

## AN EFFECT OF TRIP LENGTH ON FREEWAY ACCIDENT RATES

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**Abstract :** Road accidents are considered as the results of a complex interplay between road, vehicle, environments, and human factors. Little study, however, has been carried out on the attributes of human factors compared to the road geometric conditions and traffic conditions. The previous researches focused on mainly both traffic and geometric conditions on specific location. Therefore, it's hard to explain phenomenon of the high traffic accident rates where road and traffic conditions are good. Because of these reasons, accident analysis has contributed on geometric improvement and has not contributed on traffic management such as selection of attention section, driver napping alert, etc. The freeway incident management is also associated with reliable prediction of incident occurrences on freeway sections. This paper presents a method for estimating the effect of trip length on freeway accident rate. A PAR (Potential Accident Ratio), the new concept of accident analysis, considering TLFDs (Trip Length Frequency Distributions) is suggested in this paper. This approach can help to strengthen freeway management and to reduce the likelihood of accidents.

**Key Words:** traffic accident, human factors, fatigue, Potential Accident Ratio, Trip Length Frequency Distribution

## **1. INTRODUCTION**

Road accidents are considered as the results of a complex interplay between road, vehicle, environment, and human factors. In Korea, 3,638 accidents occurred on freeways with 456 deaths in 2003. It has been reported that the largest cause of accidents on freeways is human factors such as sleepy driving, speeding and other driving mistakes.

In the past researches, however, models were mainly focused to establish the relationship between incidents, road geometric characteristics, and traffic conditions. For example, factors that affect accident rates in previous studies include land use, weather, traffic volume, and road geometry such as curvature and horizontal alignment.

Freeways have better geometric conditions than other roads such as urban roads and highways. It is well known that driving on freeways more than 2 hours causes high possibility to sleepy driving because of a monotonous geometric conditions and a scene lacking variety.

Very few attempts however, have been made to explain human factor compared to the road geometric factor and traffic factor, although human factor takes about 80% in the cause of freeway accident. This can be attributed to the fact that the acquisition of human factor data requires the extensive use of field surveillances and involves time-consuming data processing. Several new techniques allow to collect trip length data using TCS (Tollgate Collection System) in Korea Highway Corporation, and to collect data using AVIS (Automatic Vehicle Identification System) in other road facilities in the near future. This leads use trip length data because it is related to sleepy driving in the human factor.

The purpose of this paper is to investigate the effect of trip length factor on traffic accidents. Several new term of PAR (Potential Accident Ratio), the new concept of accident analysis, considering TLFDs (Trip Length Frequency Distributions) are suggested in this study.

## **2. LITERATURE REVIEW**

### **2.1 Geometric Design Conditions**

Studies focused on geometric design and safety aim to improve highway design and to eliminate hazardous locations. The effects of design elements such as horizontal curvature, vertical grade, lane width, etc on safety have been studied. For example, Kang & Lee(2002)

found that followings are contributing geometric factors in freeway accidents: radius of curve, curve length, inter-change, and length of straight road section.

## **2.2 Traffic and Weather Conditions**

Existing studies in this area have tried to identify the relationship between traffic conditions and accident rates. Oh et al.(1999) examined the relationship between accident rates and V/C(volume/capacity) for freeway facilities. They calculated hourly accident rate and V/C for freeway sections: basic section, tunnel section and toll gate section. They suggested that relationship between accident rate and V/C is U-shaped pattern for all sections. Ivan(2004) also demonstrated that the relationship between traffic volume and accident rates is much more complex.

In contrast to conventional traffic safety studies, Oh et al.(2000) focused on the use of real-time freeway traffic data to prevent traffic accidents, by integrating advanced traffic management and information system capabilities. Their study dealt primarily with traffic conditions leading to accidents identified from both real-time traffic data, obtained from inductive loop detectors, and past accident profiles.

Lee et al.(2000) focused on verifying time-space repetition of freeway accidents and finding their cause and deterrents. They verified the existence of seasonal effect by the self-organizing map and the accident indices, and used the hierarchical cluster analysis to decide the seasonal groups in accordance with accident patterns, suggesting that seasonal factors are strongly related to the accident pattern of every seasonal group. Konduri et al.(2003) presented incident prediction models for freeway sections developed as a function of traffic volume, truck percentage and weather. They analyzed that unlike section length, traffic volume is non-linearly related to incidents.

