Comparative study on evaluation of merging capacity in Tokyo Metropolitan Expressway

Abstract:

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. 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, however merging under congested condition has not been clearly investigated. For this purpose detector data was extensively collected and analyzed in order to explain the capacity of merging sections. Results showed a significant difference in congested state compared to that of free flow merge. Comparing capacity of merging sections with that of simple highway section, it was found that merging capacity was lower than the capacity of simple section. Merging capacity showed good correlation with taper length, whereas no significant correlation with total length of acceleration lane was evident. Relative grade showed a slight effect on capacity. At merging ratio of 0.33, maximum capacity was found. To confirm these tentative results, it is required to analyze detector data for long time period at a few sections.

Introduction:

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 Segment

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 two set of detector data were used, first set of data was collected in 1991 and second set in 1998. The final result of average traffic volume in Tokyo Metropolitan Expressway based on detectors data for both two set of data are showed in Table 1. Hakozaki on-ramp has maximum capacity of 2151 veh/hr/lane, while the minimum capacity of 1703 veh/hr/lane occurred in Ikejiri on-ramp. The almost of 0.21 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. Comparing merging capacity with simple capacity, we see that capacity of 1946 pcu/hr/lane in Ryogoku is about 15 percent smaller than the capacity of simple section. Although the capacity of 2554 pcu/hr/lane in Kasai is about 11 percent bigger than the simple section, but the average capacity of all seven sections of 2203 pcu/hr/lane is about 4 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.

Table 1. Geometric and flow conditions of observed merging sections

Results:

1- *Merging capacity with respect to taper length of acceleration lane.*

In order to consider the effect of taper length and length of acceleration lane with and without marking zone, average capacity of each merging segment over 7 days are shown on Figure 2,and 3. As it mentioned before both parallel and taper type acceleration lane have been used in Tokyo Metropolitan Expressway (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 lengthease the merging process. 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 may, can be explained by this fact that driver in heavy congested condition try to merge soon after entering the acceleration lane. In other words in congested condition drivers have to accept the gaps which is happened in front of them and they can not continue to find better gaps that perhaps will behappened later, as they have experienced in free flow merge.

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. 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 slopeand merging capacity

3- Merging capacity with respect to merging ratio.

In order to considering the effect of merging ratio, capacity of each merging segments during 7 days is shown in figure 5. Although capacity is affected by geometric characteristics of each merging segments and it is more desirable to analysis the fluctuation of flow in same geometric, still it is possible to consider the general relationship between capacity and merging ratio. As a result merging capacity was well correlated with merging ratio. Capacity showed a tendency to increase when merging ratio increased till around 0.32 and then by increasing the merging ratio, capacity continuously decreased. Based on findings of these studies, merging capacity was found to be reduced when merging flow was equal or less than freeway traffic flow. Maximum capacity was found at 0.33 merging ratio. However, it is possible that due to insufficient number of merging segments for data collection, maximum capacity was not accurately determined. Generally, as the merging ratio decreased, the capacity tends to increase. Therefore when merging ratio is zero (simple section) it is expected that capacity be maximized. To explain this finding, it is strongly recommended that relative speed and capacity be examined at the same time.

Figure 5. Relationship between merging ratio and merging capacity

Conclusions and recommendations:

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. On the basis of 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., 15 percent less at Ryogoku section and 4 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- Merging capacity was correlated with merging ratio. Capacity showed a tendency to increase when merging ratio increased till about 0.32 and then by increasing the merging ratio, capacity decreased continuously.

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.

Acknowledgments:
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References:

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Table 1. Geometric and flow conditions of observed merging sections

Merging Sections	Configuration type	Capacity (Veh/hr/lane)	Capacity (Pcu/hr/lane)
Hamazakibashi	Direct Taper	Old=2069,New=1952	Old=2387,New=2389
Kasai	Parallel acceleration lane	Old=1837,New=2019	Old=2202,New=2554
Kosuge	Direct Taper	Old=1824,New=1861	Old=2181,New=2096
Ryogoku	Direct Taper	Old=1810,New=1867	Old=1946,New=2045
Horikiri	Parallel acceleration lane	New=1975	New=2225
Hakozaki	On Ramp	Old=2151,New=2055	Old=2315,New=2227
Ikejiri	On Ramp	Old=1840,New=1703	Old=2069,New=2002

Passenger-Car Equilivalient=1.7 Pcu/heavy vehicle

Notes:

The old data is based on May 1991

The New data is based on May 1998

Percentage of truckes are observed in OD census in 1991, and 1995

Figure 2. Relationship between taper length and merging capacity

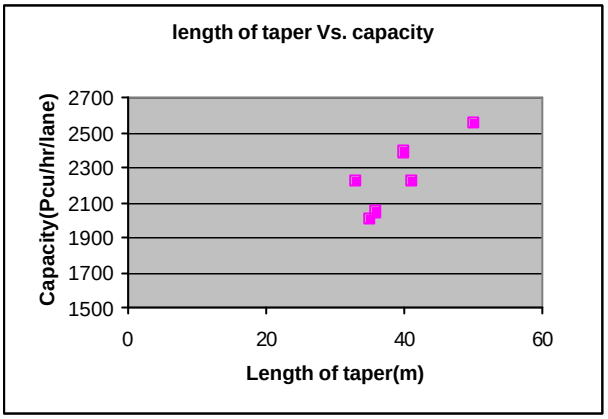

Figure 3. Relationship between Total length of merging lane with and without zebra marking and merging capacity

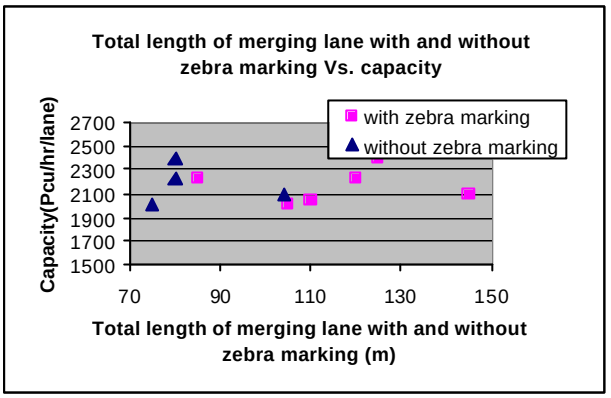

Figure 4. Relationship between relative slopeand merging capacity

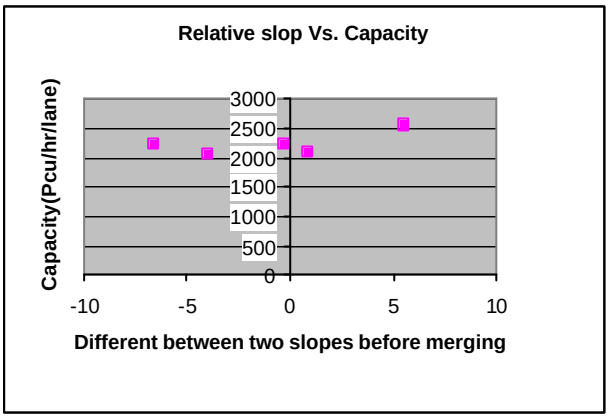

Figure 5. Relationship between merging ratio and merging capacity