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Investigation of Impacts of Truck Lane Restrictions on Multilane Highways Using Micro Traffic Simulation

미시적 시뮬레이션을 이용한 화물차량 차로이용제한 영향분석

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요 지

본 연구에서는 다차로 고속도로에서 트럭주행 차로를 제한하는 전략이 교통류 변수(평균속도, 차선변경 횟수, 총교통량의 변화)에 어떤 영향을 미치는 지를 알아보았고, 또한 본 연구에서 제안된 트럭주행 차로를 제한하는 전략에 대한 대안들의 적용 타당성을 알아보았다. 교통 시뮬레이션을 위해 두 가지 형태의 가상 네트워크와 교통수요를 설정했으며, 트럭 차량의 주행을 제한하는 차로의 수에 근거하여 3가지 실행가능한 시나리오를 설정하였다. PARAMICS 시뮬레이션 모형이 주요 분석 Tool로 사용되었다. 통계분석을 통해 시나리오에 따른 교통류 변수에 대한 영향을 분석하였다. 결과적으로, 트럭주행 차로를 제한하는 전략은 다차로 고속도로에서 교통류의 흐름에 긍정적인 영향을 미치는 것으로 나타났다. 또한, 이 연구는 트럭주행 차로를 제한하는 전략이 성공적으로 시행되기 위해 트럭 차량의 주행을 제한하는 차로의 수의 결정이 중요한 요소가 될 수 있다는 것을 보여주었다.

핵심용어 : 트럭주행차로제한, 파라믹스, 시뮬레이션모형, 분산분석

Abstract

This study was performed to investigate impacts of truck lane restrictions on multilane highways on traffic flow variables such as average speed, the frequency of lane changes, and change in traffic volume and also to verify whether or not different lane restriction scenarios were proper. Two types of hypothetical highway networks and OD demands were developed for traffic simulation models in order to conduct the experimental study. Three types of scenarios were also developed according to the number of restricted lanes for trucks. The PARAMICS microscopic traffic simulation software package was used as the primary analytical tool. Statistical analysis was conducted with simulation outputs. Results showed that truck lane restrictions may lead to positive impacts on traffic flow on multilane highways. In addition, this study demonstrated that the number of restricted lanes can be very an important factor to lead successful implementation of truck lane restrictions.

Keywords : truck lane restriction, PARAMICS, simulation model, ANOVA test

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1. INTRODUCTION

Trucking is the most frequently used mode of moving freight because of its operational flexibility. Thus trucks take care of most local deliveries as well as dominating long distance freight movements. The Federal Highway Administration (2001) estimates that the volume of domestic freight moved will increase by 87% between 1998 and 2020, whereas the volume of international freight is projected to increase by 107% during the same period. Such an increase may result in negative impacts such as traffic congestion, safety hazards, air pollution, and pavement deterioration on freeways. In order to reduce these negative externalities, a lot of efforts have been made in order to address negative impacts due to increased truck traffic by employing various truck management strategies. Truck lane restrictions, one of truck management strategies, are the most frequently used in the most states of U.S. Truck lane restrictions indicate that all trucks are only capable of traveling lanes that trucks are allowed to use whereas other vehicles are able to travel all lanes. The main objective is to separate all trucks from other traffic.

This study is performed with three traffic variables in order to determine impacts of truck lane restrictions on multilane highways on traffic flow characteristics and also to verify whether or not different lane restriction scenarios are proper. Two types of hypothetical highway networks and OD demands are developed for traffic simulation models in order to conduct the experimental study. The PARAMICS microscopic traffic simulation software package will be used as the primary analytical tool for the evaluation of truck lane restriction scenarios. The PARAMICS can model differences in behavior in each lane of a freeway, and the user can adjust these using Application Programming Interfaces (APIs). Through adjusting critical parameters such as driver behavior, mean headway between vehicles, and familiarity of drivers, the simulation can generate appropriate outputs. Traffic volume is assumed according to specification in the U.S Highway Capacity Manual (US-HCM) and truck percent is assigned values of interest to the study. These are known to be important factors related to successful implementation of truck lane restrictions.

