Effects of Traffic Condition (v/c) on Safety at Freeway Facility Sections

JAENAM CHANG
Engineer, Korea Engineering Consultants Corp., Korea
CHEOL OH
Graduate Student Researcher, University of California, Irvine, USA
MYUNGSOON CHANG
Professor, Hanyang University, Korea

ABSTRACT

The objective of this study is to clarify the relationship between volume to capacity ratios (v/c) and accident rates at various freeway facility sections. These relationships can be used as a basic reference to predict and prevent traffic accidents. The traffic volume and the number of accidents from 1992 to 1997 on Shingal-Ansan freeway in Korea were analyzed in this study. The hourly accident rate and hourly v/c were calculated for each freeway section: the basic freeway section, tunnel section, and toll gate section. The accident rate models, having an independent variable of v/c, were established by regression analysis and compared with each other. The relationship between accident rates and v/c ratios represented a U-shaped pattern for all sections. The accident rates are highest in the low hourly v/c range, decrease with an increasing v/c ratio, and then increase as the v/c ratio increases. The accident rate of the toll gate section is generally higher than that of other sections. Although the accident rate of the tunnel section is higher than that of the basic freeway section when the v/c is above 0.67, there is no significant difference in accident rates between the basic freeway and tunnel sections when the v/c is between 0.5 and 0.8. The basic freeway, tunnel, and toll gate sections have the minimum accident rates when the v/c is 0.78, 0.75, and 0.57, respectively.

1. INTRODUCTION

1.1 Research Background and Objectives

Many studies have tried to identify the effect of traffic volume on accidents. It is generally perceived that accident rates on highways increase with higher traffic volumes. However, existing research shows that the relationship between traffic volume and accident rates is not simple.

The objective of this study is to clarify the relationship between traffic condition and accident rates. In particular, this study compares these relationships at three freeway facility sections. In this study, volume to capacity ratios (v/c) were used as an index to measure traffic condition.

1.2 Research Scope

The selected sections are basic freeway, tunnel, and toll gate sections. This study examines the v/c and accident rates on the Shingal-Ansan freeway in Korea, which has been opened to traffic since 1992. The traffic volume and the number of accidents from 1992 to 1997 on this freeway were analyzed. The design speed of the Shingal-Ansan freeway, with 4 lanes, is 100 km/h, and the total length is 23.84 km. There are 4 interchanges, 2 toll gates, and 2 tunnels on this freeway. This study selected 2 sites at each section to analyze. Figure 1 shows the layout of the Shingal-Ansan freeway.

1.3 Research Approach

This study was conducted using the process below.

1. Review the existing studies and identify the problems
2. Establish the analysis method
3. Collect the traffic volume data and calculate v/c
4. Calculate hourly accident rates
5. Establish the accident rate models having an independent variable of v/c
6. Compare the accident rates at different freeway facility sections using the models.

2. LITERATURE REVIEW AND PROBLEM IDENTIFICATION

Many researchers have attempted to identify the relationship between traffic volume and accident rates. Gwynn (1967) examined the hourly accident rate on a 5.9 km section of a four-lane divided highway in New Jersey between 1959 and 1963, and reported that the highest accident rate occurred when traffic volume is low and a U-shaped function would display the observed relationship. Cerder and Livenh (1982) also showed a U-shaped relationship when accident rates were plotted as a function of hourly volume. In Greece, Frantzeskaki and Iordanis (1987) examined the relationship between traffic accident rates, v/c ratios, and level of service (LOS) on a toll road during an 89 month period (from 1975 to 1982). In the conclusion of this study, the total traffic accidents are almost constant for

