BREAKDOWN-RELATED CAPACITY AT URBAN EXPRESSWAY MERGING SECTIONS

Mohamed Shawky, Nagoya University, Student member of JSCE
Hideki Nakamura, Nagoya University, Member of JSCE

1. Introduction

Breakdown at urban expressway merging sections is an elusive phenomenon. It was observed that the breakdown not always the direct result of peak traffic volumes. Recent studies (i.e., Elefteriadou et al., 1995, Matt R. et al., 2000, and Bhagwant et al., 2001) tackled this phenomenon as a probabilistic problem. In these studies, breakdown probability models were developed as an increasing function of mainline and/or on-ramp flows. There is no agreement for the final shape of this function among them.

This paper aims to investigate the breakdown phenomenon at merging sections based on detector data and to highlight the importance of tackling this phenomenon from microscopic observations. Two main findings are presented here. First, a significant difference between the breakdown flow and the maximum outflow rates were shown as an evidence of that the peak flow is not the main factor of the breakdown phenomenon. Second, the relationship between mainline flow and merging ratio at the start of the breakdown showed that the breakdown events occur over a wide range of merging ratio at the same mainline flow, and vise versa. That proves the probabilistic nature of the breakdown phenomenon at merging sections from the aggregated detector observations approac'

2. Merging Capacity and Breakdown Phenomenon

5-minute detector data of Nagoya Urban Expressway were used in this study. The Breakdown speed was firstly estimated as 60 km/hr from the fundamental relationship between the speeds and traffic flows as shown in Figure 1. Therefore, the breakdown at merging sections can be here defined as "a reduction in the mainline speed to be under 60 km/hr and sustains for at least 15 minutes". Horita merging section is selected as case study where breakdown events frequently occur. Detector positions and layout of Horita merging section are shown in Figure 2.

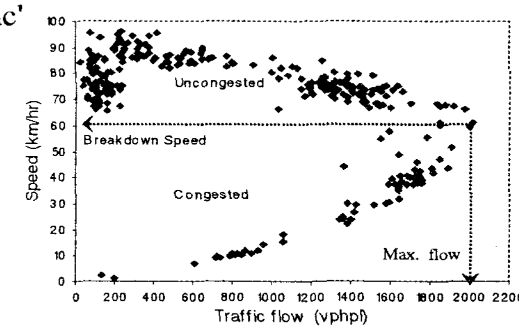

Figure 1: Example of speed- flow relationship at Nagoya Urban Expressway bottleneck

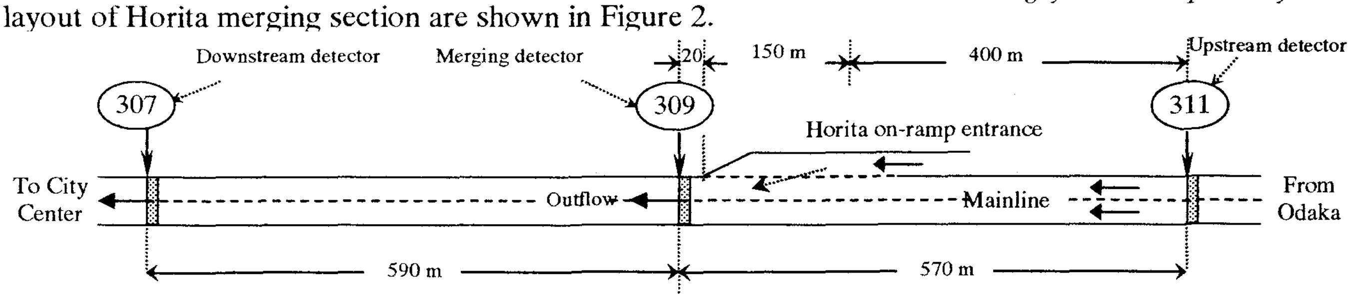

Figure 2: Detector locations and layout of Horita entrance

A typical breakdown event at Horita merging section is shown in Figure 3 (detector #309 observations). From this figure, three aspects of outflow were recognized: maximum flow, breakdown flow, and queue discharge flow. The maximum flow rates were determined from Figure 1. The breakdown flow is the outflow rate during the interval of time when breakdown starts to occur. The queue discharge flow is the average outflow rate during the breakdown period (i.e., when queues exist upstream of merging point).

