한국도로학회 논문집
第10券1號 2008年 6月
pp.35~45

고속도로에서의 트럭 차량 관련 사고 요인 분석

Analysis of Truck involved Accidents on Freeways

양 충 헌* 손 영 태**
Yang Choon Heon Son Young Tae

요 지

트럭은 상대적으로 낮은 운송비용과 그 운영의 탄력성 때문에 화물 운송에 가장 널리 이용되는 교통 수단이다. 그러나 전체 교통량에서 트럭교통이 차지 하는 비율이 높은 곳에서는 심각한 안전 문제를 일으킬 수 있다. 트럭사고는 다른 차량간의 사고 보다 더 심각한 부상이나 사상자를 야기 시킬 수 있다. 따라서, 트럭 교통과 관련된 안전 문제는 교통 시스템을 운영, 관리하는 공공부분과 이러한 시스템을 이용하는 일반 운전자에게 있어 중요한 문제이다. 본 연구에서는 트럭관련 사고 자료를 이용하여 교통 조건에 따른 사고 형태를 조사하고 통계기법을 사용하여 현장에서 조사된 사고 요인들 중 어떤 것이 가장 큰 트럭관련 사고 요인인지를 분석한다. 이 연구를 위한 자료는 TASAS 의 database를 이용하였다. 중요 사고 요인이 분석이 되면, 효과적이고 효율적인 트럭 관리 전략에 대해 논의해 볼 수 있다.

핵심용어 : 트럭; 안전; 요인분석

Abstract

Trucking is the most frequently used mode for freight movement due to relatively lower shipping costs and its operational flexibility. However, truck traffic can contribute to serious safety problems where they occupy high percentage of the total traffic. Heavy truck crashes are more likely to result in serious injuries and fatalities than are crashes involving light vehicles. Therefore, safety issues for truck traffic are very significant both for public agencies and for general travelers. The objective of our study is to find truck-involved accident patterns according to traffic conditions and main factors as well as to find the most critical factor through conventional statistical techniques. Available data were obtained from TASAS (Traffic Accident Surveillance and Analysis System). Once critical factors are identified, effective and efficient truck management strategies can be discussed.

Key word : truck traffic; safety; multiple regressions.

* Department of Civil & Environmental Engineering University of California, Irvine, Ph. D (E-mail : chyang@uci.edu)
** Department of Transportation Engineering Myongji University, Professor (E-mail : son@mju.ac.kr)

Introduction

In the past, freight transportation has had a relatively small role in transportation projects since its very small percentage of the total freeway mileage in the U.S. has the truck volumes to justify this need. However, the rising affluence of heavy-duty trucks emerges according to an increase in national economic activities as well as in international trade. Since truck traffic has different characteristics compared with passenger traffic, their trips may produce negative impacts on transportation network, especially safety aspects.

However, trucking is the most frequently used mode for freight movement due to relatively lower shipping costs and its operational flexibility (TRB, 2003). According to Bureau Transportation Statistics (BTS, 2006), truck traffic is dominant mode for freight transportation in the U. S., including 73% of the value and 67% of the weight of all freight shipped. It is obvious that continuing population and economic growth is leading to a rapid increase in freight movements and thus in truck traffic in the U.S. Federal Highway Administration (FHWA, 2001) estimated that the volume of domestic freight is expected to increase by 87% between 1998 and 2020, whereas the volume of international freight is projected to increase by 107% during the same period.

Truck traffic may contribute to serious safety hazards where they occupy high fraction of the total traffic. Truck dimensions including height, width, and length may obstruct other smaller vehicle's sight distance. Also, truck traffic has characteristics that make vehicle passing, merging, and lane-changing difficult. Conflicts between trucks and other vehicles may also lead to severe accidents in mixed traffic. It is fact that even though the total crash rates for trucks are lower than for other vehicles, their fatal crash rates are higher (TRB, 2002). Particularly, heavy truck crashes are more likely to result in serious injuries and fatalities than crashes involving light vehicles. The Federal Motor Safety Administration (FMCSA) estimates that commercial truck-involved fatalities increase approximately 50% by the year 2010.

Geometric, environmental factors and driver performance have been investigated to determine how these factors influence on truck crashes. Not only are incidents involving heavy trucks more severe and a greater hazard than vehicle accidents, they are also much more costly. Impaired trucks often block multiple lanes and require more time to be cleared. This delay results in a greater cost. Therefore, safety issues for truck traffic are very significant both for public agencies and for general travelers. Furthermore, the possibility of the implementation of general truck management strategies can be investigated to reduce safety hazards.