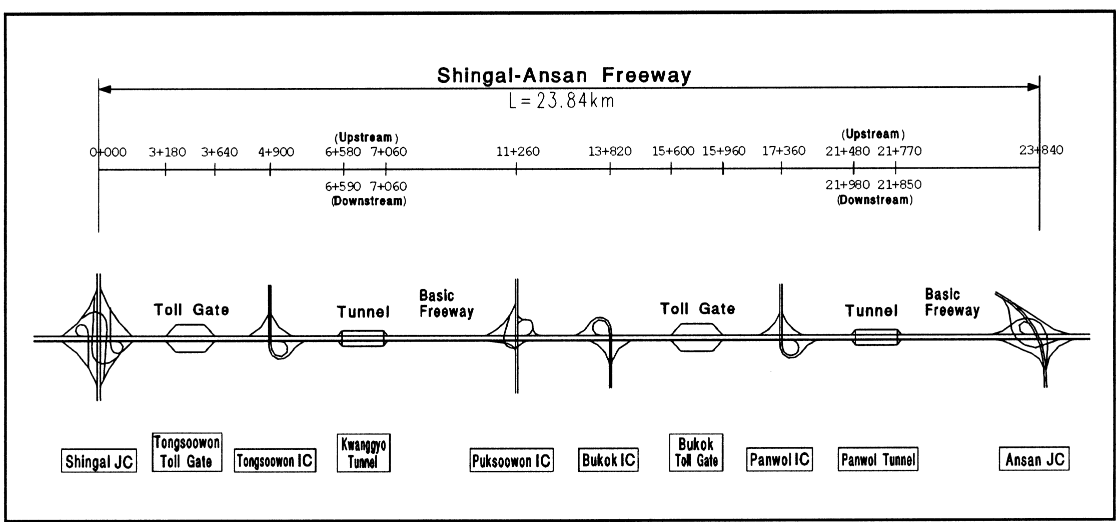

FIGURE 1 Shingal-Ansan freeway.

LOS A, B and C (up to a v/c ratio of 0.65). For higher ratios, and v/c > 1.0, accidents are more than double those for v/c ratios of 0.65. Hall and Pendelton (1989) concluded that accident rates decreased with increasing traffic volume. Min and Sisopiku (1997) reported that U-shaped models explained the relationship between v/c and accident rates for weekdays and weekends, multi-vehicle, rear-end, and property-damage-only accidents.

We are likely to believe that accident rates increase with higher traffic volume. However, as we know from previous studies, the relationship in not that simple. This study can be regarded as a meaningful analysis because there is no research dealing with clarifying the accident rate differences at various freeway facility sections.

3. DATA COLLECTION AND REDUCTION

3.1 Traffic Condition (v/c Ratios)

Traffic volume data was obtained from *Traffic Volume Surveys* published by the Korea Highway Corporation between 1992 and 1997. We reduced the traffic volume data to average hourly traffic volume. In this study, two sites at each facility section, representing similar geometric characteristics, including basic freeway, tunnel, and toll gate sections were selected. Homogeneity of the design and operational features were considered in selecting the sites.

According to the Korea Highway Capacity Manual (KHCM), the value of capacity for each section with ideal traffic conditions is 2,200 passenger cars per hour per lane (pcphpl). In order to adjust the ideal capacity to site capacity, we used adjustment factors.

Capacity for basic freeway and tunnel sections was calculated by f_w (lateral clearance adjustment factor) in KHCM and the value for the adjustment was 1.00 and 0.98, respectively. Also passenger car equivalent for truck and bus (E_T and E_B) in KHCM was used for adjustment. Because the Shingal-Ansan freeway has a range of vertical alignment between −1.9619% and +2.772%, we regarded this freeway as a general terrain area without specific grade. Therefore, 1.5 for E_T and 1.3 for E_B were used as adjustment values.

Capacity for the basic freeway and tunnel sections were calculated by Formula 1 below.

$$c = 2{,}200 \times N \times f_w \times f_{HV} \qquad (1)$$

c = Capacity (vph)

$f_{HV} = \dfrac{1}{[1 + P_T(E_T - 1) + P_B(E_B - 1)]}$ Heavy-vehicle adjustment factor

N = Number of lanes (two way directions)

f_w = Lane width and lateral clearance adjustment factor

To calculate capacity for the toll gate section, a service time needed to be used. Therefore, we used 8 seconds as the service time, as recommended in the *Freeway Design Manual*, published by the Korea Highway Corporation (KHC). Formula 2 was used for calculating the toll gate capacity.

$$c_{\text{toll gate}} = 3{,}600/8 \times \text{(the number of toll booths)} \qquad (2)$$

$c_{\text{toll gate}}$ = Capacity for toll gate section

The v/c was calculated by dividing annual hourly traffic volume with the site capacity, obtained by the above formulas. The reason why v/c was used in this study, is that v/c is a better parameter than traffic volume to represent the characteristics of highway operation and geometric features.

