Impacts of Truck-Lane Restrictions on Freeway Traffic Operations

by

Sijong Jo
Graduate Research Assistant
Department of Civil and Environmental Engineering
Florida International University
University Park Campus, EAS 3680
Miami, Florida 33174
Tel: (305) 348-6940
E-mail: sjo001@fiu.edu

Albert Gan, Ph.D.
Assistant Professor
Department of Civil and Environmental Engineering
Florida International University
University Park Campus, EAS 3680
Miami, Florida 33174
Tel: (305) 348-3116
E-mail: gana@fiu.edu

and

Gina Bonyani
Transportation Engineer
Systems Planning Office
Florida Department of Transportation
605 Suwannee Street, MS 19
Tallahassee, FL 32399
Tel: (850) 414-4707
E-mail: gina.bonyani@dot.state.fl.us

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ABSTRACT

Highways are generally designed to serve a mixed traffic flow that consists of passenger cars, trucks, buses, recreational vehicles, etc. The impacts of these different vehicle types are not uniform, thus, create special problems in highway operations and safety. One common approach to reducing the impacts of truck traffic on freeways has been to impose certain lane restrictions on trucks. Truck-lane restrictions may increase the overall operational efficiency of freeways, lead to improved traffic safety on these facilities, and provide uniform pavement wear. A variety of truck restriction methods have been implemented throughout the United States. Most restrictions, however, have been used without detailed planning or evaluation through before and after studies. The purpose of this study was to analyze changes in various measures of effectiveness (MOEs) including speed, capacity, density, and lane changes under various traffic conditions and restriction strategies. The CORSIM simulation model was used to model the effects of various truck-lane restrictions on basic freeway sections. For model development, car-following sensitivity factors were calibrated to emulate the freeway speed-flow curves in HCM 2000. Various scenarios were constructed to replicate prevailing conditions with combinations of number of lanes, free-flow speed, volumes, truck percentage, and restriction methods. Paired t-test was used to assess the changes in MOE before and after truck-lane restrictions. It was found that: (1) truck-lane restrictions reduce average speed and capacity and increase density; (2) truck-lane restrictions reduced the lane changes for all cases, except when there is a high number of restricted lanes; and (3) changes in density, speed, capacity, or lane changes after truck-lane restriction increased with increasing number of restricted lanes.

Keywords: Truck-lane restriction, simulation, freeway operations
INTRODUCTION

Highways are generally designed to serve a mixed traffic flow that consists of passenger cars, trucks, buses, recreational vehicles, etc. The impacts of these different vehicle types are not uniform, thus, create special problems in highway operations and safety. The terms “trucks” and “heavy vehicles” are interchangeable in terms of traffic operations. They are defined as (a) all single-unit trucks over 10,000 pounds and all combination vehicles, or (b) any truck that has six or more wheels in contact with the road (1). The increased operation of trucks in both volume and dimensions, coupled with the increase in passenger car volume, have added to existing problems related to traffic operations, safety, and roadway structures. Motorists complain that they are intimidated by the size of trucks and alarmed by the wind forces created when large trucks pass them on the highways. They also feel uncomfortable when they are tailgated by trucks (2). The perceived effect of large trucks is greater than passenger car equivalent (PCE) because of their large size and high visibility in the traffic stream. These factors combine to contribute to a psychological, if not an actual, barrier to motorists driving on the freeways (3).

One common approach to reducing the impacts of truck traffic on freeways has been to impose certain restrictions on truck movements as a means of minimizing the interaction between trucks and other vehicles and compensating for their differences in operational characteristics. Truck restrictions may increase the overall operational efficiency of freeways, lead to improved traffic safety on these facilities, and provide uniform pavement wear. A variety of truck restriction methods have been implemented throughout the United States. Most restrictions, however, have been used without detailed planning or evaluation through before and after studies (1,4). Only a few studies have attempted to determine the effects of truck restrictions on highway operations and safety. Two types of approaches have been used: (a) observe and collect the data in the field before and after the implementation of truck restriction, and (b) analyze data from computer simulation models. The purpose of this study was to evaluate operational performance of truck-lane restrictions on freeway basic segments. Changes in speed, density, capacity, and lane changes were compared under different truck-lane restrictions, including no restrictions.