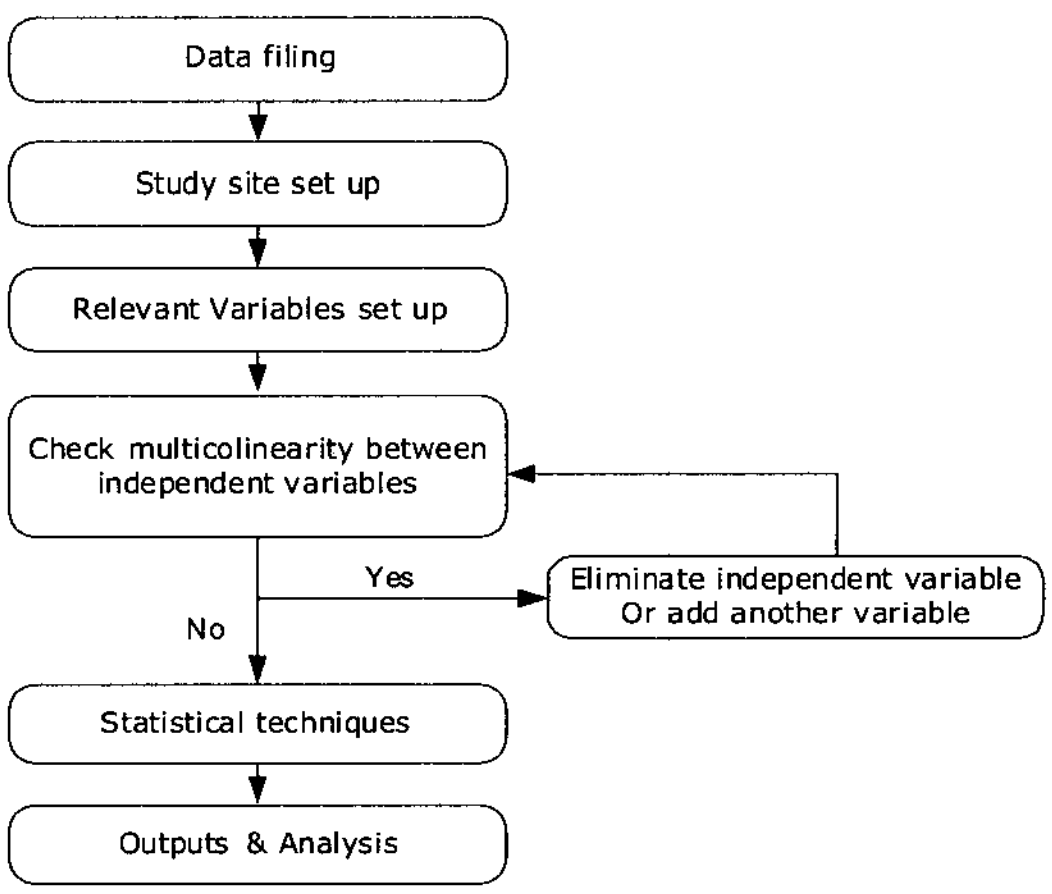


Fig. 1 Overall flow of the study

The objective of our study is to find truck involved accident patterns according to traffic conditions and main factors as well as to find the most critical factor through conventional statistical techniques. Once critical factors are identified, effective and efficient truck manage ment strategies can be discussed. The following

Literature Review

In the study by Daniel and Chien (2004), they developed the model to verify factors that impact truck safety on arterial roadway. This study represented the use of Poisson regression model and negative binomial accident prediction models for truck accidents on an urban arterial with high heavy truck volumes and a number of sig nalized intersections. They used several variables including AADT, percent trucks, posted speed, and number of lanes. The developed models can be used to evaluate truck safety on roadways with signalized intersections.

Golob and Regan (2004) used a binomial logit models as statistical method in order to describe how the probability that a crash relates to a truck is a function of the percentage of annual average daily traffic accounting for by trucks, time of days, day of the week, weather con ditions, mix of truck types, and the absolute level of average annual daily traffic. In addition, a multinomial logit model was used to assist the understanding of the patterns of truck-involved crashes by separating crashes by type, with the main types being rear end, lane changing, and run off collisions. They proposed that results from applications of these kinds of models, ap plied in a specific region, can be useful to public agencies seeking to identify and remedy problem areas either with better driver education or in-vestments in physical or intelligent transportation system infrastructure.

Brower et, al (1993) are modeled accident rates of heavy truck-tractors based on log-linear methods. Log-linear models of casualty and property-damage-only accident rates were devel-oped using number of trailers, road type, area type, and time of days as predictor variables. They found that characteristics of the operating environment were found to have larger effects on the accident rate than tractor configuration. Casualty accident risk at night was 1.4 times the risk during the day. The risk of a casualty accident in rural areas was 1.6 times that of ur-ban areas.

The AASHTO Strategic Highway Safety Plan (2004) identified 22 goals to be pursued to ach-ieve a significant reduction in highway crash fatalities. One of the hallmarks of the plan is to approach safety problems in a comprehensive manner. The range of strategies available in the guides will ultimately cover various aspects of the road user, the highway, the vehicle, the en-vironment, and the management system. As more guides are developed for other emphasis area, the extent and usefulness of this form of implementation will become ever more apparent. AASHTO's overall goal is to move away from independent activities of engineers, law enforce-ment, educators, judges, and other highway safety specialists, and to move to coordinated efforts.

Methodology

Data Source

Data was obtained from the Traffic Accident Surveillance and Analysis System (TASAS) database maintained by the California Department of Transportation(TASAS, 2002). Truck traffic data was available an average annual basis. Database contains various information on both total number of accidents and truck-involved accidents according to six routes in Orange County of Southern California. In addition, database includes total annual average daily traffic, ranging from March 1st, 2001 to February28th, 2002. In order to meet the goal of this study, we examined only for truck-involved data from entire database. The following table shows the total number of truck-involved accidents for each route.

Table 1 Thetotal number of truck-involved accidents for each route (2001 year)

Route	I-405	I-5	SR-91	SR-57	SR-55	SR-22
# of accidents	135	310	220	123	65	44

Of these routes, I-5 and SR-91 occupied high percentage of truck-involved accidents relative to other routes as 35% and 25%, respectively. According to the report, truck-involved accidents were mainly represented heavy-duty trucks. Therefore, these two routes, I-5 and SR-91, were selected as study sites. Total mileage of I-5 is much longer than that of SR-91. Furthermore, geometric characteristics seem to differ in that I-5 corridor is flat level whereas SR-91 has relatively steep grade. The following table 2 represents the total mileage of these two routes for each side.