## **2.3 Human Conditions**

Kim et al.(2001) analyzed fatigue-related collisions and injury outcomes of fatigue-related crashes using police crash data and insurance claim records. They suggested that distinct temporal and spatial patterns, as well as relationships between fatigue-related crashes and driver characteristics. Lord (2002) presented that individual risk of being in accident decreased as traffic flow increased.

However, little study has been carried out in the attributes of human factor compared to the road geometric conditions and traffic conditions. The previous researches focused on mainly

traffic volume as traffic conditions and geometric conditions on specific location. Therefore, they did not explain the high traffic accident rates where road and traffic conditions were good.

Consequently, accident analysis has contributed on geometric improvements and did not contribute on traffic management such as selection of attention sections, driver nap alert, etc. The management of freeway incidents is associated with reliable prediction of incident occurrences on freeway sections, and rapid detection and clearance of freeway incidents when they occur.

Giving information about hazardous section at upstream is based on the law of the unpredictable theory. That is a case where driver gets the risk information in advance in spite of high risks have lower traffic rates than in case of a sudden change of conditions (Lee et al., 2000). This is based on the fact that driver who have prior information about hazardous section is lower than a driven who have no prior information.

This paper presents a method to estimate the relationship between accidents and trip lengths on freeways. This approach can help to strengthen freeway management and reducing the likelihood of accidents.

### **3. ACCIDENT ANALYSIS METHOD CONSIDERING PAR**

#### **3.1 Sleepy Driving and Trip Length**

It has been known that the average physiological limitation of human to concentrate on work is 2 hours. It is also known that working in simple, monotonous environments such as familiar or simply repeating works leads to mental fatigue or sleep (Sim et. al., 1998). Freeways have better geometric conditions more than other roads such as urban roads, and highway. It is well known that driving on freeways than 2 hours causes significant mental and physical fatigue and high possibility to sleepy driving because of a monotonous geometric conditions and a simple scene.

Some differences exist between sleepiness (or drowsiness) and fatigue. Sleepiness is defined as the inclination to sleep, and psychological fatigue is defined as the decrease of task performance. The main cause of accident is a progressive withdrawal of attention to traffic and the roadway environments, which then leads to impaired performance behind the wheel. Therefore, the effects of sleepiness and fatigue on accident are similar. Sleepiness and

fatigue are also physiological states, brought about by the restriction or interruption of sleep (Kim & Yamashita, 2001).

In order to include a factor that relate sleepy driving, we incorporate a trip length concept. We suggest PAR (Potential Accident Ratio), new concept of traffic accident analysis, considering TLFDs.

### 3.2 Concept of Potential Accident Ratio Considering TLFDs

Driver’s attention upon maneuvering decreases as traveling time increases, although the decrease of maneuvering attention diverse from individuals. To reflect this physical and psychological symptom, we incorporate TLFDs (Trip Length Frequency Distributions). This is based on the concept that OD (Origin and Destination) trips include travel behaviors, namely travel distance, in the freeway network.

Generally, drivers have a tendency to drive thoughtless and inattentively as they travel beyond their physical and psychological threshold time ( $T_c$ ) that separable cautious driving status from careless driving status. Further, drivers monotonously driving more than  $T_c$ , will have a higher probability to trigger accidents than the others driving less than  $T_c$ . To consider drivers having an incident potential, we introduce a new term, Potential Accident Ratio (PAR), that is the percentages of drivers under careless driving status to the others at road point or on a road section. Figure 1 shows the concept of estimating PAR using TLFDs and  $T_c$ . In this figure a, b and c are point of traveling time.

