MACROSCOPIC STUDY ON MERGING CAPACITY IN TOKYO METROPOLITAN EXPRESSWAY*

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1. Introduction:

Statistical analysis of observed volumes are usually employed in order to estimate capacity of highway elements. Capacity of merging sections is affected by many variables including two direction of traffic flow, variety of lane configuration, various geometric design and flow conditions. Many studies have already been done on free flow merge (when the speed of freeway vehicles is fairly high almost 50-100 km/hr), however merging under congested condition has not been clearly investigated. The main objective of this study was to determine the effects of geometric design and traffic characteristics on capacity of merging sections in Tokyo Metropolitan Expressway. For this purpose detector data was extensively collected and analyzed in order to explain the capacity of merging sections.

At merging sections (figure 1), traffic jams frequently occur especially under the heavy traffic demand. Because of dropping the lane in merging sections, vehicles on merging lane competes for space. These sections maybe have no problem if their lengths and number of lanes or in other word their geometric design is sufficient. However such merging sections are likely bottlenecks when merging sections with sufficient length and good geometric design are difficult to construct, as is often the case with construction in urban areas, due to restricted budget etc. On the other hand a relationship between geometric and capacities of merging sections is not clearly known yet. Therefore, it is becomes important to evaluate capacities of merging sections in relation to their geometry and traffic characteristics.

For estimating the capacity of merging sections, macroscopic and microscopic methods can be used, however the macroscopic approach is very useful tool for validating the microscopic simulation methods.

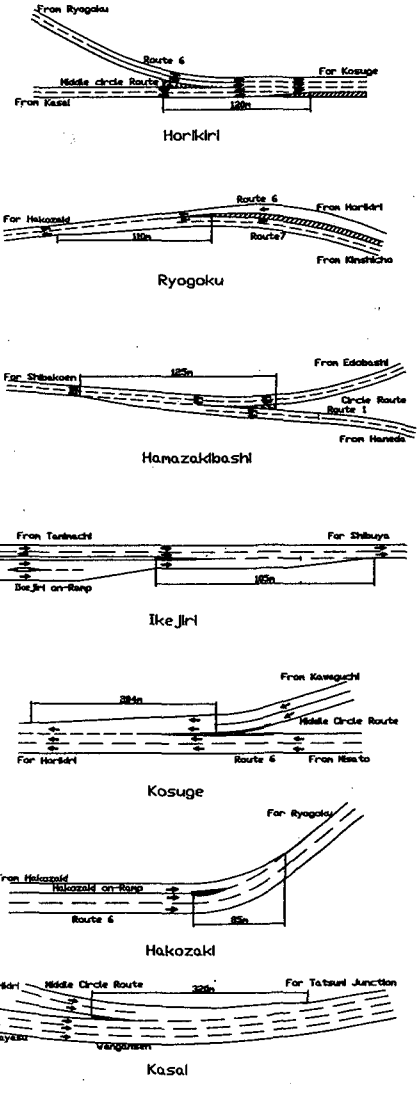

Figure 1. Tokyo Metropolitan Expressway Merging Segments

*Key words: Capacity, Merging

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2. Capacity of Merging Sections:

Capacity of merging and simple sections:
Traffic data from the Horikiri, Hamazakibashi, Ikejiri, Kosuge, Kasai, Hakozaki and Ryogoku were collected during periods when queues were forming upstream from the merging sections and downstream were free, so that the capacity could be observed. In order to observing the capacity, the time periods more than 15 minutes, when upstream were congested and downstream was free, were picked out over seven days. The observed 15 minutes volumes were multiplied by 4 to obtain hourly rates and were then adjusted to passenger-car units (Pcu) using the passenger car equivalence of 1.7 Pcu/heavy vehicle. No adjustment were made for the restricted lane width, the lateral clearance, and slope because speed were not high at capacity conditions. In this study three set of detector data were used, first set of data was collected in 1991, second set in 1995,and third set 1998. The final result of average traffic volume in Tokyo Metropolitan Expressway based on detectors data for three set of data are showed in Table 1. Hakozaki on-ramp has maximum capacity of 2163 veh/hr/lane, while the minimum capacity of 1651 veh/hr/lane occurred in Ikejiri on-ramp. The almost of 0.24 percent difference between highest and lowest capacity is obviously significant. To compare the capacities of the merging sections with capacities of "simple" (i.e., non-merging) sections, capacity observation were carried out on three simple sections of the Tokyo Metropolitan Expressway. The capacity of simple section on the Tokyo Metropolitan Expressway would generally be about 4600 pcu/hr/two lanes.

