TRIAL FOR CHANGE IN LANE OPERATION
IN THE SECTION
WITH AN AUXILIARY-LANE SECTION

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ABSTRACT
In Japan, the general arrangement used with auxiliary lanes is to add on the left and then close on the left. However, historical research shows that an inner-add outer-close arrangement results in greater usage rate equalization effect than the outer-add outer-close method at the high traffic level because it directly disperses traffic that has been disproportionately concentrated the inner lane.

With the purpose of reducing congestion and accident occurrences by equalizing disproportionate usage of the inner lane at the high traffic level and improving traffic on a section of the Chuo Expressway near the Kobotoke Tunnel, Central Nippon Expressway undertook the first ever on-site lane change trial using the inner-add outer-close on a multilane road in Japan, from January 28, 2010 to the first week of May 2011.

Results of the lane change trial showed that there are no safety problems in inner-add outer-close lane operation and that the arrangement led to improvement in lane usage rate correction and speed at the end of the section during congestion, and confirmed a decrease effect regarding the time required to pass through the congestion.
INTRODUCTION

The Chuo Expressway links Tokyo to such major tourist spots as Mt. Fuji, as well as to provincial cities. Kobotoke Tunnel, one of the tunnels on the Chuo Expressway, is infamous throughout Japan as a bottleneck that causes concentrated congestion. Central Nippon Expressway selected this location to perform the first ever inner-add outer-close lane change trial on a Japanese multilane road (see Figure 1). This report is an account of the results of the Kobotoke Tunnel Lane Change Trial, which was held from January 2010 to May 2011.

CONGESTION MEASURES

TAKEN PRIOR TO THE LANE OPERATION TRIAL

The cause of the congestion, which begins at the Kobotoke Tunnel in the inbound lanes of the Chuo Expressway, is the structure of the road: From the sag located 2.8km west of the Kobotoke Tunnel entrance begins a 4.7-km uphill slope, which crests inside the tunnel; the uphill slope and the tunnel cause congestion (see Figure 2). As a congestion measure, the existing outer-add outer-close climbing lane (a lane for slow vehicles) was extended 1 km on November 19, 2007 to complete a 1.8-km climbing lane. While this measure provided had some effect, it did not relieve congestion in a fundamental way.

PURPOSE OF THE LANE OPERATION TRIAL
It is known that at the high traffic level that precedes congestion, usage becomes disproportionately high in the inner lane. The bias (imbalance between lanes) toward the inner lane seen during times of high traffic volume causes congestion to occur before the true capacity of the two lanes has been sufficiently utilized.

Data from vehicle detectors in the Kobotoke Tunnel on the inbound lanes of the Chuo Expressway similarly show that usage is skewed toward the inner lane during the 15 minutes of high traffic volume prior to congestion.

On the other hand, historical theoretical research has shown that while the outer-add outer-close arrangement of auxiliary lane installation is the general norm in Japan, the inner-add outer-close arrangement has a higher corrective effect on lane usage because it directly disperses inner lane traffic (1).

This is why Central Nippon Expressway undertook an inner-add outer-close lane operation change on-site trial for the purpose of reducing congestion and accidents through using the existing climbing lane to correct the disproportionate use of the inner lane during periods of high traffic volume (see Figure 3)

![Figure 3. Image of lane usage rate equalization](image)

**LANE OPERATION CONFIGURATION**

As shown in Figure 4, the trial was performed over three steps. The following is an overview of each section of the trial area; the beginning section, the three-lane section, and the end section (or merge section).

**BEGINNING SECTION**

The beginning section was composed of lane markings (dot marks during the first step, then zebra striping during the second and third steps) that created a lane to the right of the inner
lane, with the lane shift section extending for 225m (180 meters of tapering). Because lines are painted to extend an existing gradual curve in the lane operation upstream prior to the trial beginning section, drivers feel little to no discomfort during the lane shift while traveling through the trial section.

THREE-LANE SECTION
The three-lane section uses the climbing lane that was used for lane operation prior to the trial. The extension of the three-lane section is 1,250m in length, and has guidance signs indicating the merge downstream at the end section (41.79kp), changeable LED signs (41.69kp, 41.54kp), warning signs (41.59kp, 41.44kp), and pavement markings (arrows). Because vehicles were seen to change from the outer lane to the middle lane at a point quite distant before the end (merge) section, the changeable LED and pavement markings installed on the safe side were removed during the third step of the trial in order to encourage use by such vehicles of the outer lane up to the end section.

END SECTION(MERGE SECTION)
The end (merge) section is configured to close the outer lane, with a 180-m lane shift section similar to a normal acceleration lane. In addition, safety measures including arrow signs and pavement markings (arrow) were installed in the tapered section.
The accident rate for the trial section (43.0kp to 41.2kp) was reduced from 173.7 incidents per 100 million vehicle kilometers prior to the trial (January 28 to December 31, 2009) to 160.7 incidents per 100 million vehicle kilometers after commencement (January 28 to December 31, 2010) (see Figure 5).

This shows that despite traffic volume having increased after the trial commenced, the number of accidents decreased. The accident rate was calculated by dividing the total number of accidents (death or injury incidents and property damage incidents) by the total number of vehicle kilometers traveled in the trial section. Further, because no major accidents occurred due to the lane operation trial after commencement, it was confirmed that there are no safety problems related to this configuration.