2. LITERATURE REVIEW OF TRUCK LANE RESTRICTION

In the study by Mannering et al (1993), truck lane restriction was evaluated through before and after case in the Puget Sound region in the State of Washington. The results of evaluation represented that average speed of all traffic was statically and significantly increased after the implementation of truck lane restriction. However, it was concluded that the increase of speed both for truck traffic and for auto traffic was less than 4 percent. Hoel and Peak (1999) have simulated with microscopic traffic simulation model to evaluate traffic flow elements on freeway segments under two conditions such as truck lane restriction and non-restriction. They represented the following results. 1) Restricting trucks from the left lane with steep grades causes an increase in the speed differential 2) Restricting trucks from the left lane with steep grades may increase density and the number of lane changes 3) Restricting trucks from the right lane causes an increase in the number of lane changes for sites without exit and entry ramps 4) Site characteristics dictate the effects of truck lane restrictions. More recently, Mugarula and Mussa (2003) examined the impact on operations and safety by restricting the median lane from truck traffic in six-lane rural freeway corridor during all hours. The results of this field study described that the 24 hour truck lane restriction policy did not have a remarkable negative effect on truck speeds. Another finding of this study indicated that the number of lane change would considerably increase if the median lane were to be opened to truck traffic. Texas Transportation Institute researchers found the general results regarding truck lane restriction. Recently, Rakha et al (2005) studied various truck lane management strategies on Interstate 81 in the state of Virginia with the INTEGRATION traffic simulation. Several scenarios related to manage truck lanes; including extra lanes, managed lanes, truck-only lanes, physical separation of trucks and non-trucks, and the addition of climbing lanes were investigated. The main objective was to quantify benefits of the efficiency, energy, environmental, and safety impacts according to different scenarios. The researchers found that the maximum benefits were obtained in the case of a physical separation of trucks from other traffic. In addition, restricting trucks from the use of the leftmost lane also provided promising results regarding efficiency, energy, and environmental impacts on the study site.

3. EXPERIMENTAL STUDY

3.1 Scenario Design

Various feasible scenarios exist for truck lane restrictions. The impacts of each scenario may also vary in accordance with traffic and geometric conditions on each site. In order to verify each impact, three feasible scenarios are developed. Determining the number of restricted lanes is of great practical importance and also can be very difficult because traffic volume, truck proportion, and facility size must be well understood. In this study, truck left lane restriction is only considered since this has been shown to be more practical than any other lane restriction. 1) Scenario 1: no strategy implemented 2) Scenario 2: trucks are restricted from the one left most lane 3) Scenario 3: trucks are restricted from the two left most lanes. Table 1 shows the vehicle classification included in the simulation. Vehicle type of truck is based on the definition represented in the California Vehicle Code.

Table 1. Vehicle Classification

Classification	Height (ft)	Width (ft)	Length (ft)	Weight (ton)	Max.speed (mph)	Acceleration (ft/s/s)	Deceleration (ft/s/s)
Non-truck	4.9	5.2	13.1	0.78	100	8.2	14.76
Truck	14.0	8.5	65.0	36.28	75	4.5	10.8

The experimental study is performed on an approximately 5-mile one-way section direction with five through lanes in case 1 and four through lanes in case 2, including a single on and off ramp. The simulations are run with different seed numbers, considering warm-up and clearance time. Figure 1 shows the hypothetical designs for case 1 and case 2, respectively.

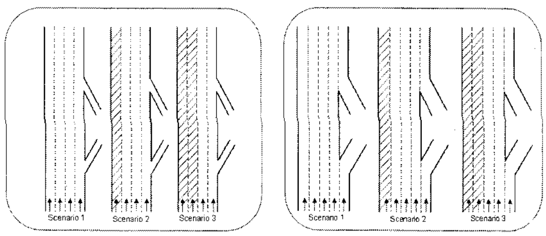

Fig 1. PARAMICS Networks of Case 1 and Case 2

3.2 Scenario Analysis

For the analysis, different levels of traffic conditions are examined using the level of service criteria for multilane highways suggested by US Highway Capacity Manual (US-HCM 2000), and the truck proportion is assumed to range from 5 percent to 20 percent for each flow rate according to the level of service.

Flow rates are selected based on the fact that most speed limits on urban highways are 60mph or 65mph. The rate of flow at the on and off ramps is fixed at 500vph. Therefore, a total of 48 combinations of traffic volume and truck percent are developed.

Table 2. LOS Criteria for Multilane Highways

LOS	Density (pc/Mi/ln)	60mph Design Speed		
		Speed	v/c	MSF*
B	20	48	0.5	1000
C	30	44	0.65	1300
D	42	40	0.80	1600
E	67	30	1.00	2000

*Maximum rate of flow (vphpl).

Source: Highway Capacity Manual Special Report 209 TRB, 2000

3.3 Traffic Flow Component

By performing experimental study, we expected to demonstrate that a change in traffic flow characteristics results from the implementation of truck lane restriction as well as to verify the feasibility of designed scenario for truck lane restrictions. The following traffic flow components are used as below.