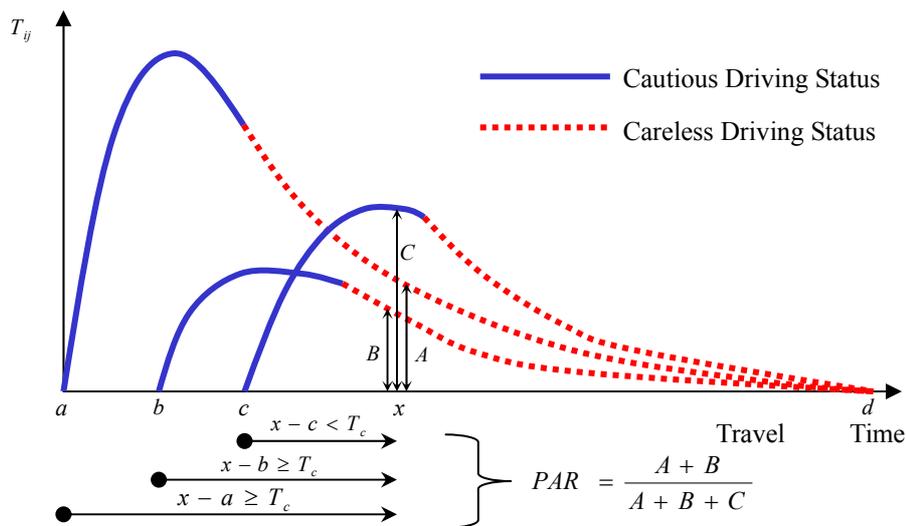


Figure 1. Concept of PAR considering both TLFDs and  $T_c$

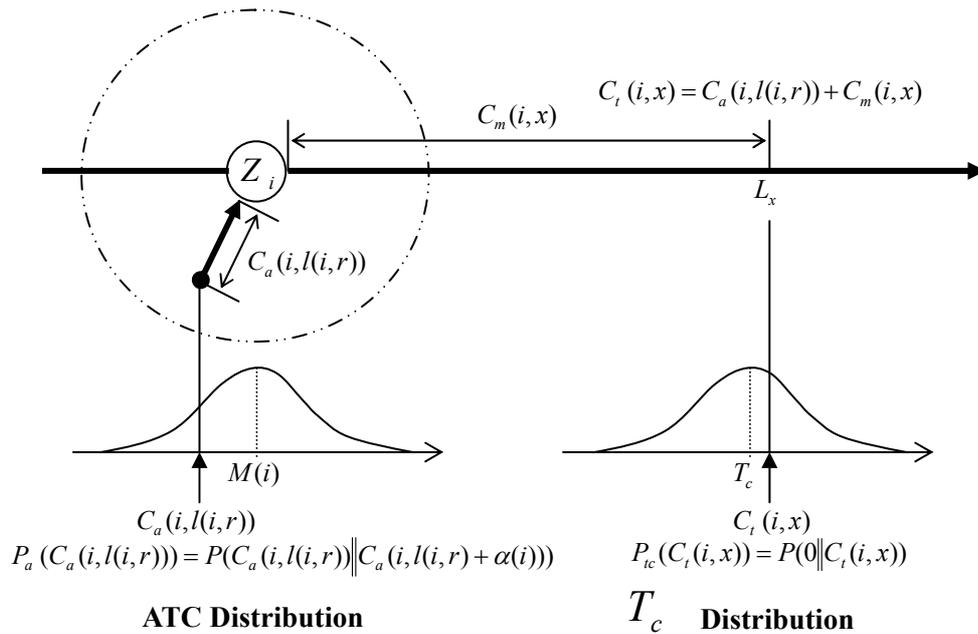


Figure 2. Estimation Process of PAR Considering both Access Time and Travel Time in Distributions.

### 3.3 Estimation of PAR With TLFDs

#### Assumptions

Access Time Cost (ATC) to tollgate to exit and enter freeway varies. The first reason is because the land-use and social-economic activity systems, and  $T_c$ , threshold value between cautious and careless driving status is diverse. The second reason is the fact that each individual has different physical and psychological conditions. These two reasons make it difficult to explain ATC and  $T_c$  by single value.

To reflect above uncertainties, we assume that ATC and  $T_c$  have normal distributions, and the two distributions are defined as ATC distribution and  $T_c$  distribution each.

#### Notations

$Z(i)$ : Zone set  $Z(i) \in Z$ . In this study a tollgate is treated as a zone.