$$(v/c)_i = \frac{AAV_i}{2{,}200 \times N \times f_W \times f_{HV}} \qquad (3)$$

$(v/c)_i$ = Volume to Capacity ratios at i time period
$AAV)_i$ = Annual Average Traffic Volume (vph) at i time period

Table 1 shows traffic volume, capacity, and v/c calculated with the above formulas. As we know from Table 1, the range of v/c at each section, the basic freeway, tunnel, and toll gate are 0.16 to 1.04, 0.16 to 1.04, and 0.10 to 0.80, respectively. The various ranges of v/c under stable and uncongested flow conditions were used. The v/c for some sections were 1.04 because we used the calculated capacity not the measured capacity at sites.

3.2 Accident Rate (AR)

Traffic accident data was collected from the data base in the Korea Highway Corporation (KHC). Accidents involving injured persons and property damage only accidents over 700 dollars are reported to the police in Korea. Table 2 shows accident data that occurred on the selected sections from 1992 to 1997. In order to compare hourly v/c with accident data, the hourly accident rate was calculated by formula 4.

TABLE 1 Traffic Characteristics Data

Sections		Traffic volume (vph)	Capacity (vph)	v/c	Section Length(km)
Basic Freeway	Basic 1	774-5613	4998-5520	0.16-1.04	2.0
	Basic 2	723-5430	4623-6007	0.16-0.90	2.0
Tunnel	Kwanggyo	774-5613	4898-5410	0.16-1.04	1.98
	Panwol	723-5430	4530-5887	0.16-0.92	1.87
Toll Gate	Tongsoowon	836-5819	8550	0.10-0.68	1.96
	Pugok	577-4333	5400	0.11-0.80	1.84

TABLE 2 Number of Accidents

Sections	1992	1993	1994	1995	1996	1997
Basic 1	3	6	1	4	3	1
Basic 2	2	5	8	5	4	3
Tunnel 1	9	16	16	3	4	3
Tunnel 2	4	15	4	3	3	3
Toll Gate 1	5	5	17	12	15	8
Toll Gate 2	9	11	14	12	31	9

$$AR = \frac{AN_i \times 1,000,000}{V_i \times L} \qquad (4)$$

AR = Hourly Accident Rate per 1 million veh-km
AN_i = the number of accidents at i time
V_i = Traffic Volume (vph) at i time
L = Section length (km)

There are two methods to determine the section length affected by traffic facility. The first method is to use the length adding influence zone distance from the starting and ending points of facility sections. Second, the length in which drivers can recognize the facility section can also be used. Regarding the latter, because it can vary due to queue length, we used the former method.

The influence zone distance is 750 m. The reason for selecting 750 m is that it is used for the influence zone distance for isolated ramps on freeways in the highway capacity manual. The analysis section lengths of the Kwanggyo Tunnel and the Panwol Tunnel are 1,980 and 1,870 m, respectively. At the Tongsoowon and Pugok tollgates, the lengths are 1,960 and 1,840 m, respectively. Considering these lengths, 2.0 km is selected for basic freeway sections.

4. DATA ANALYSIS

4.1 Basic Freeway Section

The range of v/c and AR on selected basic freeway sections was 0.16 to 1.04 and 99.34 to 1383.99. The relationship between v/c and AR for the basic freeway section represented a U-typed pattern curve similar to previous research. The value of R-square was 0.5161.

The basic freeway section has the minimum accident rate when v/c is 0.78. The accident rate appeared higher when v/c was low. There are several possible reasons for this, one of which, is that drivers can select their speed freely and the caution of drivers can be diminished because there is not much traffic obstructing other vehicles. Figure 2 shows the relationship between v/c and AR at the basic freeway section.

