Safety and Operational Evaluation of Truck Lane Restriction

This study was aimed at determining the operational and safety impacts of the 24-hour restriction of trucks from using the median lane of the six-lane Interstate 75 freeway corridor. The 139-mile corridor in North Florida is relatively uncongested operating at level of service (LOS) of B or better on typical weekdays. LOS is a measure of driver's freedom to maneuver in a traffic stream. The simulation analysis showed that opening all lanes to trucks increased the number of lane changing maneuvers by 11% in daytime, a phenomenon likely to increase crashes in the corridor given that the review of reported crashes showed that lane changing was a major contributing cause of crashes currently occurring in the corridor. The analysis of field data indicated that the difference between truck and passenger car speeds and travel times were insignificant on the unrestricted middle and shoulder lanes. Approximately two thirds of both passenger cars and trucks were traveling within the 10-mph pace, defined as the 10-mph speed range with the highest number of observations, that ranged from approximately 70 mph to 80 mph in the corridor that has speed limit posted at 70 mph. The field data also showed that trucks were able to use the middle lane to pass with reasonable delay during the truck peak hour period, using various gap acceptance thresholds.

by Renatus Mussa

INTRODUCTION

A multitude of truck restriction policies are practiced in the United States. A review by Wishart and Hoel (1996) revealed that general-ly states restrict trucks by speed, lane, time, or route. When restricting by speed, the speed limit for trucks is set lower than the speed limit of passenger cars. Lane restriction involves restricting trucks from using certain lane(s) all the time, or they may be restricted for using certain lanes during certain times of the day. Other restrictions involve prohibiting trucks from using a certain route altogether. These restrictions are intended to improve safety and efficiency of highway travel, particularly on higher-functional-class highways such as freeways. Truck dimensions—height, width, and length—raise safety concerns because the result in sight distance problems for both truck and passenger car drivers. For the truck driver, visibility is reduced on both sides and to the rear of the truck. These blind spots greatly increase potential for sideswipe crashes when the truck driver is merging or diverging from a traffic stream. For passenger car drivers, trucks reduce sight distance to traffic signs, horizontal and vertical curves, as well as increase traffic incidents on the roadway (Mannering et al. 1993).

Truck operating characteristics also raise roadway capacity concerns among traffic engineers. Concerns for efficiency stem from trucks' low capability to accelerate or maintain speed particularly on steep and sustained grades, resulting in the formation of long platoons behind them, thus reducing highway capacity. Large trucks also psychologically and physically intimidate other motorists. Psychologically, motorists feel threatened by the closeness of a truck in the adjacent lane because trucks occupy more length and width of a lane than a typical vehicle. A study by the Transportation Research Board (1986) indicated that as passenger car drivers pass wider trucks, they position themselves closer to the pavement edge, reducing the margin of safety. In addition, when traveling at high speeds, trucks create powerful air disturbances that can cause unsuspecting motorists to lose control of their relatively lightweight automobiles. Moreover, in inclement, e.g. rainy, weather trucks tend to splash water on windscreens of smaller vehicles, reducing the visibility of drivers in these vehicles.

While highway agencies implement truck restrictions with the aim of improving safety and efficiency of highway travel, occasionally there are concerns from trucking agencies which contend that some of these restrictions are excessive and negatively impact trucks' travel time and consequently the profitability of trucking companies. This study was conducted partly to address these concerns on the Interstate 75 corridor where trucks are restricted from using the median lane of the six-lane facility throughout the day. Field data were collected and a simulation analysis conducted to evaluate the safety and operating characteristics resulting from the lane restriction policy. In addition, a two-year dataset on crashes occurring in the corridor was analyzed.

The structure of this paper is as follows. First, the paper reports on the literature review that was conducted to determine the safety and operational effects of restriction policies implemented in different states in the United States. Next, the study approach is described together with the character of the corridor that was studied. The results of the crash analysis are next reported, followed by the results of operational evaluation using field and simulated data. There are concluding remarks at the end of the paper with recommendations for further research.

TRUCK RESTRICTION IN THE UNITED STATES

As indicated earlier the truck restriction strategies that are found in the United States include restriction by speed, lane, time, and/or route. This section summarizes the results of a limited number of studies found in the literature that evaluated the safety and operational efficacy of these strategies. A survey conducted by Mannering et al. (1993) showed that 12 states had speed restrictions for trucks using certain routes. The speed limit for trucks of a specific size, weight, or axle configuration was set to either 5 mph or 10 mph below the speed limit for passenger cars. The review of literature revealed a lack of formal studies evaluating the efficacy of truck speed restrictions. The argument raised for restricting truck speed is that truck crashes, like truck traffic, tends to increase during off-peak time periods and thus reducing truck speed during off-peak time periods would mitigate trucks' involvement in crashes. However, Stokes and McCasland (1984) argued that speed reduction aimed at trucks only creates a speed differential that might increase the crash potential between truck and passenger cars. Besides these hypotheses and presuppositions, the literature search did not reveal any detailed study on safety and traffic operation on routes with different speed limits for trucks and passenger cars.