$T_{ij}$ : Trips (Vehicle per day) from  $Z(i)$  to  $Z(j)$ ,  $\forall i, j$

$L$ : Link set  $L_x \in L$

$P_{ij}$ : A path chain of link set  $\{L_1, \dots, L_m\} \in L$ , from  $Z(i)$  to  $Z(j)$ ,  $\forall i, j \quad i \neq j$

$C_a(i, l(i, r))$ : Access Time Cost (min) to  $Z(i)$  in ATC distribution for  $Z(i)$  that has both Mean,  $M_a(i)$ , and Standard Deviation (SD),  $\delta_a(i)$ .  $C_a(i, l(i, r))$  have a following

probability at  $l(i, r)$ .

$$P_a(C_a(i, l(i, r))) = P(C_a(i, l(i, r)) \parallel C_a(i, l(i, r) + \alpha(i)) \quad \forall i \quad (1)$$

$\alpha(i)$ : Discrete probability section length in ATC distribution for  $Z(i)$ .

$$\alpha(i) = \delta_a(i) / n \quad n = \{1, 2, \dots\}, \quad \forall i$$

$N(i)$ : Number of discrete probability sections in ATC distribution for  $Z(i)$ .

$$N(i) = 2 \times M_a(i) / \alpha_a(i) \quad \forall i$$

$l(i, r)$ : R-th access time cost in ATC distribution for  $Z(i)$ .

$$l(i, r) = r \times \alpha_a(i) \quad r \in \{0, 1, 2, \dots, N(i) - 1\}, \quad \forall i$$

$F_{ad}(i)$ : Adjusting factor for  $P_a(C_a(i, l(i, r)))$

$$F_{ad}(i) = 1.0 / \sum_r P(C_a(i, l(i, r)) \parallel C_a(i, l(i, r) + \alpha(i)) \quad \forall i \quad (2)$$

$C_l(x)$ : Travel time cost (min) at  $L_x \quad L_x \in L$  and  $\forall x$

$R_{ik}$ : A path chain of link set  $\{L_1, \dots, L_k\} \in L$  from  $Z(i)$  to  $L_k, L_k \in L, \forall i, k$

$C_m(i, x)$ : Travel time cost (TTC, min) from  $Z(i)$  to  $L_x \quad \forall i, x$

$$C_m(i, x) = \sum_k C_l(x) \quad (3)$$

$C_t(i, x)$ : Total Travel Time Cost (TTTC, min) from  $Z(i)$  to  $L_k$  including  $C_a(i, l(i, r))$ .

$$C_t(i, x) = C_a(i, l(i, r)) + C_m(i, x) \quad \forall i, x \quad (4)$$

$T_c$ : Threshold value between cautious and careless driving status in  $T_c$  distribution that has both Mean,  $M_t = T_c$ , and SD,  $\delta_t$ .

$T_{ij}(x)$ : Trips from  $Z(i)$  to  $Z(j)$  passing  $L_x, L_x \in P_{ij}$

$T_{ij}(x, C_t(i, x))$ : Careless driving trips from  $Z(i)$  to  $Z(j)$  passing  $L_x$ , and  $C_t(i, x)$  has

probability,  $P_{tc}(C_t(i, x)) = P(0 \parallel C_t(i, x))$  in  $T_c$  distribution at  $L_x. L_x \in P_{ij}, \forall i, j, x$

$R_{par}(x)$ : PAR (Potential Accident Ratio) for  $L_x \quad L_x \in P_{ij}$

### Estimation of PAR with TLFDS

STEP1: Estimation of both  $T_{ij}(x)$  and  $C_l(x)$  for  $L_x$  is done with given  $T_{ij}, P_{ij}$ .

$$T_{ij}(x) = \sum_i \sum_j T_{ij} \quad L_x \in P_{ij}, \quad \forall i, j, x \quad (5)$$

$C_l(x)$  can be estimated with  $T_{ij}(x)$  by BPR function or surveyed travel time.

STEP2:  $T_{ij}(x, C_t(i, x))$  is estimated with both ATC and  $T_c$  distribution as following.

$$T_{ij}(x, C_t(i, x)) = \sum_i \sum_j \sum_r T_{ij} \cdot P_a(C_a(i, l(i, r))) \cdot F_{ad}(i) \cdot P_{tc}(C_t(i, x)) \quad L_x \in P_{ij}, \quad \forall i, j, r \quad (6)$$

STEP3: PAR at  $L_x$  is calculated as following.

$$R_{par}(x) = T_{ij}(x, C_t(i, x)) / T_{ij}(x) \quad \forall x \quad (7)$$

## 4. CASE STUDY

### 4.1 Study Area and Data Collection

Accident database of Korea Highway Corporation contains various sources of information: traffic accidents (location and time of the accident, type of accident, cause of accident, injuries, etc), road conditions (road surface, grade, etc), traffic conditions (the status of traffic restriction), environmental conditions (weather, light conditions, etc). However, the accident database lacks the information about traffic conditions and driver conditions (fatigue, sleepy driving, etc).

