Vol-2, Issue-12 PP. 1868-1871 ISSN: 2394-5788

GLOBAL JOURNAL OF ADVANCED RESEARCH
(Scholarly Peer Review Publishing System)

Study on Vehicle Speeds at Single-lane Exit Ramp Terminals on Freeways

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ABSTRACT
The single-lane exit ramp is the most common style of freeway exit ramp in China, of which the terminal can be divided into two types: taper-type and parallel-type. The main objective of the paper is to elaborate recommendations about the best single-lane exit ramp terminal according to safety. 4 taper-type and 4 parallel-type terminals were selected in Jiangsu Province and the space mean speeds (*SMS*) of the 200 vehicles on the deceleration lane of each sample were observed. The average SMS standard deviation of taper-type is 7.9 *kmph* comparing with 4.6 *kmph* of parallel-type, which indirectly indicates that parallel-type is safer than the other one according to the distinct relationship between crash rate and speed dispersion.

General Terms: Traffic Safety

Keywords: speed; single-lane exit ramp terminal; freeway; safety

1. INTRODUCTION
Freeways can provide a high level of mobility compared with other road types. An accident on a freeway is more likely to cause a fatality or a serious injury. Safety performance of freeway segments is affected by several factors including the entering and exiting movements at ramp terminals and associated maneuvers at the merge and diverge areas. Freeway exit ramp terminals are the sites where many driving behaviors and conflicts occur, which could result in higher traffic accident rate compared with other freeway segments or sites. An inadequate design could result in reduced capacity on off-ramps, which could make traffic spill out to main lanes and significant capacity reduction in main lanes. Compared with freeway entrance, exit is more dangerous according to a study by Lundy who reported that exits were associated with higher collision rates than entrances [1]. And then, the more statistical data have shown that freeway exit ramps could result in about double number crashes compared to freeway entrance ramps [2].

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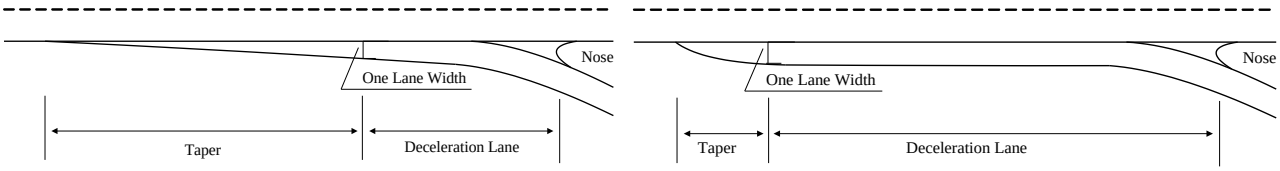
The single-lane exit ramp terminal is the most widely used layout on freeways in China, which can be divided into two types: taper and parallel, according to the Chinese Standard [3]. They are shown in Figure 1. The standard recommends to select taper type for single-lane exit ramp terminal in application, however, no reason is given.



(a) **(b)**

Fig 1: Freeway single-lane exit ramp terminal layout: (a) taper; (b) parallel

Speed standard deviation (*SSD*) was used as a surrogate measure for evaluating the safety performance since the detailed accident records are hardly collected through a regular way. The distinct relationship between crash rate and speed dispersion has been proven by many previous researches[4,5]. The space mean speeds (*SMS*) of diverging vehicles on taper and deceleration lane were collected and the results revealed the safety performances.

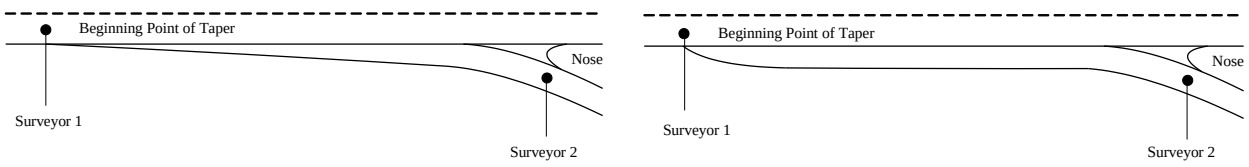
2. Field Data Collection

A field study was carried out to obtain actual vehicle speeds on taper and deceleration lane of single-lane exit ramp terminals. 4 taper samples and 4 parallel samples were selected along Huning Freeway and Ninggao Freeway in Jiangsu Province of China (see Table 1). The speed limit of the mainline for all the samples is 120 *kmph*, and the ramp speed limit is 40 *kmph*.

Table 1. Sample Sites for Speed Data Collection

No.	Site	Direction	Type
1	Huning-Changshen Interchange	Nanjing to Shanghai	Taper
2	Huning-Changshen Interchange	Shanghai to Nanjing	Taper
3	Huning-S243 Interchange	Nanjing to Shanghai	Taper
4	Huning-S243 Interchange	Shanghai to Nanjing	Taper
5	Huning-Huyi Interchange	Nanjing to Shanghai	Parallel
6	Hunig-Suzhou Industrial Park Interchange	Nanjing to Shanghai	Parallel
7	Ninggao-Shatang Interchange	Gaochun to Nanjing	Parallel
8	Ninggao-Ninghang Interchange	Gaochun to Nanjing	Parallel

The time that the vehicle passing the beginning point of the taper and the nose on the ramp were recorded continuously by two surveyors. The locations are illustrated in Figure 2. The surveyor 1 at the beginning point of the observed the approaching vehicles, if one vehicle made a lane change from inner lanes to outer lane or the right-turn indicator flashed, the surveyor 1 recorded the time when the vehicle passed the beginning point of the taper, meanwhile, he signaled the surveyor 2 to record the time when the vehicle passed the nose. The length of the taper and the deceleration lane of the sample exit ramp was calibrated by Google Earth, and the *SMS* of that vehicle was obtained. The formula to calculate the SMS is shown in Equation (1).