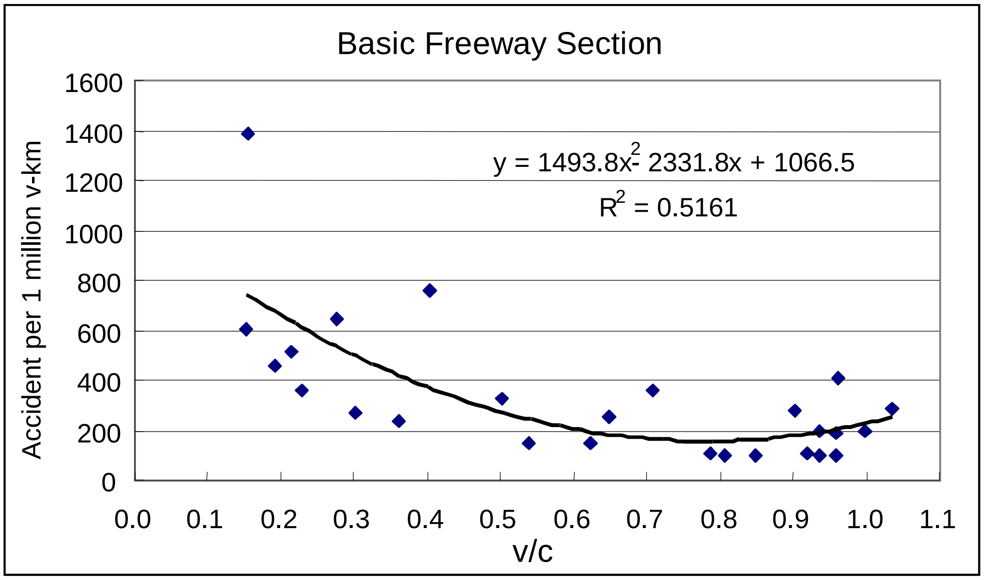

FIGURE 2 Relationship between v/c and AR at basic freeway section.

4.2 Tunnel Section

The pattern of accidents at tunnel section also represented a U-type curve and the ranges of v/c and AR were 0.16 to 1.04 and 105.45 to 766.13, respectively. The relationship between v/c and AR by regression analysis represented a polynomial function form. R-square was 0.5079. The tunnel section has the minimum accident rate when v/c is 0.74. Figure 3 shows the relationship between v/c and AR at tunnel section.

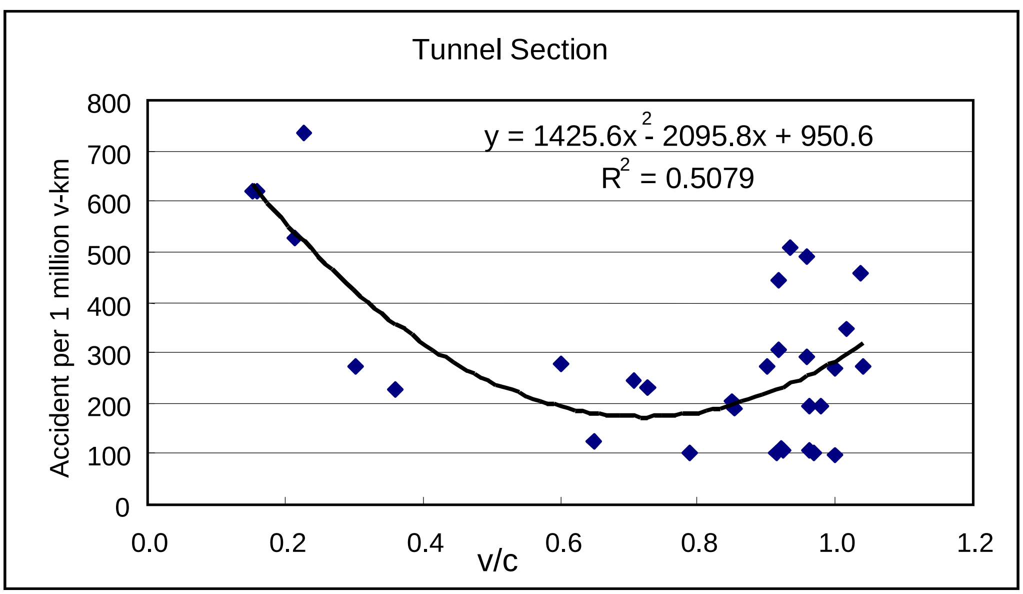

FIGURE 3 Relationship between v/c and AR at tunnel section.