LITERATURE REVIEW

The most common reasons for using truck-lane restrictions are (a) to improve highway operation, (b) to reduce accidents, (c) to facilitate even wear out of pavement, and (d) to ensure better operation and safety through construction zones (5). While the main benefit of improved highway operations is accident reduction, only a small number of states had expressed that their restrictions were directed toward reducing traffic accidents (4). There are, in general, two types of lane restrictions: (a) to prohibit trucks from using the leftmost lane(s), and (b) to restrict trucks from the rightmost lane(s).

Restricted from Left-Lane(s)

Truck restriction from the left-lane(s) keeps slower trucks to the slower outer lanes. Figure 1 shows the lane assignments for restriction from the leftmost lane. This restriction removes trucks from the faster inside lane and may reduce truck speed and the psychological impact of
trucks on passenger car drivers (1). However, concentrating trucks in the right lane(s) may make the access points (exit or entrance ramp) unsafe and difficult to travel. Since most signs are above the right lane, a high concentration of trucks in the right lane may reduce the visibility of signs to drivers in the inner lane(s) (6). It may also worsen the pavement deterioration on the outer lane(s). Restrictions from the left lane have been implemented on I-95 in Broward County, Florida and on the Capital Beltway (I-95 and I-495) in Virginia (7). In the Broward County case, three or more axle trucks were banned from the leftmost lane of a 25-mile, 3-lane section on I-95 in the county (8).

![Figure 1. Truck Restriction from Leftmost Lane.](http://www.doh.dot.state.nc.us/preconstruct/traffic/safety/trucksafety/trucklane/)

**Restricted to Left-Lane(s)**

Another type of truck-lane restriction is to prohibit trucks from using the rightmost lane(s). This method has been used as a temporary measure to even wear of pavement and has been implemented on I-90/I-94 near Madison, Wisconsin (9). Since trucks have to shift to the left lanes, some safety problems arise near interchanges and weigh stations where lane changes are required.

**Lane Restrictions with Barriers**

A special type of lane restriction involves lanes that are separated by barriers. Two types of separated facilities are reported in the literature. One provides different roadways for each vehicle type, and the other provides one exclusive roadway for heavy or light vehicles and the other roadway for mixed traffic. Figure 2 shows the layout of a separated facility implemented along a 33-mile section on the New Jersey Turnpike. It consists of two parallel roadways within the same right of ways. Directional flows are separated by concrete median barrier and the inner
and outer flows are separated by a metal beam guardrail. Trucks and buses are restricted to travel on the outer roadway, but passenger cars can use either the inner or the outer roadway. About 40% of passenger cars were reported to use the outer lanes. In California a section of I-5 north of Los Angeles was reconstructed to separate truck facility to provide uninterrupted truck movements (4). Mason et al. (10) and Middleton et al. (11,12) investigated the feasibility of exclusive truck-lane facilities in the median area of the I-35 corridor from Dallas to San Antonio. An exclusive truck facility was recommended for a half-mile long section where LOS was low and median was wide enough (at least 36 ft wide) to build the facility.

![Conceptual Illustration of Separated Facility in New Jersey Turnpike.](image)

Figure 2. Conceptual Illustration of Separated Facility in New Jersey Turnpike.

**Truck-Lane Restriction Studies**

Only a few studies on truck-lane restrictions can be found in the literature. Hanscom (9) investigated truck-restriction effects on speed differentials between lanes by comparing manually collected speed data before and after the restriction on a three-lane per direction facility of I-290 near Chicago. Trucks were restricted from using the leftmost lane of the facility. The AADT on the facility was 78,500 and the trucks accounted for 13% of the total traffic. Contrary to the expected results, speed differentials between the restricted lane (trucks were not allowed) and unrestricted lanes were actually decreased after the implementation of truck restriction.