Table 2 The total mileage of each route

Route	Northbound	Southbound
I-5	796.5 mile	796.3 mile
Route	Eastbound	Westbound
SR-91	22.5 mile	22.6 mile

Source:PeMS (2005)

Data Description

Table 3 Data of Interstate 5

Northbound Side												
Month	1	2	3	4	5	6	7	8	9	10	11	12
Number of Accident	11	11	12	12	13	14	14	15	15	16	16	17
VMT (million)	119	114	124	128	157	163	162	169	159	177	179	168
Speeding	3	14	3	4	6	4	5	4	2	4	0	5
Other Violations	6	1	7	6	4	5	5	7	9	7	13	9
Trucks Percent (%)	6	5	6	6	6	6	7	6	6	6	7	6
Non Peak	5	6	9	7	12	10	7	7	12	13	12	12
Southbound Side												
Month	1	2	3	4	5	6	7	8	9	10	11	12
Number of Accident	16	13	14	11	8	9	9	14	15	13	11	11
VMT (million)	29	25	65	33	34	33	46	33	21	34	57	34
speeding	1	3	1	6	3	3	3	1	6	1	2	1
Other Violations	7	2	2	1	0	5	1	5	2	3	4	8
Trucks Percent (%)	7	8	7	7	8	7	7	7	7	6	7	7
Non Peak	14	12	11	6	5	4	7	7	8	5	4	4

Two routes have high percentage of truck traffic, ranging from 5% to 17%. In order to perform the analysis, they were separated into directions such as southbound, northbound, eastbound, and westbound. In addition, trucks can be categorized into three types according to their weights.

- Light Duty Truck: with weights between 3864kg and 6364kg
- Medium Duty Truck: with weights between 6364kg and 15,000kg
- Heavy Duty Trucks: with weights exceeding 15,000kg

The following table 3 and 4 describe all data information, including month, causal factors, and so forth.

Table 4 Data of SR-91

Eastbound Side												
Month	1	2	3	4	5	6	7	8	9	10	11	12
Number of Accident	8	11	8	11	8	9	6	9	8	5	8	10
VMT (million)	29	25	65	33	34	33	46	33	21	34	57	34
speeding	1	3	1	6	3	3	3	1	6	1	2	1
Other Violations	7	2	2	1	0	5	1	5	2	3	4	8
Trucks Percent (%)	7	8	7	7	8	7	7	7	7	6	7	7
Westbound Side	5	6	9	7	12	10	7	7	12	13	12	12
Month												
Number of Accident	8	6	17	9	8	9	12	9	6	19	27	33
VMT (million)	30	42	29	39	27	31	23	32	28	19	7	33
speeding	3	0	4	3	3	5	6	2	2	2	3	3
Other Violations	3	4	11	5	2	2	4	2	3	6	9	2
Trucks Percent (%)	7	13	3	8	6	6	4	7	9	4	3	7

Statistical Technique

This study makes use of a conventional multiple regression model and thus we need to define dependent and independent variables. The following variables were used for independent ones for the analysis.

Truck Vehicle-mile-traveled (VMT)

Truck VMT is considered as a common factor for calculating accident rate and measure of effectiveness in the transportation system. Intuitively, as truck VMT are increasing, accidents may also be increased. In general, VMT can be expressed as bellows:

$$\text{VMT} = \text{Truck Traffic Volume} \times \text{the total distance}$$

Speeding

According to NCHRP (2003) Report, driving too fast or speeding is one of main factors for truck-involved accidents, especially for heavy trucks, therefore speeding can be considered as an independent variable.

Other violations

In this study, "other violations" imply the following components.

- Failed to yield
- Failure to obey traffic devices
- Changing lanes improperly
- Inattentive

Percentage of truck traffic

As mentioned earlier, most goods are conveyed by trucks, since trucking offers lower shipping costs and its operational flexibility. As the volume of truck is increasing, conflicts between trucks and other vehicles are also increased.

Non-peak time periods

In general, it is known that peak time of truck traffic is different from that of auto traffic. Peak time of traffic can be categorized into 4 time period such as AM, MD, PM, and NT. Of these, MD (Midday) has highest truck traffic on freeway routes. That means, peak time of truck traffic is immediately after auto that of auto traffic. In fact, V/C ratios in the midday period for some freeway segments are as high as or higher than they are in the morning peak period. The interstate 5 is known for truck route, so this variable is applied in this route.

The general multiple regressions form:

$$Y = \alpha + \beta_x X + \beta_z Z + ... + \beta_n N$$

Where,

Y= the number of truck-involved accidents

α = Intercept term

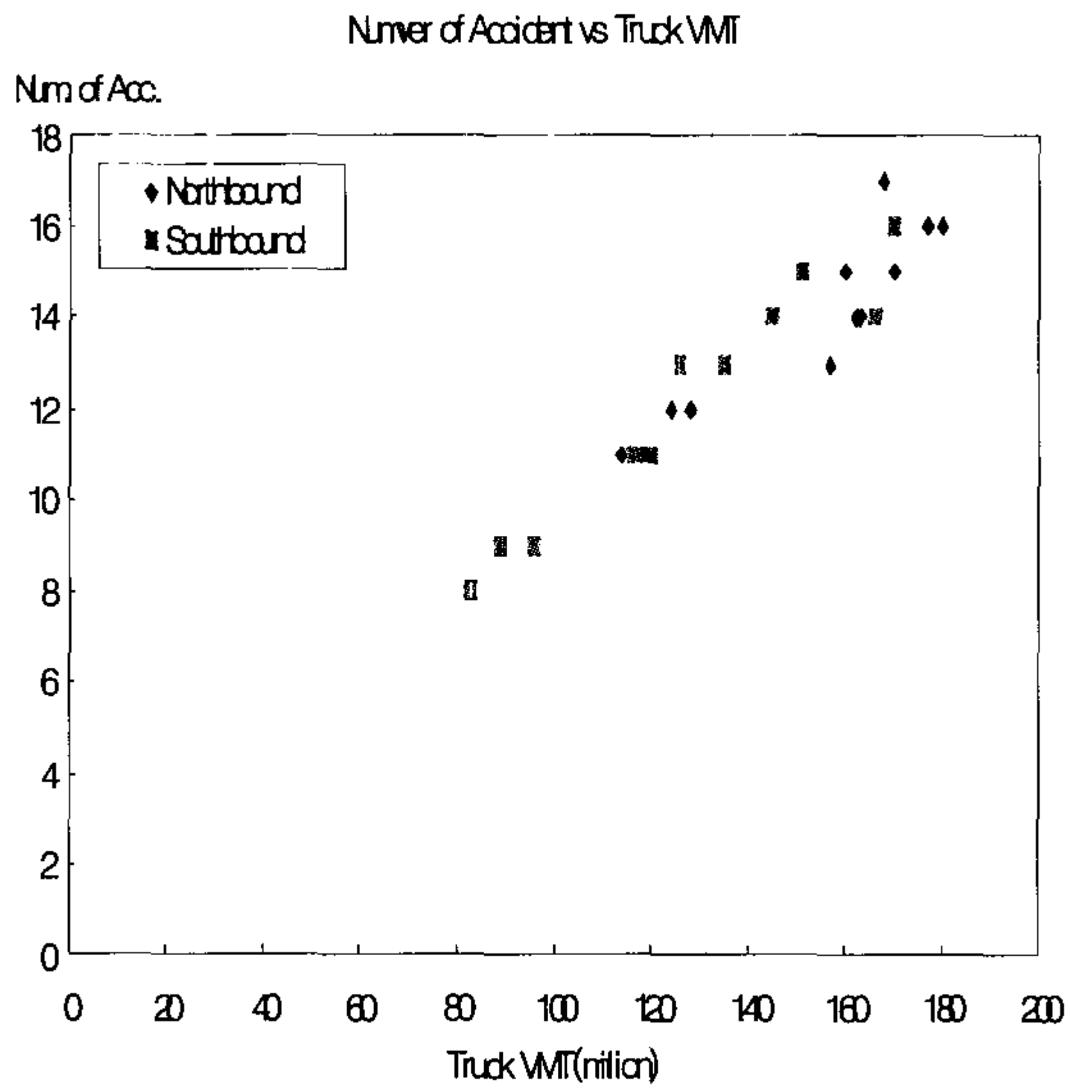
$\beta_x \cdots \beta_n$ =Coefficients of independent variables