Average Speed

Average speed or average travel time can be used to a measure of freeway service quality. Gan and Jo (2003) found that increase in average speed tends to appear under low truck volume, and low ramp volume, while average speed is insignificantly decreased under high truck percentages of total traffic or high ramp volumes. They found that reduction in average speeds resulting from truck lane restrictions would be insignificant except when most lanes are restricted (three out of four lanes, for example). In this study, changes in average speeds across scenarios are examined in order to identify whether or not truck lane restrictions lead to beneficial impacts in terms of the improvement of traffic flow efficiency.

The frequency of lane changes

The frequency of lane changes is used as a measure of safety impacts. Intuitively, as the frequency of lane changes increases, the likelihood of a collision increases. This measure can be obtained from the total lane changes divided by the total volume. Although truck lane restrictions theoretically reduce the frequency of lane changes by decreasing interactions among vehicles, the study of Hoel and Peek found that the implementation of truck lane restriction lead to an increase in the frequency of lane changes in the level sections whereas definitely reduce in the steep grade. They recommended that a truck climbing lane is preferable to truck lane restriction when the grade exceeds 4. Since this measure can be used to determine the consistency of traffic flow, by examining difference in the frequency of lane changes across scenarios, the impacts of truck lane restrictions on safety can be investigated.

A change in traffic volume

Truck lane restriction basically forces trucks to divert from the restricted lanes and thus other vehicles can occupy the vacated capacity on the restricted lanes. In other words, the implementation of truck lane restrictions may result in throughput improvement on that facility. The study of Gan and Jo (2003) demonstrated that a relatively small number of restricted lanes, for example one out of three lanes or one or two out of four and five lanes generally provide a higher capacity (up to 25%) than no restriction on lanes. Increase in throughput may be considered an important operational benefit.

4. STATISTICAL ANALYSIS

One-Way analysis of variance (ANOVA) tests are used to produce a one-way analysis of variance for the quantitative traffic flow components. The P-value represents the difference in variance of the various components across scenarios. In addition, the Tukey's honestly significant difference (HSD) test is used for multiple comparisons among scenarios. This can compare the difference between each pair of means of scenarios with appropriate adjustment for the multiple testing. The null hypothesis is that the means across each pair of scenario is the same regardless of maximum rate of flow and truck percentage of total traffic. All statistical tests were conducted using a 95% confidence interval. The three columns represent, from left to right, the average speed, the frequency of lane changes, and the traffic volume.

Table 3. P-values of Case 1

	Truck Percent											
MSF	5%			10%			15%			20%		
1000	0.028	0.000	1.000	0.000	0.000	1.000	0.001	0.000	1.000	0.000	0.000	1.000
1300	0.000	0.000	1.000	0.000	0.000	0.748	0.000	0.000	0.414	**0.000**	**0.000**	**0.028**
1600	0.000	0.000	0.035	0.000	0.001	0.074	**0.000**	**0.000**	**0.002**	**0.000**	**0.000**	**0.021**
2000	0.002	0.219	0.070	0.000	0.153	0.019	**0.001**	**0.000**	**0.008**	**0.000**	**0.001**	**0.015**

*From the leftmost column, average speed, the frequency of lane changes, and traffic volume in order

All P-values related to average speed rejected the null hypothesis because they are smaller than significance level (0.05), implying that they are obvious differences among scenarios. These may result from an increase in speed on restricted lanes from trucks due to the absence of trucks, and thus average speed increases. For the frequency of lane changes, likewise, most P-values rejected the null hypotheses except 5% and 10% of truck proportion at 2000 vphpl. The difference in traffic volume across scenarios appears when maximum rate of flow is relatively high and truck proportion is equal to or more than 10%. On the other hand, under LOS B, low traffic conditions, there are no significant differences among scenarios in terms of traffic volume in the range of defined truck percent. All traffic flow components may change when traffic goes to 1300 vphpl and 15 percent truck traffic. The bold values in table 3 show conditions under which all three components change.