Zavoina et al. (5) examined speed changes to assess the operational effects of a truck-lane restriction on I-20 near Fort Worth, Texas. A system of tape-switches was installed across the traffic lanes to collect speed data by classification, direction, period (peak or non-peak), and lanes. The arithmetic means of the speeds of each vehicle classification in each lane was examined. It was found that, in general, speed change patterns of cars were identical to those of trucks although the variation of cars was smaller than that of trucks. Since the changes were different for direction (increase in eastbound but decrease in westbound) and period (decrease in peak period but increase in off-peak period), it could not be concluded that the changes in speed were due to truck-lane restriction.
Since Wildermuth’s pioneering work (13), simulation has been used to assess the effects of truck restriction. Garber and Gariraju (14) investigated the effect of truck-lane restriction and differential speed limit on speed distribution using the SIMAN simulation language. Minderhoud and Hansen (15) investigated the impacts of exclusive truck lane at on- and off-ramp sections with the SIMONE microscopic simulation model.

Hoel and Peek (7) evaluated freeway truck-lane restrictions on speed, density, and lane changes under various scenarios using the FRESIM microscopic simulation model. A total of 24 scenarios were constructed based on two lane-restriction variables (whether or not there are restrictions), three uphill grades (0%, 2%, 4%), and four different initial volume distributions by lane, as follows:

1. equal distribution among the lanes (33%, 33%, 34%, for the left, center, and right, respectively),
2. some shifted vehicles to the right lanes (30%, 35%, 35%),
3. middle lane accommodates 50% and remaining traffic evenly distributed between left and right lanes (25%, 50%, 25%), and
4. estimate of actual distribution (25%, 38%, 37%).

For each scenario, 20 combinations (five values for traffic volume and four for truck percentage) were tested on a hypothetical 3-mile section with three lanes in each direction. The volumes were ranged from 1,000 to 3,000 vph per direction and the truck percentages, from 10% to 40%. The simulation period was one hour and the free-flow speed was assumed 65 mph. Paired sample t-test was used to determine whether or not the differences between before and after restrictions were significant. It was found that the speed differentials, i.e., “speed difference between average speed of trucks and the average speed of cars”, generally increased under steep upgrade conditions. This behavior is similar to that observed in truck climbing lanes, where slower trucks voluntarily move to climbing lanes with reduced speed and non-truck traffic use all the regular lanes to maintain their travel speed or experience less reduced speed. Except for cases involving steep grades, significant speed differentials were not observed. The study also found that the density increased after the restrictions, in general. However, the density decreased in steep grade (4% case) due to trucks having difficulty climbing the grade, causing the traffic to spread out. Lane changes were found to be decreased when the grade were 2% or 4% because trucks were no longer traveling fast to pass slower moving vehicles.

**MODEL DEVELOPMENT**

Recognizing the difficulty of collecting sufficient data for empirical modeling that covers many number of involving variables, this study uses the simulation approach to evaluate the impact of various truck restrictions on traffic operations. Simulation can evaluate many possible design alternatives within a reasonable time frame and budget without losing the interdependencies among the many variables. Furthermore, simulation approaches can provide the systematic and comprehensive analysis tools over the entire sections of the freeway, which consist of basic, ramps, and weaving sections. In addition, it was also recognized that the complex interactions
among the many variables of interest are unlikely to be modeled mathematically or sufficiently observed in the field.

Simulation Model

CORSIM (CORidor SIMulation), a stochastic and microscopic simulation model developed by the U.S. DOT, was selected as the simulator in this study. CORSIM can explicitly simulate truck restrictions (with biased or restricted options) and individual vehicle movement with various driver types. It is also able to analyze a wide range of traffic, geometric and control variables and it provides a rich set of performance measures including lane changes, travel time, delay, speed, density, and fuel consumption. Its use of the ASCII file format for both input and output files enables the automated execution of multiple simulation runs with slight modification of the corresponding input data and easy extraction of the output data for analysis. In addition, CORSIM provides graphic display tools to verify the traffic movements and geometric conditions through a visual animation environment.

Simulation Model Calibration

Crowther (16) proposed a way to validate the CORSIM model by calibrating the car-following sensitivity factors with respect to the capacity for the steady-state case based on the relationship below:

\[ c = \frac{1}{q_c} - \frac{h_j}{u_c} \]  \hspace{1cm} (1)

where  
\( c \) = car-following sensitivity factor (mean value),
\( q_c \) = desired flow rate (veh/sec),
\( h_j \) = jam density headway (ft/veh), and
\( u_c \) = minimum speed at which maximum flow rate occurs (ft/sec).