$X, ..., N$ = Independent variables

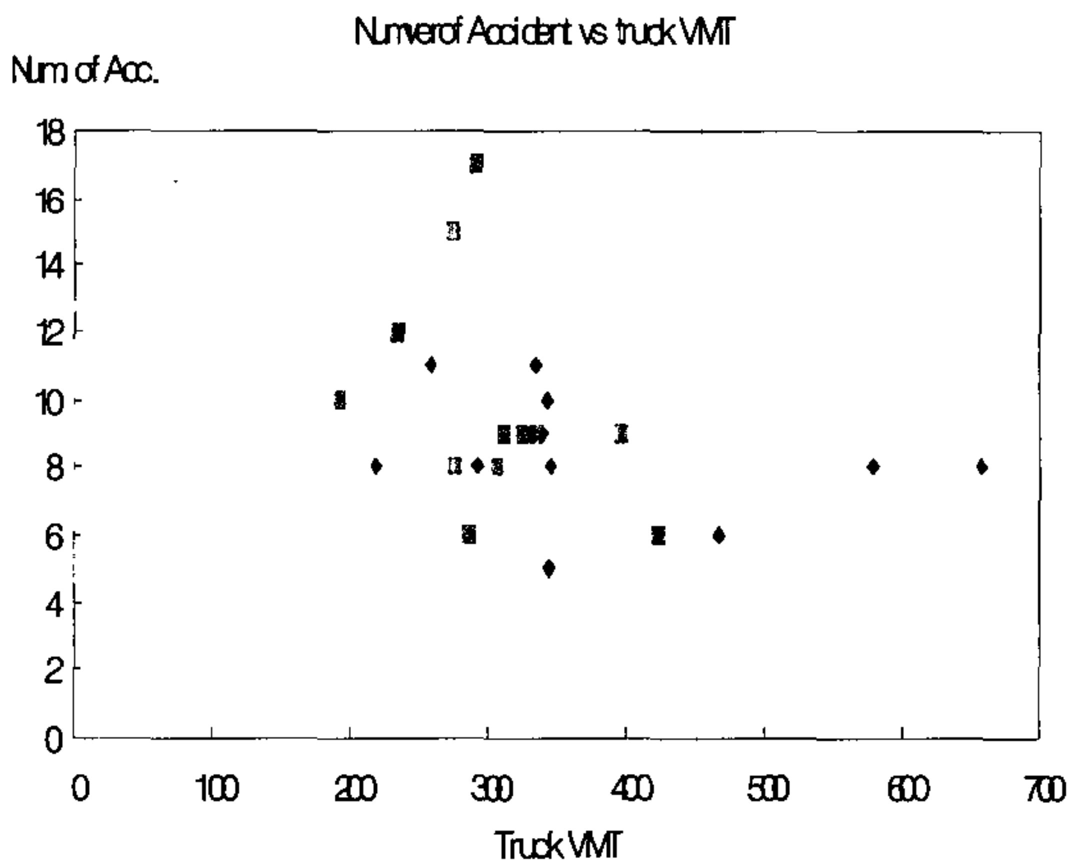
Accident pattern

Truck accident patterns were examined according to causal factor-pair of accident.. The following fig. 2 shows truck VMT versus truck percent for each study site.

As seen above figure, as truck VMT is increasing, the number of truck-involved accidents appear to be increased in both directions on Interstate 5.