Merging Sections	Configuration type	Capacity (Veh/hr/lane)	Capacity (Pcu/hr/lane)
Hamazakibashi	Direct Taper	Old=2071,New=1944 Long period=1988	Old=2389,New=2441
Kasai	Parallel acceleration lane	Old=1858,New=2067	Old=2229,New=2615
Kosuge	Direct Taper	Old=1824,New=2021	Old=2181,New=2277
Ryogoku	Direct Taper	Old=1871,New=1847	Old=1943,New=2023
Horikiri	Parallel acceleration lane	New=2068	New=2330
Hakozaki	On Ramp	Old=2163,New=2051	Old=2328,New=2223
Ikejiri	On Ramp	Old=1846,New=1679 Long period=1651	Old=2048,New=1973

Passenger-Car Equilivallent=1.7 Pcu/heavy vehicle
Notes:
The old data is based on May 1991
The long period data is based on May 1995
The New data is based on May 1998
Percentage of truckes are observed in OD census in 1991, and 1995

Table 1. Geometric and flow conditions of observed merging sections

Comparing merging capacity with simple capacity, we see that capacity of 1943 pcu/hr/lane in Ryogoku is about 16 percent smaller than the capacity of simple section. Although the capacity of 2615 pcu/hr/lane in Kasai is about 14 percent bigger than the simple section, but the average capacity of all seven sections of 2231 pcu/hr/lane is about 3 percent smaller than the capacity of a simple section. In other words among seven sections, which presented in Table 1, five sections had capacity smaller than 4600 pcu/hr/lane.

3 . Results:

(1) Merging capacity with respect to taper and acceleration lane length.

In order to consider the effect of taper length and length of acceleration lane with and without zebra marking, average capacity of each merging segment over 7 days are shown on figure 2,and 3. In Tokyo Metropolitan Expressway both parallel and taper type acceleration lane have been used (Taper length is measured from the point where lane width is reduced from 3 meters). As shown in figure 2, capacity showed a tendency to increase when taper length increased. It is expected that desirable geometric design such as taper length ease the merging process. It seems that by increasing the taper length, in congested condition, those drivers who did not achieve to merged early, could squeeze to merge with freeway vehicles and longer taper help them. In addition, by increasing the taper length the lateral motion of vehicles is slower and therefore the smother merging could be observed. figure 3 is shown the capacity with respect to total length of merging lane with and without zebra marking. Capacity of merging segments were not significant related to total length of merging lane either include or exclude the zebra marking. This result was not correspondent to those results that gained based on free flow merging. J.W. Hess (1963) showed that by increasing the length of acceleration lane, free flow merge, increased. J.A.Wattleworth et.al. (1967) showed that ramps with low convergence angle and long acceleration lanes have associated with them low mean and standard deviation of accepted gap number. It should be mentioned here that the gap acceptance quality and even gap acceptance capacity "is not equal" with "capacity". However, when drivers are familiar with site, it can be help for having high capacity even in poor geometric design. This is important that although in this study, length of acceleration lane length (includes taper length ranged only from 85 to 145 meters and did not cover longer acceleration length which often may be used, but no

effect of acceleration length even in this range on capacity is important. In addition in free flow condition, the main purpose of acceleration lane is to give drivers enough time in order to adjust them speed with freeway driver's speed and find the best gap for merging. Whoever in congested condition drivers have to keep the queue till they reach to the head of the queue, might be at the first part of taper length and then merge with adjustment freeway lane. In other words in congested condition when a driver reach to the end part of the acceleration lane, he noses into the freeway lane and force the lag vehicle to yield. In this case, the long length of acceleration lane does not show better usage than a short one.

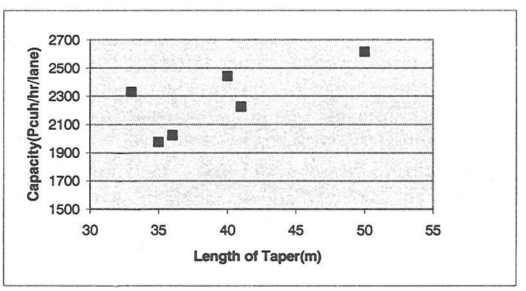

Figure 2. Relationship between taper length and merging capacity

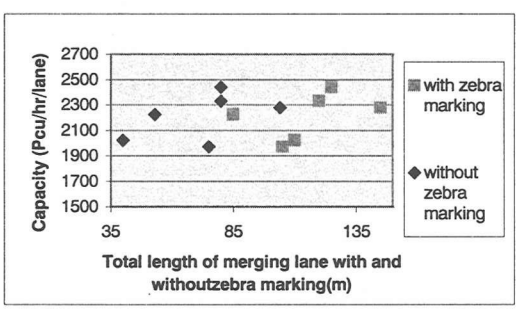

Figure 3. Relationship between Total length of merging lane with and without zebra marking and merging capacity

(2) Merging capacity with respect to freeway and ramp grade:

In order to considering the effect of freeway and ramp grade, the average capacities of each merging segment over 7 days with respect to "relative grade (ramp grade minus freeway grade) is shown in figure 4. As a result, capacity showed a slight tendency to increase when relative grade increased.