Since the equation is only applicable to the steady state, the car-following sensitivity factors must be calibrated by systematical trial-and-error. Payne et al. (17) calibrated car-following sensitivity factors to achieve the desired capacity by conducting a series of simulation runs. After a series of runs, car-following sensitivity factors that replicate the speed-flow relationship in HCM 2000 (18) were obtained. The jam density headway is not a direct input data for CORSIM; it is calculated as sum of the vehicle length, \( L \), and the minimum vehicle separation constant. For calibration, the jam density was assumed at 190 veh/mi (or 28 ft/veh) in accordance with HCM 2000. The maximum flow rates were assumed at 2400 veh/hr, 2350 veh/hr, and 2300 veh/hr for free-flow speed (FFS) 70 mph, 65 mph, and 60 mph, respectively. As shown in Figure 3, flow rates from the CORSIM model were calibrated as close to those of HCM 2000 as possible.
Simulation Scenarios

After the CORSIM model was successfully calibrated to replicate the speed-flow relationships in HCM 2000, especially for near-capacity conditions, various truck-lane restriction strategies were considered. A total of 12 different truck-lane restriction strategies were considered for three-, four- and five-lane basic freeway segments, including the non-restricted case. Figure 4 illustrates the different restriction strategies for the different number of freeway lanes. To determine the operational performance changes caused by truck-lane restriction, a base case (restriction 0) must be run without any lane restrictions. Various scenarios were constructed to represent the prevailing conditions, including number of lanes, free-flow speed, volumes, and truck percentage. The values simulated for each independent variable are listed in Table 1. The different input combinations resulted in a total of 1,701 scenarios.

TABLE 1 Independent Variables and Associated Input Values

<table>
<thead>
<tr>
<th>Independent Variable</th>
<th>Input Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Lanes</td>
<td>3, 4, 5 (per direction)</td>
</tr>
<tr>
<td>Free-flow Speed (mph)</td>
<td>60, 65, 70</td>
</tr>
<tr>
<td>Traffic Volume per Lane</td>
<td>10, 400, 800, 1200, 1600, 1800, 2000, 2200, 2400</td>
</tr>
<tr>
<td>Percent of Trucks</td>
<td>0%, 5%, 10%, 15%, 20%, 25%</td>
</tr>
</tbody>
</table>
Truck-lane operations are modeled in CORSIM mainly through Record Type 20. Two types of truck movement restrictions on mainline are allowed. The first is the “biased” option that allows trucks to leave their lane and then return to the lane after passing slower moving vehicle(s). This option was modeled when only one lane was available for trucks after the implementation of the truck-lane restriction (e.g., restriction 4 in the five-lane case in Figure 4). The second type is the “restricted” option that does not allow a truck to leave a truck lane (i.e., into a non-truck lane) to pass another vehicle.

Due to stochastic characteristics of CORSIM model, each simulation run may generate slightly different outputs. To overcome the randomness in the simulation outputs and obtain statistically stable results, multiple runs are required. Because of the many variables involved, coupled with limitation on computer time, it was determined that five replications were to be

\[X = \text{Trucks are prohibited from using this lane.}\]
\[T = \text{Trucks must use this lane.}\]
\[B = \text{Trucks are biased to this lane and can use the left adjacent lane to pass.}\]
performed for each scenario, resulting in a total of 8,505 simulation runs (i.e., $1701 \times 5$). The simulation period was one hour in duration.

**Automated Procedure for Multiple Simulation Runs**

Due to the high number of simulation runs, two programs were developed to automate the entire procedure: (a) A preprocessor to create simulation data based on different combinations of traffic volume, truck percentages, and random number seeds, and (b) a postprocessor to perform multiple simulation runs with the various scenarios and extract the appropriate simulation output from each run for further analysis. This automated procedure allows the complete process to be repeated, when necessary. This is important because several model fine-tunings were needed during the model development process. Note that a shell program called RunCOR was used to execute CORSIM in the batch mode (i.e., command-line executable) without using TSIS, the original shell environment of CORSIM. Although TSIS provides the “scripting” feature that facilitate multiple CORSIM runs, a modification of data in accordance with the scenario developments or extraction of the output MOE values cannot be done by using the pre-made script.

