3%</td>
<td>15.2%</td>
</tr>
<tr>
<td>2011/05/30–2011/06/05</td>
<td>8460</td>
<td>3376</td>
<td>2082</td>
<td>1294</td>
</tr>
<tr>
<td></td>
<td></td>
<td>39.9%</td>
<td>24.6%</td>
<td>15.3%</td>
</tr>
<tr>
<td>2011/06/06–2011/06/12</td>
<td>7858</td>
<td>3011</td>
<td>1823</td>
<td>1188</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38.3%</td>
<td>23.2%</td>
<td>15.1%</td>
</tr>
<tr>
<td>Total Average over 3 Weeks</td>
<td>8157</td>
<td>3175</td>
<td>1934</td>
<td>1241</td>
</tr>
<tr>
<td></td>
<td></td>
<td>38.9%</td>
<td>23.7%</td>
<td>15.2%</td>
</tr>
</tbody>
</table>
Graphs in Figure 8 are the distribution charts of travel speed of the emergency vehicle during one week after the system implementation. Variability in vehicle speeds is observed within the range between 30km/h and 50km/h regardless of day or night. Currently, a uniform travelling speed of the emergency vehicles is applied by emergency vehicle category in order to predict the arrival time at each intersection, however, the prediction method for the arrival time at each intersection needs to be improved for more effective use of the FAST preemption.

Verication Period: 7 days between Monday, 28 March 2011 and Sunday, 3 April 2011

Figure 8. Post-Implementation EV Speed Distribution Chart (during daytime on the left and during nighttime on the right)

The preemption method for determining for extending green time is characterized by the more likelihood of the emergency vehicle, which is predicted to pass the intersection later, crossing the intersection on green. On the other hand, in case of red time extension, the vehicle which is predicted to cross the intersection earlier is more likely to cross the intersection on green (as shown in Figure 9).

Based upon the analysis of the vehicle speed distribution charts, more effective preemption will be possible for a majority of emergency vehicles by setting the green time extension to a vehicle speed of 30km/h as well as red time reduction to 50km/h.

A further study is also necessary to refine the prediction method on the intersection arrival time based on the statistics such as vehicle models, time of day, day of week, and geographic regions.
CONCLUSION

Effectiveness measurement results indicate that the FAST preemption method helped reduce the crossing-on-red ratio by approx. 15 points, preventing ambulances from getting involved in accidents at the intersections and improving response time to emergency calls.

By the time of year 2014, most of the police cars on patrol as well as all ambulances in Tokyo will have in-car devices installed, enabling the FAST traffic signal preemption throughout Tokyo. This will allow to improve the response time by emergency vehicles to emergency calls and to prevent the accidents at the intersections, however, not all the intersections have been put under control by FAST preemption yet. For the future, the MPD intends to install infrared beacons as required in order to further expand the coverage areas and to use the FAST preemption method more effectively. Furthermore, the MPD aims to build a society in which both emergency vehicles and ordinary vehicles can drive safely and smoothly together in the same traffic network by verifying the impact of the increased coverage of the FAST preemption throughout Tokyo on congestion experienced on the surrounding roads as well as on ordinary vehicles.