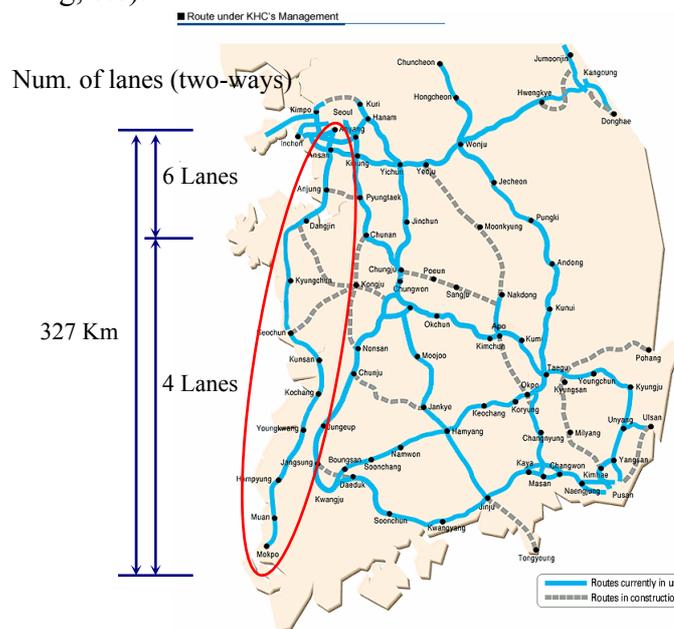


Figure 3. Target Freeway Route and Location in South Korea

Figure 3 shows the freeway route 15 that is the target route named West Coast Sea Freeway. The design speed of the route was 120kph and the length of route reaches 327km.

Vehicle trip data of inter-tollgates is monitored by Toll Collecting System (TCS). TCS is a

closed electronic toll pricing system and monitors more than 99.9% of vehicle trips between tollgates on real time. Detailed information on all of traffic accidents are collected and documented into a traffic accident database of FTMS. So the trip and traffic accident data is considered to have high quality and accuracy to satisfy this study. In this paper we did not consider different vehicle types.

#### 4.2 Definition of Network for Analysis

The freeway route 15 in figure 3 is composed of 27 zones and 26 links. Link (i) is defined to connect zone (i) and zone (i+1). Northbound is a direction to zone (1) from the other zones, northbound in Figure 3, and southbound is vice versa.

#### 4.3 Traffic Accidents and Travel Behavior Analysis

Traffic accident pattern (Number of Accidents, NA, per year) in Figure 4 shows two patterns that are distinguished by link 11. The accident frequencies of the first from section from link 11 to 26 is higher than those of the second section from link 1 to 11. Figure 5 shows link volume (vehicles per day per lane) pattern which decrease monotonously from north to south. Close examination of both traffic accidents and link volumes implies that number of traffic accidents cannot hardly explained by traffic volume only.

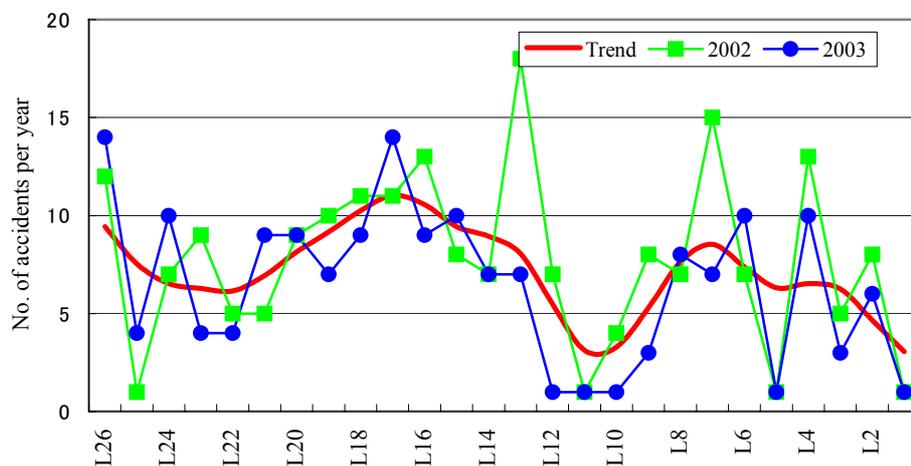


Figure 4. Number of South-bound Traffic Accidents per Year according to Location(L)