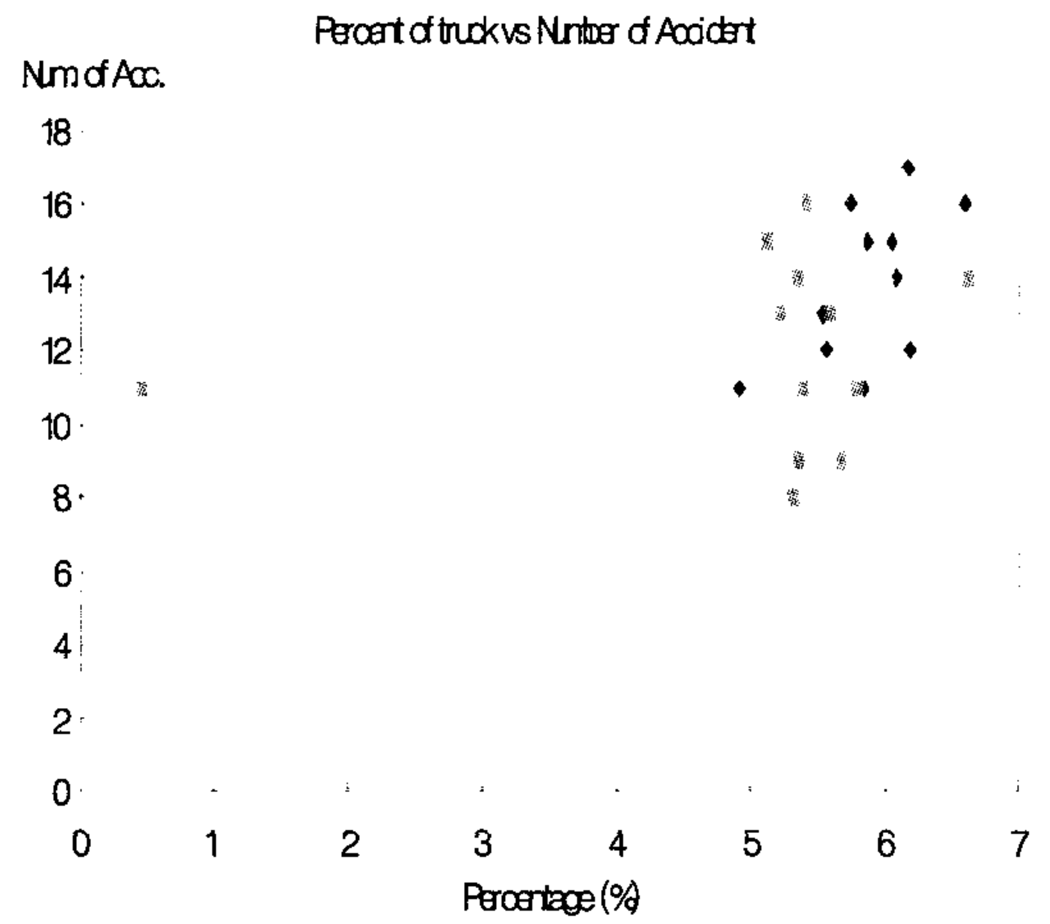


I-5 Northbound

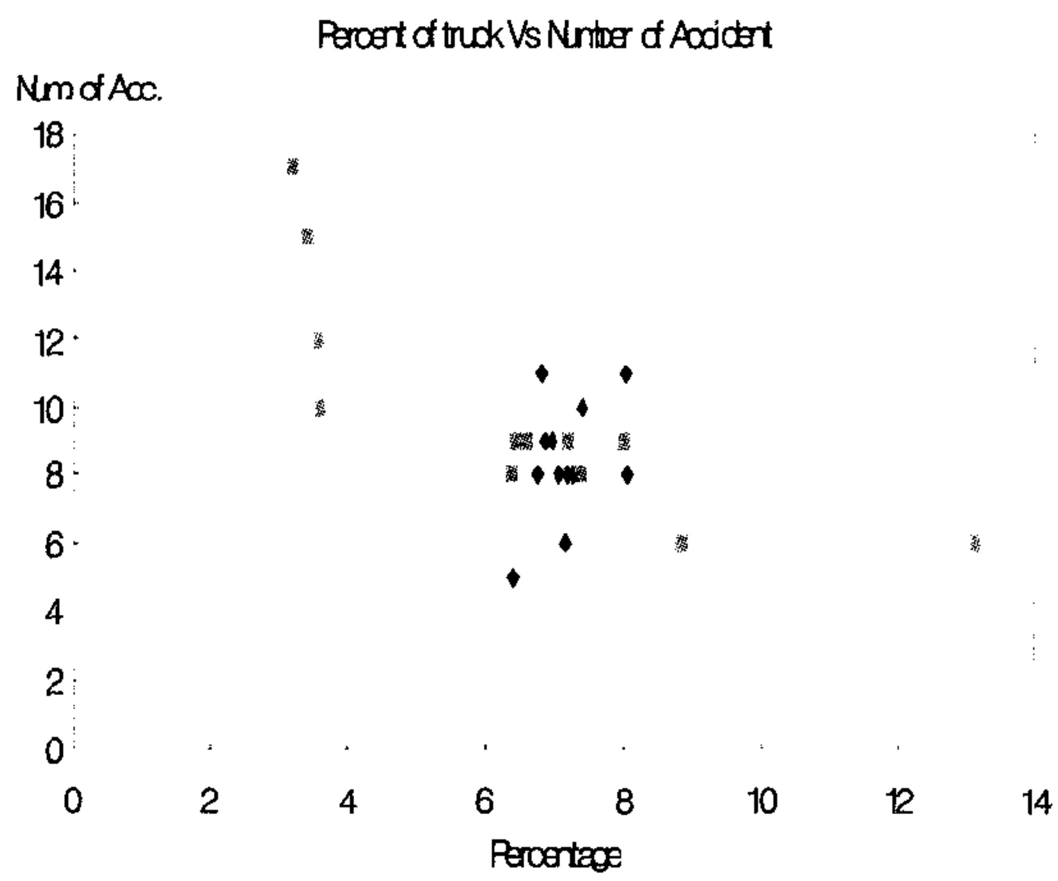


I-5 Southbound

Fig. 2 Total number of truck-involved accidents versus truck percent



SR-91 Eastbound



SR-91 Westbound

Fig. 3 Total number of truck-involved accidents versus truck percent

Likewise, an increase in truck percent is asso ciated with an increase in the number of truck involved accidents in both directions on Interstate 5.

SR 91, unlike Interstate 5, there are no clear causal relationship between two factors on both directions.