**Simulation Model Development**

A base CORSIM input file was coded for each of the restriction strategy in Figure 4 using the TRAFED graphical user interface. CORSIM describes networks as nodes and links. Figure 5a shows the link-node diagram of the base network for three-lane and four-lane facilities. Node 8001 is the entry node that is used to specify the entry volume. For five-lane facilities, since the maximum entry volume is limited to 9,999 vph, a second entry link 8002 was added to model the near-capacity conditions. As shown in Figure 5b, entry link (8001,1) is assigned four lanes and entry link (8002,8) is assigned one lane. Together, these two links allow the total entry volume to exceed 9,999 vph.

Since traffic on the section close to the entry link is generally not stable, especially under heavy entry volume, several intermediate links are included so that statistics from the unstable flow can be excluded. The TRAFVU animation was observed to determine the required length of this section. The final outputs were extracted from link (2,3) for three- and four-lane freeway cases. For the five-lane case, link (4,5) was used.

**FIGURE 5 Link-Node Diagrams for Freeway Base Networks.**

![Diagram](image-url)
OPERATIONAL PERFORMANCE

This section compares the operational performance of different truck-lane restrictions in terms of average speed, capacity, density, and lane changes.

Average Speed

Figure 6 shows that the average speed after the implementation of truck-lane restriction decreased gradually until the saturation point when the truck volume was low. This trend is the same as that of non-restricted case shown in Figure 1. The figure shows that the speed of non-restricted case (R0) is consistently higher than that of restricted cases (R1, R2). The speeds drop more quickly in the restricted cases when the link approaches the capacity. Significant speed reductions occur at high truck percentages (20%) and higher number of restricted lanes (R2). A similar trend was found for four and five-lane cases. These results suggest that truck-lane restrictions will be more suitable for rural freeways where the flow rates are relatively low, where improved safety through truck separation can be realized without causing a reduction in average speeds.

Statistical analysis was performed to test if there were significant changes in speed after truck-lane restrictions. Average speed from each truck restriction scenario was compared with the base case (non-restricted). The paired sample t-test was conducted for pairs of scenarios with the same characteristics except for presence or absence of truck-lane restrictions. For significance test, the following hypotheses were tested:

\[ H_0 : \mu_1 = \mu_2 \quad H_1 : \mu_1 < \mu_2 \]

where \( \mu_1 \) = average link speed after restriction, and \( \mu_2 \) = average link speed without truck-lane restriction (base case).

Table 2a shows that the average speeds after restrictions were reduced. Although statistical significance was found, the actual reductions were small and largely negligible under less congested conditions and low truck percentages. Table 2b shows the speed changes as a function of truck percentages and number of restricted lanes for three-lane freeways. The speed reductions were found to be significant at congested conditions, especially with high truck percentages. Significant speed reductions occurred just before reaching the capacity. Since the actual flow rates after the restriction were smaller than the capacity or flow rates under non-restriction case (R0), the speed after restriction were found to be higher than that of non-restricted case (R0), as shown in the Figure 6. Since trucks were confined to one non-restricted lane, the most speed reduction occurred in the truck-moving lane. The concentration of trucks in one lane caused a reduction in the overall average speed, especially under a high percentage of trucks and at near-capacity conditions. A similar speed reduction after the truck-lane restrictions was found for the four- and five-lane cases.
R0 denotes the restriction 0 (base case).

