EFFECTS OF TRAFFIC FLOW CONDITIONS ON CRASH RATES AT DIFFERENT EXPRESSWAY FACILITY TYPES

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1. INTRODUCTION

Many studies have showed that crash rates are related to traffic flow conditions on expressways. However, most of them focused on basic segments or analyzed at the whole segments without differentiation of facility types. Vehicle maneuvers at different facility types are often different, thus crash characteristic may be different as well. Therefore, this paper aims to quantify relationships between crash rates and traffic flow conditions at different expressway facility types.

2. STUDY SITE AND DATABASES

The study site of this research is Nagoya urban expressway network (NEX). The total length was about 69.2km for 8 routes until 31/12/2009, and there were over 250 detectors installed in approximately 500m intervals. Four databases were used in this study: 1) crash record with occurrence time in minute and locations in km; 2) detector data recorded traffic volume, time-mean occupancy and speed per 5 minutes; 3) geometric design data and 4) locations and periods of lane/section closures. The period of the data above is three years (01/01/2007~31/12/2009) except for those on Kiyosu route which opened from 01/12/2007.

3. DATA COLLECTION AND PROCESSING

Expressway facilities were segmented into five types as shown in Fig.1. Other than those facility types, curves with small radius are a special geometric design for urban expressways in terms of road safety. As shown in Fig.2, crash rates at curves with small radius (R≤100m) are significantly high. Hence those curves can be defined as tight curves for NEX and regarded as a special section to be analyzed. Since crash samples at weaving segments and toll gate sections are limited, basic/merge/diverge segments and tight curves were extracted for the following analysis.

This study defined influence area of detectors that were bounded by the midpoints between neighboring detectors in the same curves, or by the boundaries of different curves. Then detector data before at least 5 minutes the recorded time were extracted to describe traffic flow prior to crashes inside this influence area. Invalid detector data, such as negative value, zero speed/volume or unrealistically high speed (>200km/h) were excluded in this study. Besides, crashes occurred in the locations and periods of lane/section closures were excluded as well. Consequently, a total of 1591 crashes with valid detector data remained.

The critical speed which classifies uncongested/congested flow regimes was defined as the speed at maximum volume of bottlenecks (Fig.3). The threshold speed of both flow regimes was selected as 45km/h at tight curves, whose traffic characteristics are different from other facility types (Fig.4). For classifying traffic flow conditions, estimated density calculated by traffic volume and time-mean speed was regarded as the measure of effectiveness. For uncongested/congested flow regimes, the aggregation intervals of density were set as 10veh/km and 30veh/km, respectively, based on the number of available crash samples.

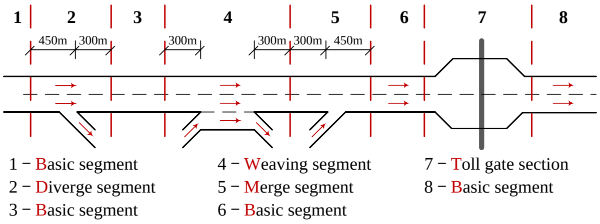

Fig.1 Segmentation of expressway facilities

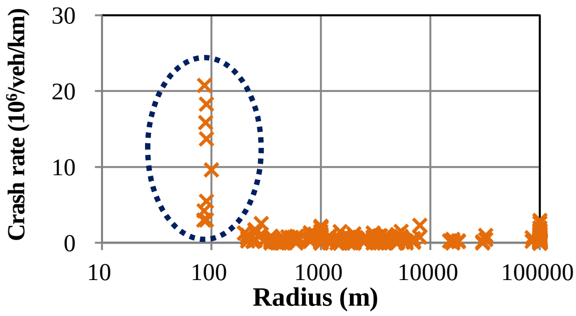

Fig.2 Distribution of crash rates to radius

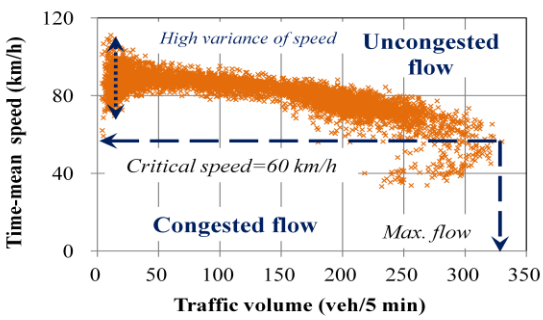

Fig.3 Speed-flow of a bottleneck (Takatsuji on-ramp)

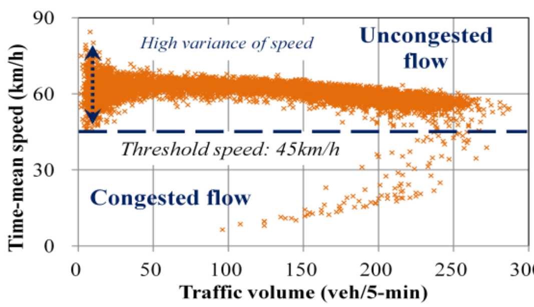

Fig.4 Speed-flow of a tight curve (Tsurumai curve)

4. CALCULATION OF CRASH RATES

After matching geometric design data, detector data and traffic flow condition for each crash record, crash rate for traffic flow condition i (CR_i) can be calculated by the following formula:

$$CR_i = \frac{CN_i \times 10^6}{\sum Q_{ij} L_j} \quad (1)$$

Where i is the category of traffic flow condition, j is detector number, CN_i is the number of crashes for traffic flow condition i

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and $Q_{ij}L_j$ is the vehicle-km of traveled in influence area j for traffic flow condition i.