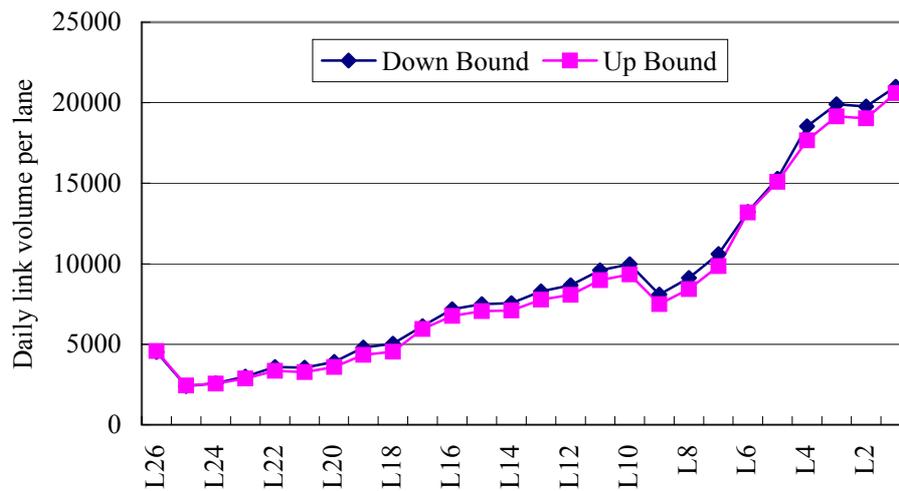


Figure 5. Link Volume According to Location (L) in 2002

Figure 6 shows down-bound TLFDs from departure zone (i), zone (i) ∈ {1,...,10} to other down zone (j), zone (j) ∈ {1,...,27}. The TLFDs explain that vehicle trip behaviors vary heavily because the social-economical activities of intra zones diverse dynamically, and show relatively longer trip length than that of an urban network.

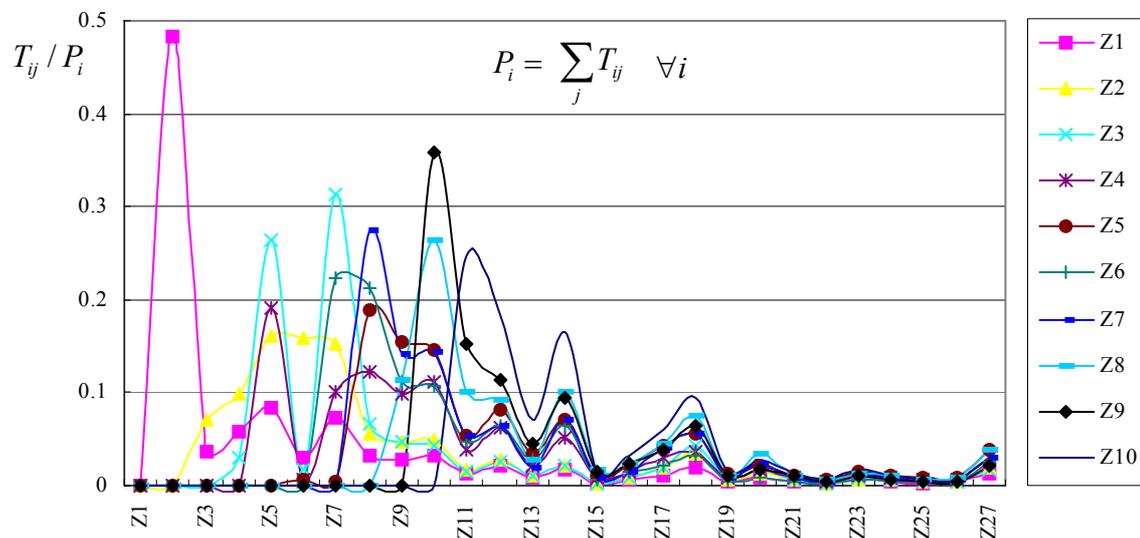


Figure 6. Southbound TLFDs (Trip Length Frequency Distributions) in 2002

#### 4.4 Establishment of Accident Rate (AR)

As the target of this study is to build a prediction model for traffic accident analysis in mesoscopic network level, NAMVKL (Number of Accidents per Million Vehicles • Km per Lane) is used as AR.

$$\text{NAMVKL} = \text{Million} \times \text{NA} / (365 \times \text{LV} \times \text{LD}) \tag{9}$$

Where, NA: Number of accidents at link (i) per year

LV: Volume of link (i) per lane per day

LD: Distance (Km) of link (i)

#### 4.5 Relationship between NAMVKL and Link Volume

As Figure 7 indicates, the relationship between NAMVKL and volume is a sort of downward concave curve. In this figure each link is represented for two separate years and directions. The large differences indicated that accident rate, namely NAMVKL in this paper, is hardly explained by only link volume. This is because link volume does not contain the information on drivers' physical and psychological status.