More than 350 breakdown events were observed at Horita merging section over 12 months of data and histograms for each outflow aspect are shown in Figure 4. It shows that these outflows are normally distributed with different values of mean and standard deviation. This significant difference proves that the breakdown event refers neither to maximum outflow nor to the queue discharge

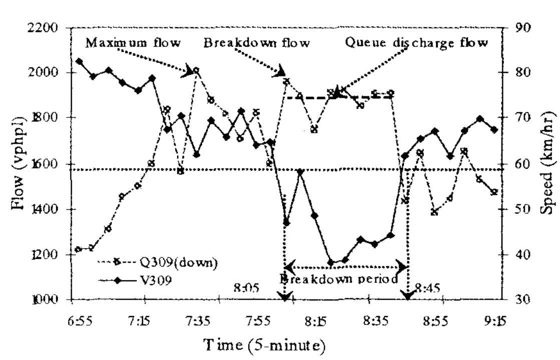

Figure 3: Example of breakdown phenomenon at Horita merging section.

flow but it ranges over them. In addition, a relationship was drawn between the mainline upstream flow and the merging ratio (i.e., upstream flow/on-ramp flow) at the start time interval of each breakdown event as shown in Figure 5. It shows that breakdown events occur over a wide range of merging ratio at the same mainline flow, and vise versa as an evidence of the probabilistic nature of the breakdown.

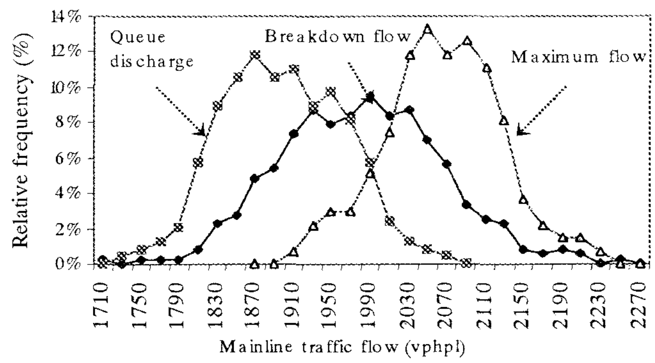

Figure 4: The histograms of the different outflow aspects

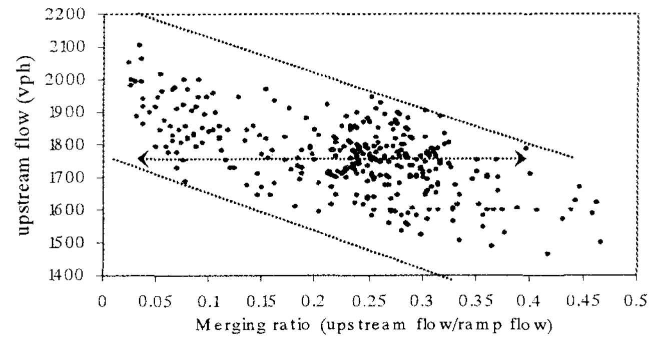

Figure 5: Upstream flow versus merging ratio at the start of each breakdown event

The above findings show the inability of the aggregated detector observations for determining the factors that lead to the breakdown phenomenon at expressway merging sections. Then, it highlights the limits of the existing control strategies that rely on detector observations for controlling the merging sections such as ramp metering systems. These systems look at the merging capacity as a constant value lower than the maximum observed outflows by a safety margin to avoid the probability of the breakdown. As a result, they can not utilize the full capacity of these sections.

In order to maximize the merging capacity, the interaction between the mainline and on-ramp flows should be investigated from microscopic observations such as the merging speeds, accelerations, relative speeds, lag times, gap acceptance, vehicle types, mainline lane changing, etc. By investigating the impact of these variables on the breakdown (i.e., mainline speed), a microscopic control strategy could be developed. This strategy aims to decrease the impact of the merging process on the mainline flow. That can be achieved by controlling the mainline and ramp driver behavior via automated control systems or by providing information to them. This control system should be developed from the driver point of view, therefore behavior models at merging area should be developed carefully.

3. Conclusion and Future Research

This paper showed the limits of the aggregated detector observation for determining the reasons of the breakdown phenomenon at urban expressway merging sections. Then, the importance of tackling this phenomenon form the microscopic approach was highlighted.

The next step of this research investigates the interaction driver behavior at merging section (i.e., merging, lane changing, and following behavior) and its impact on the breakdown phenomenon based on developed microscopic simulation models. Then, automated merging system will be developed. This system controls the mainline to create acceptable gaps for merging vehicles and controls the merging vehicle to assure that each merging vehicle will meet its specific gap at a correct time and the correct speed.

4. References

- Bhagwant P., Sam Yagar, David Tsui, and Horace Look (2001) *"Study of Breakdown-Related Capacity for a Freeway with Ramp Metering"* Transportation Research Board.
- Lily Elefteriadou, Roger P. Roess, and William R. McShane (1995) *"Probability Nature of Breakdown at Freeway Merging Junctions"* Transportation Research Record no.1484 pp. 80-89.
- Matt R. Lorenz and Lily Elefteriadou (2000) *"Defining Freeway Capacity as a Function of the Breakdown Probability"* Proceeding of the 4th International Symposium on Highway Capacity.

Acknowledgment

Authors are grateful to Nagoya Public Cooperation and Nagoya Expressway Association, for their cooperation in providing data necessary for this study.