5. EFFECTS OF TRAFFIC DENSITY

For uncongested flow, largest number of crashes (NOC) and highest crash rates (CRs) exist at tight curves in low density conditions as shown in Fig.5. Then CRs at tight curves follow a decreasing tendency to traffic density. As explained in Ng and Sayed (2004), geometric inconsistency has adverse impacts on road safety, which may induce great difference of running speed between neighboring alignments. Tight curves in NEX are just a typical design of geometric inconsistency. With the increase of traffic density, the difference of running speed between neighboring alignments would reduce. So CRs at tight curves decrease and the difference of CRs from other facility types get smaller. For other facilities, CRs at merge segments increase rapidly in high density conditions and get higher than CRs at diverge/basic segments. The tendencies of CRs at merge/diverge/basic segments in low density conditions are not clear in Fig.5. So paired t-test of CRs at those facility types was done as shown in Table 1, and the results confirm that: CRs between diverge and basic segments aren't significantly different, while CRs at merge segments are significantly larger than CRs at diverge/basic segments. At merge segments, merging behaviors may interrupt the mainline flow, and induce slow-down or lane-changing actions of drivers in mainlines. Those behaviors may increase the possibility of vehicle conflicts. Furthermore, this conflict possibility may also increase with the increase of traffic density. Meantime, strong interruptive behaviors don't exist at diverge/basic segments, and hence the possibility of vehicle conflicts may be not as high as that at merge sections.

For congested flow, CRs at the four facility types follow increasing tendencies to traffic density as shown in Fig.6. CRs at tight curves are still much higher than the values at other facilities. Due to the limited visibility of tight curves, it may be difficult for drivers to react to speed reduction caused by shockwave from downstream quickly. Regarding basic/merge/diverge segments, no clear difference for the tendencies of CRs exists. The F-test in Table 2 also demonstrates that facility types aren't the significant influence factor for the difference of CRs along traffic density. Since the speed is low, the impacts of geometric features on multiple-vehicle crashes may reduce (Christoforous et al., 2011). Furthermore, breakdown initiating at bottlenecks may propagate to upstream sections which may consist of several facility types.

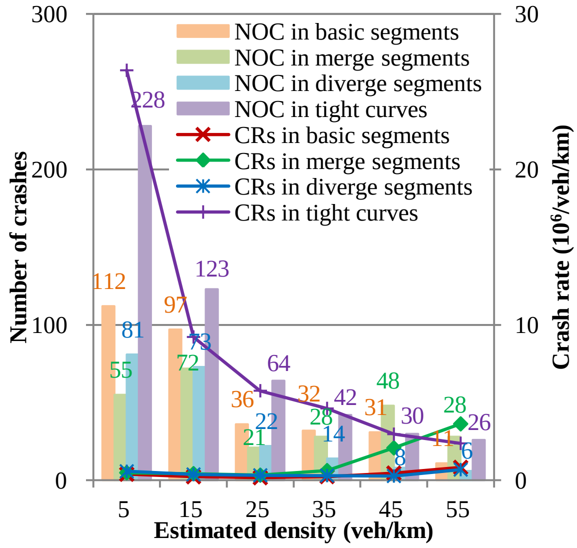

Fig.5 Crash rates for uncongested flow

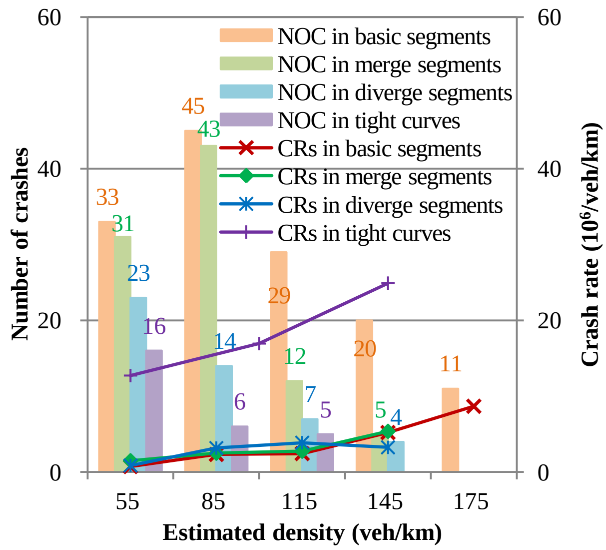

Fig.6 Crash rates for congested flow

Table 1 t-test of crash rates for uncongested flow [1]

Paired	t-value	df	Sig.
Pair1: basic / merge segments	-2.781	5	0.019
Pair2: basic / diverge segments	-1.070	5	0.310
Pair3: merge / diverge segments	2.320	5	0.043

[1] Crash rates at basic/merge/diverge segments

Table 2 F-test of crash rates for congested flow [1]

		F-value	df	Sig.
Corrected mode (difference of CRs)		11.444	3	0.002
Significance of influence factor	Estimated density	31.997	4	0.000
	Facility types	0.117	2	0.891

[1] Crash rates at basic/merge/diverge segments

6. CONCLUSIONS

The impacts of traffic density on CRs at different facility types were presented. For uncongested flow, CRs at tight curves are highest in low density conditions comparing to other facility types, and then follow a decreasing tendency to traffic density. CRs at merge segments are much higher than the values at diverge/basic segments in high density conditions. No significant difference of CRs exists between basic/diverge segments. For congested flow, CRs at the four facility types follow increasing tendencies to traffic density. CRs at tight curves are still highest. The tendencies of CRs during basic/merge/diverge segments are not significantly different. Comparing to the other facility types, tight curves are less safe, and deserve more attention.

ACKNOWLEDGEMENTS

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