This would be related to this fact that when ramp drivers present on the level higher than freeway drivers, they have a good sight distance so have a good view therefore they could prejudging and better understand the situation which are present. In other words if ramp driver beyond the merging point can see as much as they need, therefore, can judge whether the driver immediately ahead of them merge or not. In this sense drivers able to observe the freeway in the proper prospective and evaluate freeway traffic before reaching the merging point, therefore they can judge their speed, if necessary decelerate or accelerate and perform a smooth merge. In addition since we know in congested condition drivers many times have to stop-and-go before merge and therefore if driver present on downgrade, starting to move and accelerate is easier and faster. However, more detailed analysis on the sight view at every sight are required to finalize conclusion.

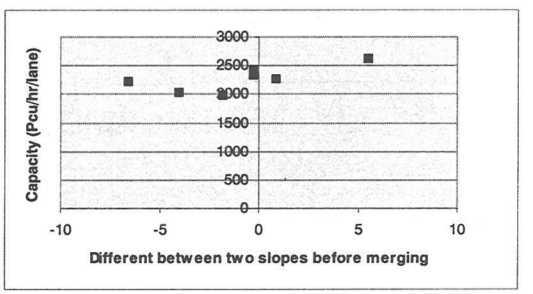

Figure 4. Relationship between relative slope and merging capacity

(3) Merging capacity with respect to merging ratio.

In order to considering the effect of merging ratio, capacity of Hamazaki-bashi merging segment during two months is shown in figure 5.

In order to eliminate the effect of geometric characteristic on merging ratio the long period detector data employed in Hamazaki-bashi and Ikejiri merging segments. As a result capacity of merging segments were not significant related to merging ratio.

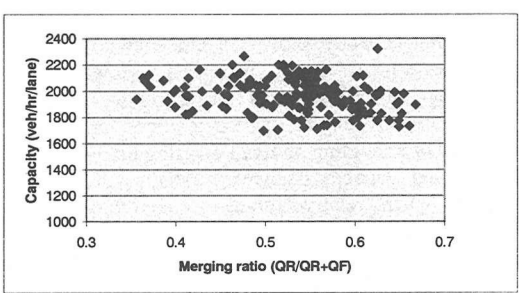

Figure 5. Relationship between merging ratio and merging capacity

The wide range of fluctuation of merging ratio from 0.35 to 0.67 in Hamazaki-bashi and from 0.07 to 0.42 in Ikejiri had no significant affect on merging capacity.

The distribution of ramp and freeway volumes of Hamazaki-bashi is shown in figure 6. We expected that the volumes distribute along a line with minus one slope. Although based on figure 6, when the freeway volume is dominated, the merging volumes were slightly higher but this different was not so significant and still the volumes distributed along minus one slope line.

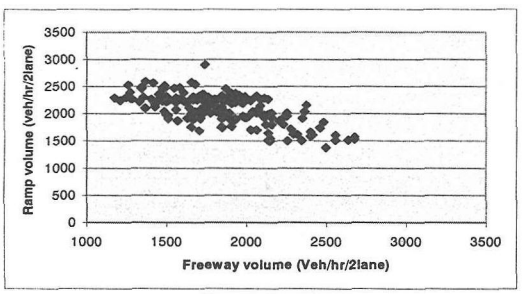

Figure 6. Distribution of ramp and freeway volume

4. Conclusions:

Capacity of merging segments was observed through vehicle detectors in seven merging sections of Tokyo Metropolitan Expressway. The effect of geometric and traffic characteristic on merging capacity were examined. Based on the studies described in this paper, the following conclusions may be drawn connecting the traffic and geometric characteristics on merging capacity.

1- Comparing capacity of merging sections with that of a simple highway section, it was appeared that merging capacity was almost lower than the capacity of a simple section (e.g., 16 percent less at Ryogoku section and 3 percent less as average of all seven sections).

2- Merging capacity showed a tendency to increase when length of taper increased. However no significant difference was observed in merging capacity when length of acceleration lane either including or excluding of zebra marking increased

3- Merging capacity showed a slight tendency to increase when relative grade (ramp grade minus freeway grade) increased.

4- Observing capacity of Hamazaki-bashi and Ikejiri merging segment for two months evidenced that merging capacity was not correlated with merging ratio. Whoever as we expected the ramp and freeway volumes distributed along a line with minus one slope. Based on the results of this study, in most case, the affect of geometric and traffic characteristics on merge behavior are different in free flow and congested merge.

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