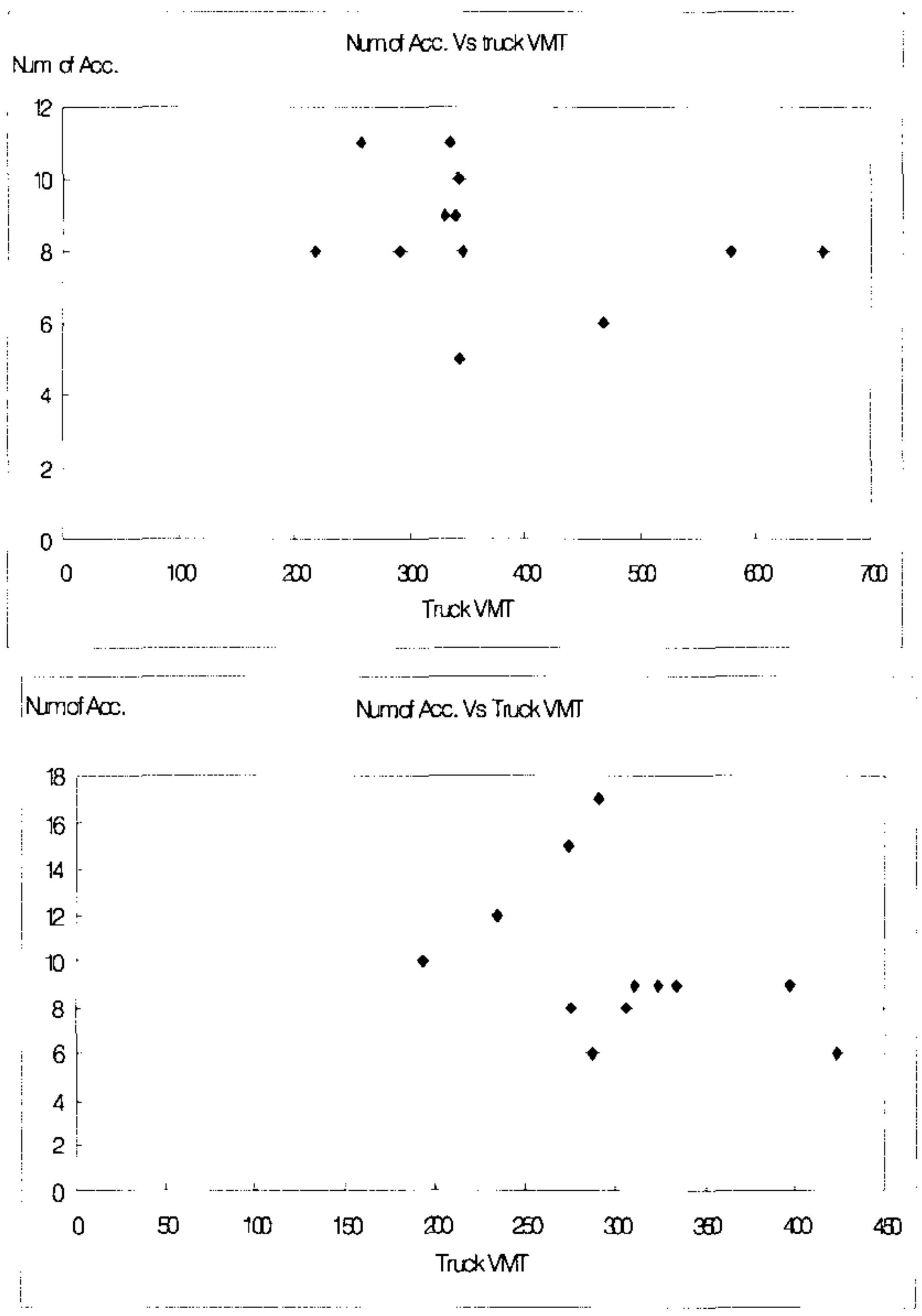
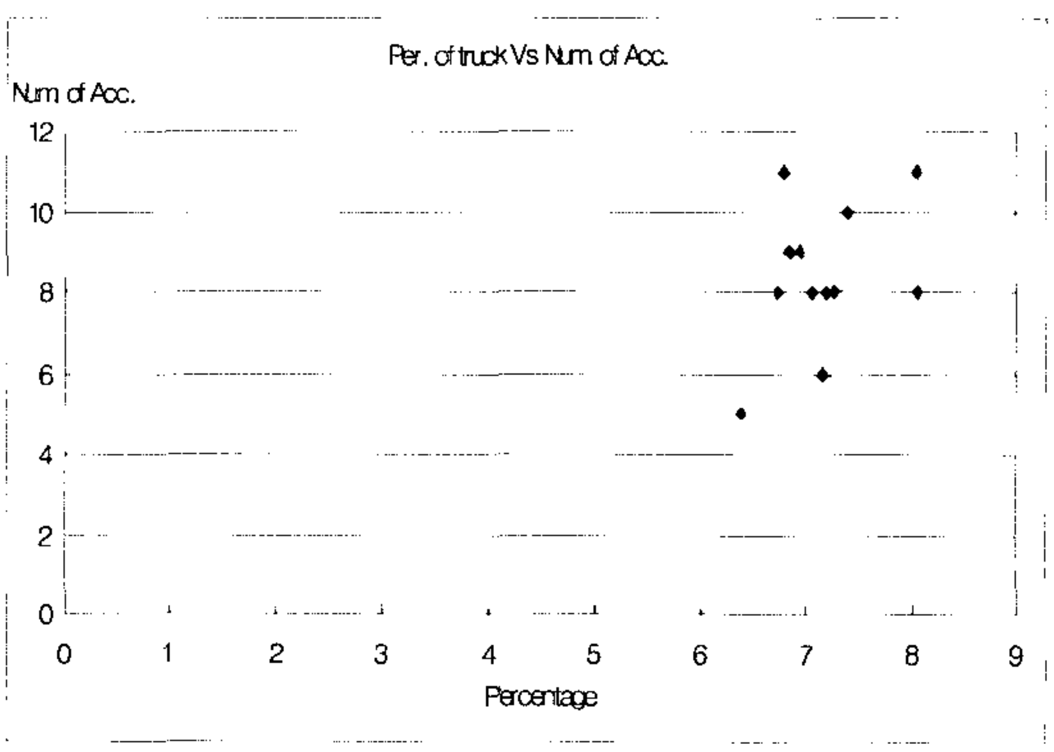


Fig.4 The total number of truck-involved accidents versus Truck VMT (million)

Similarly, the uncertainty of the relationship between two factors on SR-91 is shown in Fig. 5. Through data descriptions, we may come to conclusion that truck-involved accidents are not likely to be proportional to truck VMT or truck percent according to geometric characteristics.