Table 4. F-values of Case 2

	Truck Percent											
MSF	5%			10%			15%			20%		
1000	0.000	0.001	1.000	0.000	0.000	1.000	0.000	0.000	1.000	0.000	0.000	1.000
1300	0.000	0.519	1.000	0.000	0.000	0.963	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
1600	0.000	0.000	0.961	**0.000**	**0.000**	**0.007**	0.000	0.000	0.897	0.000	0.000	0.839
2000	0.000	0.003	0.247	**0.000**	**0.000**	**0.004**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**

*From the leftmost column, average speed, the frequency of lane changes, and traffic volume in order

The above table 4 provides the results of P-values for three traffic flow components under case 2. Average speeds across scenarios are significantly different under the same null hypothesis as in Case 1. For the frequency of lane changes, unlike case 1, only one condition, when truck traffic was 5 percent and 1300 vphpl, the P-values does not reject the null hypothesis. All traffic flow components simultaneously change when the maximum rate of flow is more than 1300vphpl and trucks are more than 10 percent of traffic. Results for case 2 is rather different those of case 1. This suggests that impacts of truck lane restrictions are dependent upon geometric conditions. In addition, total traffic volumes are likely to increase when truck proportion is equal to or more than 10percent of total traffic in both cases. Table and shows Tukey's HSD results that are performed multiple comparisons among scenarios.

Table 5. Tukey' s HSD test of Case 1

Average speed		Multiple comparison of Case 1			
MSF		Truck Percent			
1000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.576 (1.44)	0.002 (-1.02*)	0.004 (-1.28*)	0.000 (-3.78*)
Scenario 1	Scenario 3	0.146 (?2.86)	0.000 (-2.00*)	0.001 (-1.48*)	0.000 (-5.54*)
Scenario 2	Scenario 3	0.025 (-4.30*)	0.002 (-0.98*)	0.805 (-0.20)	0.004 (-1.76*)
1300 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.995 (0.06)	0.212 (-1.14)	0.038 (-1.88*)	0.000 (-3.02*)
Scenario 1	Scenario 3	0.859 (-0.34)	0.003 (-2.66*)	0.000 (-6.20*)	0.000 (-7.40*)
Scenario 2	Scenario 3	0.008 (-0.40*)	0.080 (-1.52)	0.000 (-4.32*)	0.000 (-4.37*)
1600 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.034 (-1.96*)	0.096 (-1.68)	0.000 (-3.20*)	0.021 (-2.04*)
Scenario 1	Scenario 3	0.000 (-5.14*)	0.000 (-4.70*)	0.000 (-6.34*)	0.000 (-6.68*)
Scenario 2	Scenario 3	0.001 (-3.18*)	0.004 (-3.02*)	0.000 (-3.14*)	0.000 (-4.64)
2000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.073 (-1.58)	0.001 (-1.88*)	0.674 (-0.61)	0.000 (-2.28*)
Scenario 1	Scenario 3	0.001 (-3.09*)	0.000 (-4.70*)	0.001 (-3.48*)	0.000 (-4.75*)
Scenario 2	Scenario 3	0.087 (-1.51)	0.000 (-2.88*)	0.005 (-2.87*)	0.000 (-2.44*)

*Statistically significant at the level of significance 0.05

Table 6. Tukey' s HSD test of Case 2

Average speed		Multiple comparison of Case 2			
MSF		Truck Percent			
1000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000(-1.14*)	0.000(-1.42*)	0.000 (-1.72*)	0.000(-1.84*)
Scenario 1	Scenario 3	0.000(-1.86*)	0.000(-2.58*)	0.000(-2.96*)	0.000(-3.98*)
Scenario 2	Scenario 3	0.002(-0.72*)	0.000(-1.16*)	0.001(-1.24*)	0.000(-2.14*)
1300 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.001(-1.70*)	0.000(-1.96*)	0.000(-3.57*)	0.000(-3.20*)
Scenario 1	Scenario 3	0.000(-3.32*)	0.000(-4.48*)	0.000(-7.13*)	0.000(-5.96*)
Scenario 2	Scenario 3	0.001(-1.62*)	0.000(-2.52*)	0.000(-3.56*)	0.000(-2.76*)
1600 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000(-2.08*)	0.000(-3.58*)	0.000(-3.68*)	0.000(-2.48*)
Scenario 1	Scenario 3	0.000(-4.38*)	0.000(-6.90*)	0.000(-6.20*)	0.000(-5.44*)
Scenario 2	Scenario 3	0.000(-2.30*)	0.000(-3.32*)	0.000(-2.52*)	0.000(-2.96*)
2000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000(-2.02*)	0.000(-1.82*)	0.000(-2.28*)	0.000(-3.10*)
Scenario 1	Scenario 3	0.000(-4.00*)	0.000(-5.16*)	0.000(-5.59*)	0.000(-6.82*)
Scenario 2	Scenario 3	0.000(-1.98*)	0.000(-4.34*)	0.000(-3.31*)	0.000(-3.72*)

*Statistically significant at the level of significance 0.05

Average speeds in scenario 2 and 3 increases compared to those in current conditions based on mean difference values in parenthesis. Particularly, scenario 3 is good for all cases. This is obvious evidence that truck lane restrictions would positive impacts on traffic flow.