(a) 60 mph FFS and 10% Trucks

(b) 60 mph FFS and 20% Trucks

FIGURE 6 Flow-Speed Relationship for Three-Lane Freeway.
TABLE 2a Speeds Before and After Restrictions

<table>
<thead>
<tr>
<th>Number of Lanes</th>
<th>$\mu_1 - \mu_2$</th>
<th>Sample Size</th>
<th>$T$</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>-1.34</td>
<td>540</td>
<td>-7.469</td>
<td>0.000</td>
</tr>
<tr>
<td>4</td>
<td>-2.06</td>
<td>810</td>
<td>-11.186</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>-3.69</td>
<td>1080</td>
<td>-17.172</td>
<td>0.000</td>
</tr>
</tbody>
</table>

TABLE 2b Speed Changes by Truck Percentages and Number of Restricted Lanes for Three-Lane Freeways

<table>
<thead>
<tr>
<th>Truck Percentage</th>
<th>No. of Restricted Lanes</th>
<th>Difference</th>
<th>$T$</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 %</td>
<td>1 (R1)</td>
<td>-0.2750</td>
<td>-1.399</td>
<td>0.168</td>
</tr>
<tr>
<td>5%</td>
<td>2 (R2)</td>
<td>-0.8669</td>
<td>-2.197</td>
<td>0.032</td>
</tr>
<tr>
<td>10%</td>
<td>1 (R1)</td>
<td>-0.1337</td>
<td>-0.466</td>
<td>0.643</td>
</tr>
<tr>
<td>10%</td>
<td>2 (R2)</td>
<td>-1.0824</td>
<td>-2.111</td>
<td>0.039</td>
</tr>
<tr>
<td>15%</td>
<td>1 (R1)</td>
<td>0.0600</td>
<td>0.232</td>
<td>0.818</td>
</tr>
<tr>
<td>15%</td>
<td>2 (R2)</td>
<td>-1.8889</td>
<td>-3.304</td>
<td>0.002</td>
</tr>
<tr>
<td>20%</td>
<td>1 (R1)</td>
<td>0.1550</td>
<td>0.404</td>
<td>0.688</td>
</tr>
<tr>
<td>20%</td>
<td>2 (R2)</td>
<td>-3.3969</td>
<td>-4.732</td>
<td>0.000</td>
</tr>
<tr>
<td>25%</td>
<td>1 (R1)</td>
<td>-0.2602</td>
<td>-0.603</td>
<td>0.549</td>
</tr>
<tr>
<td>25%</td>
<td>2 (R2)</td>
<td>-5.6924</td>
<td>-6.056</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Capacity

Figures 7a to 7c show the effects of truck percentages on capacity under different truck-lane restrictions for three- and four-lane cases, respectively. It can be seen that the capacity reduces with increasing number of restricted lanes, that the magnitude of reduction increases with increasing percentage of trucks.

Density

Changes in density were investigated to quantify the effects truck-lane restrictions. The paired sample t-test was again used to determine if average densities before-and-after truck-lane restrictions were significant. Since all the traffic and geometric conditions were identical to each other before and after the truck restriction, except for the presence or absence of truck restriction, the paired sample t-test was an appropriate statistical analysis method. The following hypotheses were tested:

\[ H_0 : \mu_1 = \mu_2 \quad H_1 : \mu_1 > \mu_2 \]

where $\mu_1$ = average density after restriction, and $\mu_2$ = average density without truck-lane restriction (base case).

Table 3a shows that the average link density after truck-lane restriction ($\mu_1$) increased slightly. Table 3b shows that, although a statistical significance was found, the absolute difference is meaningful at high percentages of trucks, high number of restricted lane, and at near-capacity.
conditions. In general, increasing the truck percentages and the number of truck-restricted lanes increase changes in density.

(a) Three-Lane, 60 mph FFS

(b) Four-Lane, 60 mph FFS
TABLE 3a Average Density Changes Before-and-After Restriction

<table>
<thead>
<tr>
<th>Number of Lanes</th>
<th>$\mu_1 - \mu_2$</th>
<th>Sample Size</th>
<th>t</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>0.2941</td>
<td>540</td>
<td>2.458</td>
<td>0.014</td>
</tr>
<tr>
<td>4</td>
<td>0.9396</td>
<td>810</td>
<td>7.463</td>
<td>0.000</td>
</tr>
<tr>
<td>5</td>
<td>2.3693</td>
<td>1080</td>
<td>14.556</td>
<td>0.000</td>
</tr>
</tbody>
</table>

TABLE 3b Density Changes by Truck Percentage and Number of Restricted Lanes for Three-Lane Freeways