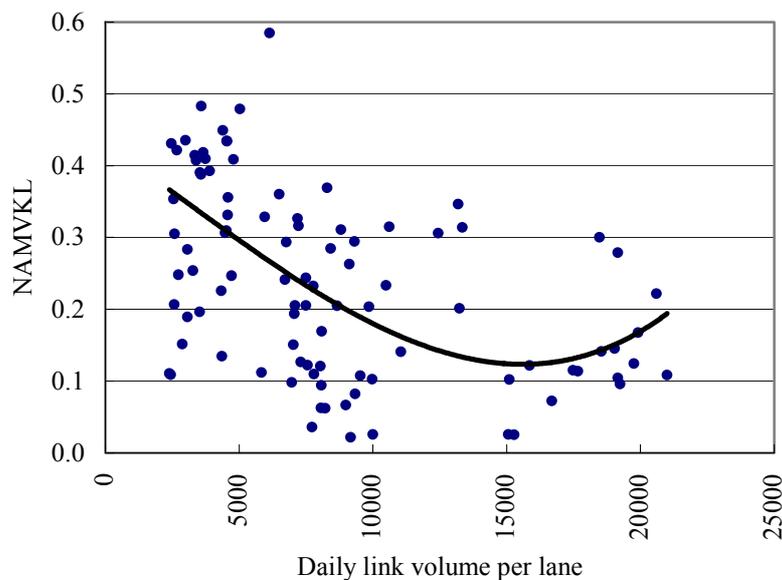


Figure 7. Relationship between NAMVKL and Volume

#### 4.6 Relationship between NAMVKL, Link Volume and PAR

Close examinations on figure 8 indirectly implies following three relationships. Link volume value for link (i) is link volume (i) / Max {link volume (i)}.

- 1) As link volume is low and PAR is high, then NAMVKL is relatively high.
- 2) As link volume is moderate and PAR is middle, then NAMVKL is relatively moderate or low.

3) As link volume is high and PAR is low, then NAMVKL is relatively low.

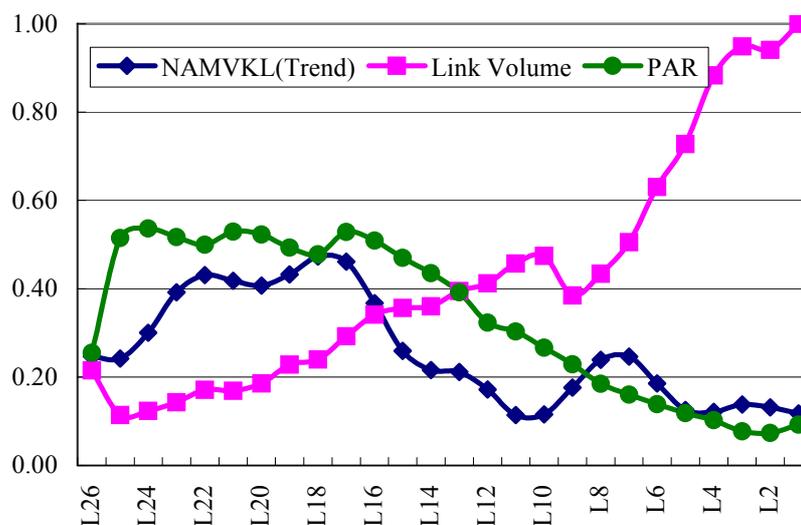


Figure 8. Relationship between NAMVKL and Volume and PAR according to Location(L)

The first relationship can be explained that low interactions between vehicles due to low link volume cause drivers under Careless Driving Status (CDS) and therefore lead to higher probability to cause traffic accidents. The second moderate interaction due to moderate volume leads to pay enough attention for drivers under CDS so accidents might be relatively moderate or low. The last might be explained that high link volume causes accidents per se but increases the interactions and drivers under CDS will pay attention to their driving so accidents might be relatively decrease. The last can be explained that high interactions caused by high volume let drivers pay high attentions and therefore reduces accidents.