Results of average speeds in case B shows more clear evidence that truck lane restrictions may be positive being sound traffic flow.

The frequency of lane change results is thoroughly examined since this variable describes safety concerns. The frequency of lane changes in scenario 2 and 3 statistically increase compared to those of scenario 1 in most cases. This may imply that truck lane restrictions would increase likelihood of crashes in this case.

Unlike in case 2, the frequency of lane changes in scenario 3 decreases compared to both scenarios 1 and 2 when maximum rate of flow is beyond 1600 vphpl, irrespective of truck percent.

Total volume is not changed when level of service criteria indicates B in Case 1. However, traffic volume of scenario 2 and 3 increased compare with that of scenario 1 when flow of rate exceeds 1300 vphpl.

In case 2, the results show somewhat different from case 1. When maximum rate of flow is 1600 vphpl, the total volume of scenarios 2 and 3 tend to be reduced relative to that of scenario 1. However, they are negligible because they are not statistically significant in most cases. It is noted that total volume may increase when truck lane restriction is implemented.

Table 7. Tukey's HSD test of Case 1

Frequency of lane changes		Multiple comparison of Case 1			
MSF		Truck Percent			
1000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000 (-0.41*)	0.000 (-0.62*)	0.000 (-1.00*)	0.060 (-0.69)
Scenario 1	Scenario 3	0.000 (-0.36*)	0.000 (-0.64*)	0.000 (-1.52*)	0.016 (0.89*)
Scenario 2	Scenario 3	0.236 (0.05)	0.947 (-0.02)	0.000 (-0.49*)	0.000 (1.58*)
1300 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000 (-0.54*)	0.000 (-0.63*)	0.002 (-0.30*)	0.000 (-0.73*)
Scenario 1	Scenario 3	0.000 (-0.81*)	0.000 (-0.48*)	0.001 (-0.34*)	0.000 (-0.59*)
Scenario 2	Scenario 3	0.044 (-0.27*)	0.078 (0.15)	0.841 (?0.03)	0.001 (0.14*)
1600 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000 (-0.30*)	0.001 (-0.27*)	0.000 (-0.38*)	0.000 (-0.44*)
Scenario 1	Scenario 3	0.010 (-0.15*)	0.017 (-0.17*)	0.027 (-0.21*)	0.001 (-0.21*)
Scenario 2	Scenario 3	0.016 (0.14*)	0.220 (0.09)	0.065 (0.17)	0.001 (0.23*)
2000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.197 (-0.10)	0.170(-0.14)	0.001 (-0.24*)	0.001 (-0.38*)
Scenario 1	Scenario 3	0.746 (-0.04)	0.959 (-0.02)	1.000 (0.000)	0.564(-0.08)
Scenario 2	Scenario 3	0.528 (0.06)	0.258 (0.12)	0.001 (0.24*)	0.005 (0.3*)

*Statistically significant at the level of significance 0.05

Table 8. Tukey's HSD test of Case 2

Frequency of lane changes		Multiple comparison of Case 2			
MSF		Truck Percent			
1000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.001 (-0.27*)	0.000 (-0.47*)	0.000 (-0.58*)	0.000 (-0.59*)
Scenario 1	Scenario 3	0.129 (-0.11)	0.051 (-0.16)	0.028 (-0.22*)	0.467 (-0.11)
Scenario 2	Scenario 3	0.024 (0.16*)	0.001 (0.30*)	0.001 (0.36*)	0.001 (0.47*)
1300 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.512 (-0.32)	0.000 (-0.40*)	0.000 (-0.42*)	0.000 (-1.11*)
Scenario 1	Scenario 3	0.951 (-0.08)	0.749 (-0.04)	0.268 (-0.07)	0.347 (0.30)
Scenario 2	Scenario 3	0.690 (0.238)	0.000 (0.36*)	0.000 (0.35*)	0.000 (1.41*)
1600 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.001 (-0.22*)	0.000 (-0.27*)	0.000 (-0.30*)	0.000 (-0.39*)
Scenario 1	Scenario 3	0.835 (0.02)	0.002 (0.10*)	0.507 (0.05)	0.361 (0.07)
Scenario 2	Scenario 3	0.000 (0.25*)	0.000 (0.38*)	0.000 (0.35*)	0.000 (0.46*)
2000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.327 (-0.06)	0.000 (-0.17*)	0.004 (-0.11*)	0.000 (-0.17*)
Scenario 1	Scenario 3	0.040 (0.11*)	0.001 (0.14*)	0.000 (0.25*)	0.000 (0.62*)
Scenario 2	Scenario 3	0003. (0.17*)	0.000 (0.31*)	0.000 (0.36*)	0.000 (0.80*)