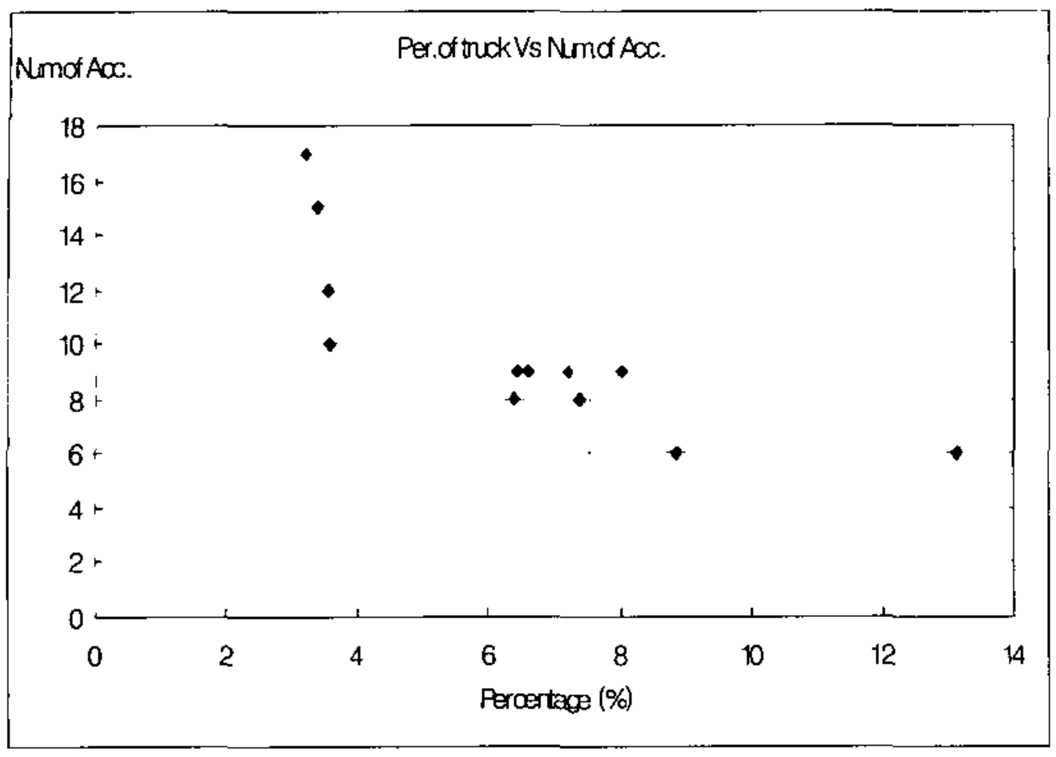


Fig.5 The total number of truck-involved accidents versus percent of truck

Analysis Results

The analysis was performed using the SPSS computer program package. Confidence intervals for the coefficients were estimated on the basis of standard errors produced by SPSS. Prior to perform multiple regression analysis, correlations among the selected independent variables were examined to lead to reasonable results by excluding the possibility of the occurrence of multicolinearlity.

Table 5 Correlations among independent variables on I-5 northbound

	VMT	Speeding	Violation	Truck percent	Non-peak
VMT	1	0.261	0.032	0.09	0.095
Speeding		1	**-0.822**	-0.707	-0.361
Violation			1	**0.620**	0.446
Truck percent				1	0.457
Non-peak					1

As shown above table 5, three independent variables such as speeding, other violation, and truck percent were highly correlated on northbound of I-5. In order to avoid multicolinearlity, after that either speeding or other violation variables were eliminated, and examined correlations repeatedly. However, high correlations still existed. Therefore, combinations of independent variables that have low correlation values were developed, and multiple regressions were performed. Regression results for some combinations seem to not be reasonable since coefficients of independent variable have negative value. As a result, the best combination of independent variables was turned out to be included truck VMT and speeding. This result appears more logical.

Table 6 Correlations among independent variables on I-5 southbound

	VMT	Speeding	Violation	Truck percent	Non-peak
VMT	1	0.525	0.327	0.181	0.573
Speeding		1	-0.274	0.189	**0.730**
Violation			1	-0.145	-0.099
Truck percent				1	0.110
Non-peak					1

There were no significant correlations among the selected independent variables other than speeding and non-peak variables on southbound of I-5. Multiple regression analysis was performed with four independent variables. However, coefficients of two independent variables such as other violations and truck percent showed negative values. This result did not seem to be sound as well. After taking these variables away, multiple regression analysis was running. According to ANOVA results, P-values for both directions were less than 0.05, implying at least one independent variable was statistically significant on that route.

Table 7 Results for the I-5 North and Southbound

I-5	Dependent Variable	Independent Variables	Coefficients	P-value	T-value	VIF	Adjusted R-squared
North	Number of Truck Accidents	Constant	1.940	0.098	1.846	-	0.944
		Truck VMT	0.844	0.000	10.279	1.073	
		Speeding	0.309	0.004	3.770	1.073	
South	Number of Truck Accidents	Constant	1.138	0.016	1.513	-	0.952
		Truck VMT	0.847	0.000	10.544	1.489	
		Non-peak	0.207	0.03	2.573	1.489	

Variance inflation factor (VIF) represents whether or not multicolinearlity between independent variables exists. According to table 9, VIF values were less than 10 for both directions, and thus it might be concluded multicolinearlity between the selected independent variables did not exist. On northbound of I-5, the analyses showed that the increase of truck VMT and speeding was associated with an increase in the number of truck-involved accidents. In addition, this is statistically significant at conventional level. On southbound of I-5, likewise, there was no multicolinearlity between the selected independent variables. Combination of truck VMT and non-peak time variables was statistically significant based on P-value. Thus, truck VMT was common a factor that causes truck-involved accidents to all directions on I-5.