#### 4.7 Traffic Accident Rate Prediction Model

We use traffic accident rate (Y) as dependent variable and PAR ( $X_1$ ), traffic volume per lane ( $X_2$ ) as independent variables. Since it has been reported that accident rate has non-linear relation to traffic volume, we formulate non-linear relationships on accident rate, traffic volume, and PAR. Among various non-linear models we selected the model that show high R-square and significance of variables. It is founded that the model using PAR and traffic volume as independent variables is better than the model using PAR or traffic volume as independent variables. The value in parenthesis is t-value. Comparison of observed accident data with predicted accident data is given in Figure 9.

(Model using PAR as independent variables)

$$Y = 0.178 - 0.388X_1 + 1.487X_1^2 \quad (R^2 = .441)$$

(1.735) (0.640)\* (0.258)\*      \*= not significant

(Model using traffic volume as independent variables)

$$Y = -4.518 + 1.217(\ln X_2) - 0.076(\ln X_2^2) \quad (R^2 = .389)$$

(-.981)\* (1.173)\* (-1.305)\*      \*= not significant

(Model using PAR and traffic volume as independent variables)

$$Y = -23.979 - 5.046X_1 + 7.7556X_1^2 + 5.828(\ln X_2) - 0.339(\ln X_2^2) \quad (R^2 = .693)$$

(-3.996) (-3.902) (4.259) (4.076) (-4.104)

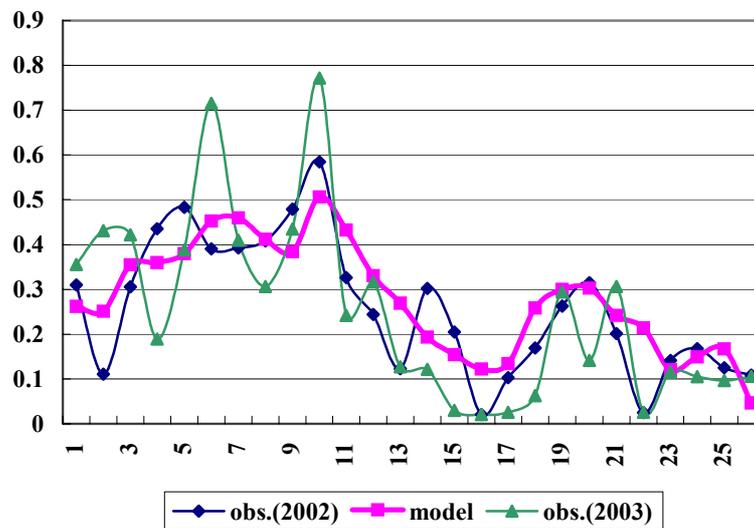


Figure 9. Comparison of Observed with Predicted Accidents

## 5. CONCLUSION

Little study has been carried out in the attributes of human factor compared to the road geometric factors and traffic factors. Therefore, existing models have limitation to explain the phenomena of high traffic accident rates where road and traffic conditions are good. Consequently, accident analysis has mainly contributed on geometric improvement and did not contribute on traffic management such as selection of attention section, driver napping alert, etc.

This paper presents a method to estimate the relationship between accident and trip length on freeway. This paper introduces PAR (Potential Accident Ratio), the new concept of accident analysis, considering TLFs (Trip Length Frequency Distributions).

We analyzed relationship between the PAR, traffic volume and traffic accident using trip behavior and accident database on the West Sea Coast freeway in the year 2002. We also developed accident prediction model and compared it to year 2003. The case study showed that strong relationship between the PAR, traffic volume and traffic accident on freeway exists.

This approach is considered to be helpful for strengthening freeway management and reducing the likelihood of accidents. The freeway incident model developed in this study can constitute a useful decision support tool for analysis of traffic accident and the implementation of freeway patrol systems. Further, it is useful for selecting optimal location of shoulder rumble strips and sonic napping alert system. In case of knowing the trip length or travel time by the AVIS, the applicability of developed model will be higher. Future research needs the more specific accident model considering vehicle types such as passenger car, bus, and freight vehicle.

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