(a) **(b)**

Fig 2: Time recording Locations: (a) taper; (b) parallel

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$$SMS = \frac{T_{nose} - T_{taper}}{L_{taper} + L_{deceleration}} \quad (1)$$

where: *SMS* is the space mean speed of the vehicle on the taper and deceleration lane; T_{nose} is the time the vehicle passing the nose of the exit ramp; T_{taper} is the time the vehicle passing the beginning point of the taper; L_{taper} and $L_{deceleration}$ are the lengths of taper and deceleration lane, separately.

3. Data Analysis

The samples listed in Table 1 were selected and 200 vehicles of each sample were observed. The *SMS* of each vehicle was calculated by Equation (1), and the *SSD* of each sample was calculated as Equation (2).

$$SSD = \sqrt{\frac{n\sum_{i=1}^{n} SMS_i^2 - (\sum_{i=1}^{n} SMS_i)^2}{n(n-1)}} \quad (2)$$

where: *SSD* is the speed standard deviation; SMS_i is the space mean speed of the vehicle *i* on the taper and deceleration lane; *n* is the number of the observed vehicles of one sample, *n*=1,2,...,200. The results are listed in Table 2 and the comparisons between the taper type and parallel type are illustrated in Figure 3.

Table 2. Results of Observed *SMS*

Sample No.		Average *SMS* (*kmph*)	Average	*SSD* of *SMS* (*kmph*)	Average
Taper	1	83.3	75.2	8.35	7.9
	2	78.8		7.69	
	3	76.5		7.58	
	4	62.1		8.03	
Parallel	5	72.1	65.9	6.34	4.6
	6	62.7		4.26	
	7	65.5		3.33	
	8	63.4		4.55	

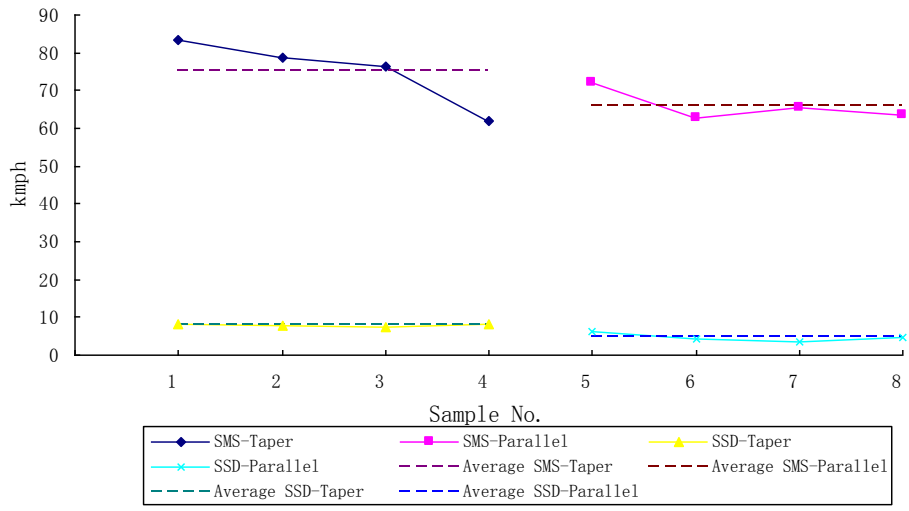

Fig 3: Comparisons of SMS and SSD between Taper and Parallel Single-lane Exit Ramp Terminals

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The average standard deviation of the space mean speed of taper exit ramp terminal samples is 7.9 *kmph*, which is more than the 4.6 *kmph* of parallel samples. The results indicates that the vehicle speed disperses more widely around the taper-type terminals, that means the safety performance of the parallel-type single-lane exit ramp terminal is better than the one of the taper-type in operation.

4. Conclusions

The single-lane exit ramp is most widely applied on Chinese freeways, of which the terminals can be divided into two types: taper and parallel. To recommend the best layout, 4 taper-type and 4 parallel-type terminals were selected in Jiangsu Province and the SMS of the 200 vehicles on the deceleration lane of each sample were observed. The average SMS standard deviation of taper-type is 7.9 *kmph* comparing with 4.6 *kmph* of parallel-type, which indirectly indicates that parallel-type single-lane exit ramp terminal is safer than the other one.

5. ACKNOWLEDGMENTS

The authors would like to thank the support of the National Natural Science Foundation of China (Nos.51208232, 51208100 and 51308192) and Scientific Research Foundation for Advanced Talents of Jiangsu University (No.13JDG074).

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