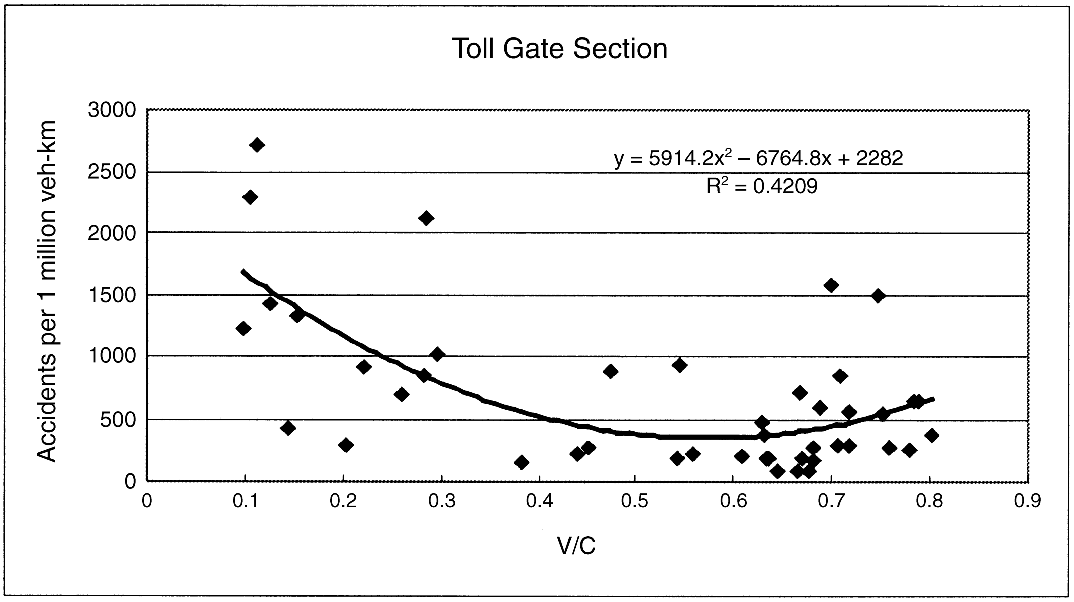

FIGURE 4 Relationship between v/c and AR at basic toll gate section.

4.3 Toll Gate Section

The pattern of accidents at toll gate sections represented a U-type curve, and the ranges of v/c and AR were 0.10 to 0.80, and 89.83 to 2713.77. The relationship between v/c and AR by regression analysis represented polynomial function form. R-square was 0.42. The toll gate section has the minimum accident rate when v/c is 0.57. Figure 4 shows the relationship between v/c and AR at toll gate section.

5. COMPARISON OF RELATIONSHIP

The accident rate models consisting of an independent variable of v/c by regression analysis were established as shown in Table 3.

As Figure 5 shows, the accident rate of the toll gate section is higher than that of the basic freeway and tunnel sections throughout the whole range of v/c.

TABLE 3 Accident Rate Model for Each Section

Facility	Model	R-square
Basic Freeway	$AR=1493.8(v/c)^2-2331.8(v/c)+1066.5$	0.5161
Tunnel	$AR=1425.6(v/c)^2-2095.8(v/c)+950.6$	0.5079
Toll Gate	$AR=5914.2(v/c)^2-6764.8(v/c)+2282.5$	0.4209