SR-91 has relatively small fraction of truck traffic so non-peak time variable was not considered. Unlike I-5, four independent variables were used.

Table 8 Correlations among independent variables on the SR-91 Eastbound

	VMT	Speeding	Other Violation	Truck percent
VMT	1	-0.381	-0.135	-0.158
Speeding		1	-0.563	0.233
Other Violation			1	-0.306
Truck percent				1

Table 9 Correlations among independent variables on SR-91 Westbound

	VMT	Percent of truck	Speeding	Other violations
VMT	1	**0.768**	-0.433	-0.203
Truck percent		1	**-0.666**	-0.523
Speeding			1	0.081
Other violations				1

According to the results, there were no specific significant correlations among the selected independent variables for analyzing on eastbound of SR-91. First of all, multiple regression analysis was performed with four independent variables. Through several combinations of independent variables, multiple regression analysis was performed. However, any of combinations of independent variables did not satisfy the goal of the analyses. In other words, the results showed that there were no statistically significant at conventional levels in any of analyses. This finding may imply that the selected independent variables would not properly interpret which variables impact on truck-involved accidents even no matter how they are combined.

On westbound of SR-91, independent variables were highly correlated with each other. Therefore, the analyses were also performed with three combinations of these variables in order to keep away from multicolinearlity.

Table 10 Results for the SR-91Westbound

SR-91	Dependent Variable	Independent Variables	Coefficients	P-value	T-value	VIF	Adjusted R-squared
West	Number of Truck Accidents	Constant	3.015	0.012	3.179	-	0.860
		Speeding	0.937	0.004	7.075	1.906	
		Other violations	0.907	0.000	3.827	1.906	

On westbound of SR-91, combination of speeding and other violations provided the most statistically acceptable results on the basis of P-value for each coefficient.

Conclusion

Since I-5 is considered as major truck route in Orange County, trucks seem to form a large proportion of the traffic mix. In order to perform the analysis of truck-involved accidents on that route, non-peak time variable should be considered as an independent variable since usually, peak time of truck traffic differ from that of passenger traffic. Truck traffic is highest at MD (midday) peak. From passenger traffic point of view, this time period would be non-peak time. On southbound of I-5, this variable was statistically important.

Unlike I-5, truck VMT and truck percent may not appropriate as explanatory variables on SR-91. If a proportion of the total truck traffic occupies more than 10 percent, conflicts between trucks and other vehicles tend to be increased. However, truck VMT of that route not only was relatively small, but also few percentage of truck traffic has more than 10 percent. In this case, other factors could affect truck-involved accidents rather than these two causal factors.

In addition, any combination of the selected independent variables was not statistically remarkable at conventional levels on eastbound of SR-91. This finding may imply that it cannot rule out the possibility that truck-involved accidents would more strongly related to other explanatory variables such as geometric characteristics and driver behavior, environmental factors, and pavement conditions and so forth.

Based on the results, effective and efficient truck management strategies can be suggested to reduce safety hazards associated with critical factors.

- Improved warning signing: There are two types of signing improvements. The one is that improved warning signs used to warn drivers of safety hazards, and the other is that improved directional or information signs to help drivers reach a destination of find a location. By using this strategy, truck VMT could be reduced, receiving the shortest path information and also warn drivers to keep driving safely.

-Time-of-day restrictions for trucks: The time-of-day characteristics of truck travel are highly different than those of general-purpose traffic. Basically, truck drivers strive to avoid driving during peak commuting hours. Truck volumes tend to peak in the midmorning after the morning peak and again in the mid-after noon, before the evening peak. This strategy can increase the possibility of reducing conflicts be tween trucks and other vehicles.

ITS Program (AVCSS): Advanced Vehicle Control and Safety Systems (AVCSS) tech nologies include motorist warning systems that it can detect when a truck is moving too quickly to negotiate an upcoming curve and then flash ing a warning beacon, or collision avoidance system. These systems can make possible to travel under safety condition.

Acknowledgments

This paper is a product of research project (CTRM ; Construction Technology Road Map #05 Building the foundationsI) 02) sponsored by Ministry of Land, Transportation and Maritime Affairs.

Reference

Daniel and Chien (2004). "Truck Safety Factors on Urban Arterials", *Journal of trans portation engineering.*

Golob and Regan (2004), *"Truck involved crash es and traffic levels on urban freeways"*, UCTC. Report.

Blower and Campbell and Green (1993). "Accident rates for heavy truck-tractors in Michigan, The journal of accident analysis and prevention.

NCHRP Report 500 (2004). *"A Guide for Reducing Collisions Involving Heavy Trucks"*, Transportation Research Board.

B.L. Bowman and H.S. Plum (1990). "Examination of Truck Accidents on Urban Freeways," ITE Journal, pp. 21-26.

Washington Bypass Study: *"Technical Memorandum No. 3"*, Traffic, Bellomo-McGee Inc., Vienna, Va., April 1990.

Strategies for Managing Increasing Truck Traffic (2003). National Cooperative Highway Research Program Synthesis 314, Transportation Research Board.

Garber, N.J and Gadiraju Ravi. *"Effects of Truck Strategies on Traffic Flow and Safety on Multilane Highways"*. In Transportation Research Record: Journal of the Transportation Research Board, No.1256, TRB, National ResearchCouncil, Washington, D.C., 1986, pp. 49-54.

Federal Highway Administration (2006). Available at www.bts.gov/publications/freight FHWA, Washington D.C.

Federal Highway Administration (2004). Freight Transportation: Improvements and the Economy. FHWA, Washington D.C

접 수 일: 2007. 12. 12
심 사 일: 2008. 1. 2
심사완료일: 2008. 5. 13