**LANE USAGE**

Figure 6 shows the lane usage for each point during the 15 minutes prior to congestion occurrence. Table 1 and Figure 6 also show the location from which the data was obtained.
The beginning section (detection point A) is the section with a lane shift created using dot marks during the first step and then zebra striping during the second and third steps. The inner lane usage rate in the beginning section (detection point A) decreased 0.7% in the second step and 0.6% in the third step, down from 13.1% in the first step. This was because some vehicles straddled the dot marks during the first step, while such vehicles decreased during the second and third steps with the zebra striping.

Prior to trial commencement, the three-lane section (detection point B) saw a low 8% usage of the left lane, but after commencement that rate increased to between 22.8% and 25.7%, confirming that the lane was being utilized effectively.

Prior to trial commencement, the end section (detection point C) was 53.5%, but decreased to between 50.3% and 51.3% after commencement, indicating roughly equal usage of the outer and inner lanes.

Figure 7 shows lane usage rates calculated for each traffic volume level based on non-congestion (40km/h or faster) period data, for both the outer and inner lane. While the level at which inner lane volume exceeded outer lane volume was 185 vehicles (per five minutes) prior to trial commencement, that number increased to 235 vehicles (per five minutes) after commencement. This is a marked improvement in driving conditions enabled by maintaining a “keep left” trend at an increased traffic volume.

However, the effects seen through this lane operation were not successfully kept all the way to the bottleneck (detection point D), as no notable decrease in inner lane usage rate was observed at detection point D.

<table>
<thead>
<tr>
<th>Detection point</th>
<th>Location (KP)</th>
<th>Detection point positioning</th>
<th>Data obtained</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>42.676</td>
<td>Located in the 3-lane section, near the beginning of the additional lane</td>
<td>Read from VTR data</td>
</tr>
<tr>
<td>B</td>
<td>41.8</td>
<td>Located in the 3-lane section, 400 m upstream of the end of the additional lane</td>
<td>Read from VTR data</td>
</tr>
<tr>
<td>C</td>
<td>41.21</td>
<td>Located in the 2-lane section, slightly downstream of the end of the additional lane</td>
<td>5-minute aggregate based on data obtained from a vehicle detector</td>
</tr>
<tr>
<td>D</td>
<td>40.43</td>
<td>Located in the 2-lane section, near the bottleneck</td>
<td>5-minute aggregate based on data obtained from a vehicle detector</td>
</tr>
</tbody>
</table>

Table 1. Main vehicle detection points
Figure 6. Lane utilization rate

Figure 7. Lane usage for each traffic volume level
(end section of the trial section :detection point C)
AVERAGE SPEED DURING CONGESTION

Figure 8 shows the QV diagram in the outer lane comparing five-minute data collected prior to and following trial commencement, as collected by the vehicle detector positioned in the end section of the lane operation section (detection point C).

In non-congested periods (40km/h or faster), speeds of 80km/h were rarely if ever measured during traffic volume of 100-150 vehicles per five minutes prior to trial commencement, while after commencement that speed was frequently observed.

In congested periods (40km/h or slower), higher levels were detected after commencement than were prior to commencement.

Further, Figure 9 shows the comparison of average speed for each lane in the end section (detection point C) from the time congestion occurred until it dissipated. The average speed during congestion in the outer lane was 14.1km/h prior to commencement, then increased to between 21.7km/h and 23.0km/h after commencement. The average speed during congestion in the inner lane was between 23.4km/h and 23.9km/h after commencement, indicating that the difference in lane speed had been largely eliminated, improving safety.
AVERAGE TIME REQUIRED TO PASS DURING CONGESTION

Figure 10 shows a comparison of the average time required to travel from the Uenohara Interchange to Hachioji Junction during congested periods prior to and following the trial.

The section on which this study was performed is 7.4km downstream from the Uenohara Interchange and Hachioji Junction, the first point at which traffic separates or merges downstream from the study section, lies 5.1km downstream.

Data for the comparison were gathered from 11 vehicle detectors positioned along the above section, with time required to pass calculated as the summation of time required to pass through each detector’s range during five minute speed periods, for the entire section.

The average time required to pass during congestion prior to the trial, 27 minutes, decreased 2.3 minutes (8.5%) to 24.7 minutes after commencement, improving the level of service provided to users.

TRAFFIC CAPACITY

Figure 11 shows calculation and comparison of traffic capacity prior to and following trial commencement. Traffic capacity was gained from the data from the vehicle detector inside the Kobotoke Tunnel bottleneck (detection point D). Sample data are not entirely clear due to limitations caused by fluctuation, but very little to no difference was found in the traffic capacity. One reason for this might be that the lane usage equalization effect gained at the end (merge) section (detection point C) of the trial section may have not been maintained up to the bottleneck (detection point D) downstream.
CONCLUSION

In heavy traffic volume on the inbound lanes of the Chuo Expressway at the Kobotoke Tunnel, Central Nippon Expressway performed the first ever inner-add outer-close lane operation change on-site trial on a multilane road in Japan for the purpose of correcting disproportionate use of the inner lane and reducing congestion and accidents.

The trial results gained from on-site vehicle detection data indicate that the lane usage equalization expected for the end (merge) section (detection point C) of the trial section was successfully realized.

However, the lane usage equalization effect realized at the end (merge) section(detection point C) of the trial section was not maintained up to the bottleneck location(detection point D), and therefore expected traffic capacity improvement was not clearly realized.

On the other hand, the trial resulted in positive effects including improved average speed and shortened average time required to pass between major facilities during congestion.

One future challenge is to take measures that would maintain the lane usage equalization gained at the end (merge) section (detection point C) of the trial section up to the bottleneck location (detection point D).

ACKNOWLEDGMENT

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REFERENCES