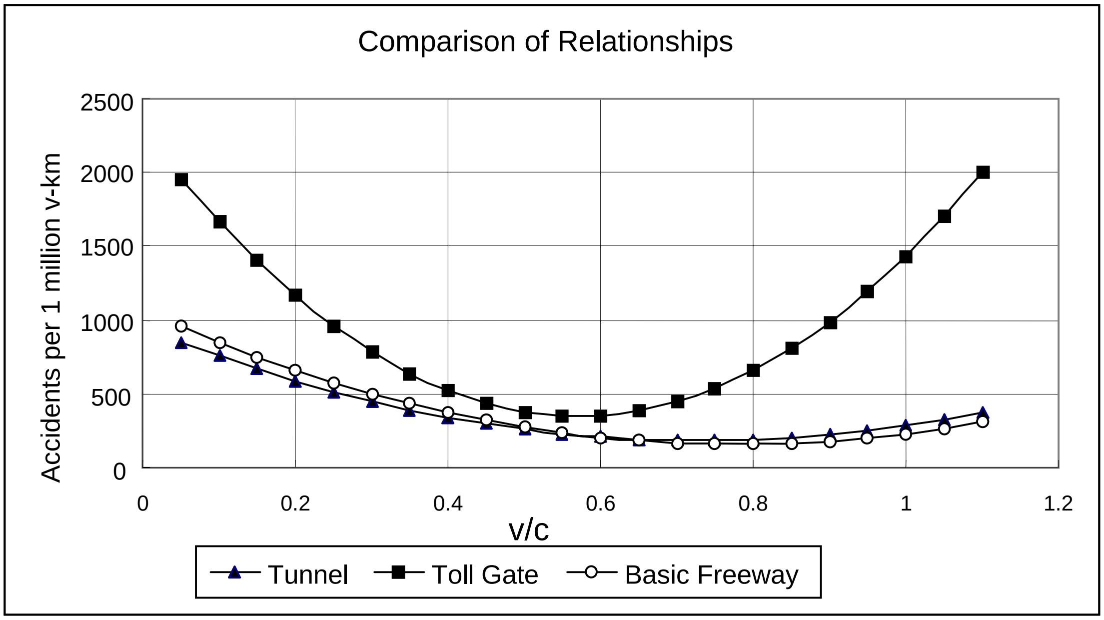

FIGURE 5 Comparison of relationship between v/c and AR.

The result of the comparison indicates that accident rates are higher in the low hourly v/c range, and then decrease as v/c ratio increases, and increase as the v/c ratio approaches and exceeds 1.0. Although the accident rate of the tunnel section is higher than that of the basic freeway section when the v/c is above 0.67, there is no significant difference of accident rates between the basic freeway and the tunnel section when the v/c is between 0.5 and 0.8. Table 4 shows v/c when the accident rates have the minimum values.

6. CONCLUSIONS

The objective of this study was to clarify the relationship between v/c, representing traffic condition, and the accident rate representing safety on various freeway facility sections. Accident rate models for facility sections were established by regression analysis with reliable data. R^2 values are in the range of 0.4209 to 0.5161.

The major findings are as follows:

1. Tunnel and Basic Freeway.
When v/c is above 0.67, the accident rate of the tunnel section is higher than that of the basic freeway section. However, there is no significant difference of accident rates between them.

TABLE 4 v/c with Minimum Accident Rate

Section	Basic Freeway	Tunnel	Toll Gate
v/c	0.78	0.75	0.57

2. Toll Gate and Other Facility Sections.
The accident rate of the toll gate section is, in general, higher than that of other sections.

3. Minimum Accident Rate.
Basic freeway, tunnel, and toll gate sections have the minimum accident rates when v/c is 0.78, 0.75, and 0.57, respectively.

4. Limitation of Research.
As R^2 values of the accident rate models established in this study are 0.4209 to 0.5161, the model did not fully explain the relationship between v/c and accident rates. In order to obtain a better result, additional explanatory variables of highway geometric and other traffic conditions should be considered.

REFERENCES

1. *Freeway Traffic Volume Statistics*. (1992–1997). Korea Highway Corporation.

2. *Freeway Traffic Accident Statistics*. (1992–1997). Korea Highway Corporation.

3. *Highway Capacity Manual*. (1992). Korea Ministry of Construction.

4. Freeway Design Manual. (1992). Korea Highway Corporation.

5. Ceder, A., and M. Livenh. (1982). Relationship between Road Accident and Hourly Traffic Flow-I and II, *Accident Analysis and Prevention*, Vol.14, No.1, 1982, pp. 19–44.

6. Frantzeskakis, J.M., and D.I. Iordanis. (1987). Volume-to-Capacity Ratio and Traffic Accident on Interurban Four-Lane Highways in Greece, *Transportation Research Record 1112*, TRB, National Research Council, Washington, D.C., pp. 29–38.

7. Gwynn, D.W. (1967). Relationship of Accident rate and Accident Involvements with Hourly Volumes, *Traffic Quarterly*, July 1967, pp. 407–418.

8. Hall, J.W., and O.J. Pendleton. (1989). Relationship Between V/C Ratios and Accident Rates, Report FHWA-HPR-NM-88-02. FHWA, U.S. DOT, June 1989.

9. Min, Z., and V. P. Sisopiku. (1997). Relationship between V/C Ratios and Accident Rates, *Transportation Research Record 1581*, TRB, National Research Council, Washington, D.C., pp. 47–52.