*Statistically significant at the level of significance 0.05

Table 9. Tukey's HSD test of Case 1

Traffic volume		Multiple comparison of Case 1			
MSF		Truck Percent			
1300 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000	0.824(13.6)	0.527(63.2)	0.992(7.4)
Scenario 1	Scenario 3	0.000	0.992(-2.8)	0.987(-8.8)	0.052(-165)
Scenario 2	Scenario 3	0.000	0.756(-16.4)	0.441(-72.0)	0.04(-172.4*)
1600 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.656 (69.2)	0.92(-30.4)	0.086(-141.0)	0.993(-6.2)
Scenario 1	Scenario 3	0.149 (-157.2)	0.082(-185.4)	0.002(-276.5*)	0.03(-155.6*)
Scenario 2	Scenario 3	0.032(-226.4*)	0.157(-155.0)	0.1(-135.0)	0.04(-149.4*)
2000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.176(-119.0)	0.334(-108.0)	0.995(-5.4)	0.994(-8.6)
Scenario 1	Scenario 3	0.071(-152.8)	0.015(-244.4*)	0.014(-185.4*)	0.02(-255.0*)
Scenario 2	Scenario 3	0.851(-33.8)	0.190(-136.4)	0.016(-180.0*)	0.03(-246.4*)

*Statistically significant at the level of significance 0.05

Table 10. Tukey's HSD test of Case 2

Traffic volume		Multiple comparison of Case 2			
MSF		Truck Percent			
1300 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000	0.000	0.162 (95.2)	0.000
Scenario 1	Scenario 3	0.000	0.000	0.000(273.4*)	0.00(-680.6*)
Scenario 2	Scenario 3	0.000	0.000	0.008(178.2*)	0.00(-680.6*)
1600 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.000	0.537(25.2)	0.901(9.0)	1.000(0.2)
Scenario 1	Scenario 3	0.967(8.0)	0.006(88.4*)	0.897(9.2)	0.862(9.0)
Scenario 2	Scenario 3	0.967(8.0)	0.044(63.2*)	1.000(0.2)	0.867(8.8)
2000 vphpl		5%	10%	15%	20%
Scenario 1	Scenario 2	0.712(-21.4)	0.4(-38.4)	0.267(-39.6)	0.726(-19.4)
Scenario 1	Scenario 3	0.221(-47.6)	0.003(-119.6*)	0.000(-130.0*)	0.00(-562.0*)
Scenario 2	Scenario 3	0.606(-26.2)	0.037(-81.2*)	0.007(-90.4*)	0.00(-542.6*)

*Statistically significant at the level of significance 0.05

5. CONCLUSION

This study was performed to examine effects of truck lane restriction on traffic flow characteristics. These variables can also be defined as performance measures to reflect operational and safety aspects on the implementation of truck lane restrictions and to validate designed whether or not these scenarios are plausible. Scenario 2 and 3 both appear to lead to increased average speeds. In addition, the average speed under scenario 3 (two left lanes restricted) is higher than under scenario 2 (single leftmost lane restricted). The frequency of lane changes may vary according to geometric conditions (e.g. number of lanes and physical configuration of on and off ramps). Other studies have found that truck lane restriction would provide improved safety due to a reduction in lane changes but this study found that these results may be various according to geometric conditions. When truck lane restriction is implemented, traffic throughput is likely to increase. This is because space in the restricted lanes is available to passenger cars which can travel with higher speeds. These results would suggest that truck lane restrictions could work well when the rate of flow is more than 1300vphpl and trucks are at least 10 percent of the total traffic. These results are also consistent with the previous study of Grezeback et al (1990), which found that "Truck traffic makes a relatively small contribution to freeway congestion except on those few highly congested freeways where truck volumes exceed 10 percent of total vehicles".

In addition, each scenario-pair (scenario 1 and 2, scenario 2 and 3, and scenario 1 and 3) shows statistically different results. Therefore, the number of restricted lanes can be considered as a very important factor to consider.

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