<table>
<thead>
<tr>
<th>Truck Percentage</th>
<th>No. of Restricted Lanes</th>
<th>Difference</th>
<th>t</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 %</td>
<td>1 (R1)</td>
<td>-0.0672</td>
<td>0.429</td>
<td>0.669</td>
</tr>
<tr>
<td>5 %</td>
<td>2 (R2)</td>
<td>0.3331</td>
<td>1.105</td>
<td>0.274</td>
</tr>
<tr>
<td>10%</td>
<td>1 (R1)</td>
<td>-0.2523</td>
<td>-1.027</td>
<td>0.369</td>
</tr>
<tr>
<td>10%</td>
<td>2 (R2)</td>
<td>-0.1444</td>
<td>0.369</td>
<td>0.713</td>
</tr>
<tr>
<td>15%</td>
<td>1 (R1)</td>
<td>-0.3715</td>
<td>-1.649</td>
<td>0.105</td>
</tr>
<tr>
<td>15%</td>
<td>2 (R2)</td>
<td>0.5766</td>
<td>1.427</td>
<td>0.159</td>
</tr>
<tr>
<td>20%</td>
<td>1 (R1)</td>
<td>-0.5745</td>
<td>-1.942</td>
<td>0.058</td>
</tr>
<tr>
<td>20%</td>
<td>2 (R2)</td>
<td>1.1521</td>
<td>2.416</td>
<td>0.019</td>
</tr>
<tr>
<td>25%</td>
<td>1 (R1)</td>
<td>-0.4687</td>
<td>-1.532</td>
<td>0.131</td>
</tr>
<tr>
<td>25%</td>
<td>2 (R2)</td>
<td>2.3355</td>
<td>3.834</td>
<td>0.000</td>
</tr>
</tbody>
</table>

(a) Five-Lane, 60 mph FFS

FIGURE 7 Capacity and Truck Percentage.
Lane Changes

The number of lane changes per vehicle is used to determine the uniformity of traffic flow. Low number of lane changes indicates that there is a lower need to pass the slower moving vehicles. The paired sample t-test was used to test the statistical significance of lane changes. Note that the sample size of each scenario in Table 4 is 270. Truck-lane restrictions affect the lane changing behavior in two different ways: (a) lane changes increased when more lanes are restricted (the R2 case), and (b) lane changes decreased when two or more lanes were provided for trucks (the R1 case). Figure 8 shows that significant variations were found for cases involving higher truck percentages. A similar phenomenon was found for the four- and five-lane cases.

### TABLE 4 Lane Changes by Number of Restricted Lanes

<table>
<thead>
<tr>
<th>Lanes</th>
<th>No. Restricted Lanes</th>
<th>Lane Changes</th>
<th>Difference</th>
<th>t</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Before</td>
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SUMMARY AND CONCLUSIONS

One common approach to reducing the impacts of truck traffic on freeways has been to impose certain lane restrictions on trucks. A variety of truck restriction methods have been implemented throughout the United States. Most restrictions, however, have been used without detailed planning or evaluation through before and after studies. This study examines changes in various measures of effectiveness (MOEs) including speed, capacity, density, and lane changes under various traffic conditions and restriction strategies. The CORSIM simulation model was used to model the effects of various truck-lane restrictions on basic freeway sections. For model development, car-following sensitivity factors were calibrated to emulate the freeway speed-flow curves in HCM 2000. Various scenarios were constructed to replicate prevailing conditions with combinations of number of lanes, free-flow speed, volumes, truck percentage, and restriction methods.

The results show that truck-lane restrictions in general induced speed and capacity reduction and density increase. The variations, however, were negligible under low to medium flow rate and low number of restricted lanes. Truck-lane restrictions were found to reduce lane changes when two or more lanes were provided for trucks. Since lane changes are a major cause of crashes, a reduction in lane changes through truck-lane restrictions can potentially improve traffic safety. In general, truck-lane restrictions were found to have little impacts on the MOEs examined at low to medium flow rates, suggesting that truck separation may be more suitable for rural freeway conditions, that in this case improved safety can be realized without a reduction in operational performance. At urban areas where capacity is critical, truck-lane restrictions may be undesirable.

ACKNOWLEDGEMENT

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REFERENCES