Lane restriction practices vary widely in the United States with some restrictions being site specific or statewide and compliance is either mandatory or voluntary. When applicable, trucks are generally restricted to using rightmost lane(s) of freeways because the left lane(s) are regarded as passing lanes, but there are some places where trucks are restricted from using right lanes instead of left lanes. A simulation analysis of truck lane restriction in Virginia found that restricting lanes in areas with a high proportion of merging and diverging traffic might not be safe (Hoel & Peek, 1999). The study also found that restricting trucks from using left lanes on roads with steep grades caused an increase in speed differential and a decrease in density (vehicles per mile) and the number of lane changes. A number of studies recommend that truck lane restriction is effective when the limited access road has more than two lanes in each direction (Stokes and McCasland, 1984; Hoel and Peek, 1984).

Route restriction involves restricting all trucks, or trucks of specific size, weight, or axle classification, from traveling on certain routes. In some situations, trucks are prohibited from entering the central business district through designation of bypass and business routes. Another route restriction method is designed to guide trucks along specific roadways to downtown areas, industrial facilities, or major commercial areas. Such restrictions concentrate truck volumes onto roadways designed and constructed to serve heavier vehicles. The literature search did not find any study quantifying the effectiveness of route restrictions but because the efficient routing of trucks would undoubtedly involve the freeway system, this method of restriction generally does not affect freeways.

Restrictions by time-of-day are ostensibly instituted to prevent trucks from using a lane or a road during those times when traffic congestion is at its highest level. On some urban freeways, traffic volumes tend to peak during the typical commuter morning and evening peak periods. As a result, some states restrict trucks from using a freeway or specific lane(s) on the freeway in order to reduce peak traffic and increase travel speeds. Kearney (1975) argued that complete restriction of truck traffic on urban freeways could potentially increase average network speeds by about 10 mph during the peak hours. However, one study hypothesized that because of latent travel demands that exist on many urban freeways, removing trucks from the freeways would not significantly improve operations (Stokes and McCasland 1984).

A survey of states by Mannering et al. (1993) and Wishart and Hoel (1996) found that time-of-day restrictions vary in application ranging from restriction during a defined peak hour to restriction only in 12 hours of daylight. In some cases, the restriction is only on urban sections of interstate freeways while in other cases it is implemented statewide. The time-of-day restriction can be for all week or, as in some states, only Monday through Friday. This study was aimed at analyzing safety and operations on the Interstate 75 corridor in North Florida where there is a 24-hour restriction for trucks to use two rightmost lanes of the six-lane freeway in the northbound and southbound directions. The next section describes site characteristics and location of the corridor.

SITE LOCATION

Interstate 75 is a major north-south interstate freeway in the United States, originating in Miami, Fla., and passing through six states before ending in Sault Ste. Marie, in Ontario, Canada. The 139-mile corridor that was studied is located in central Florida from Exit 328 (Florida Turnpike) in the south to Exit 467 (County Road 143) in the north. This stretch of road is primarily rural in character with 23 interchanges spaced approximately eight miles apart. However, the city of Gainesville is located in the middle of the corridor. Because of the urban nature of the city, there are four interchanges that are closely spaced—approximately three miles apart. The study corridor has three lanes in each direction and is in primarily rolling terrain. There are 7-foot by 6-foot signs posted on overhead bridges, the median, and at a truck weighing station. The posted signs read, "TRUCKS WITH 6 WHEELS OR MORE MUST USE 2 RIGHT LANES." The truck restriction practice on this stretch of I-75 dates back to August 1998 and was implemented following a Florida Depart-ment of Transportation study which showed that a similar truck restriction policy on Interstate 95 in Palm Beach county reduced the number of crashes involving heavy vehicles. However, the same study found that there was no significant reduction in non-truck crashes (Florida Department of Transportation 1982).

STUDY APPROACH

The purpose of the study was to evaluate safety and operating characteristics in this corridor. Thus, two-year crash data for 1999 and 2000 were acquired from the Safety Office of the Florida Department of Transportation. Of importance in the crash analysis was the determination of contributing causes and crash type that resulted from conflicts between trucks and passenger cars.

Field data on volume, headway, and speed were collected for the purpose of evaluating traffic operations in the study corridor. The Florida Department of Transportation has installed loop detectors in more than 300 locations throughout the state highway system to collect traffic continually throughout the year. Two such sites in the study corridor were utilized in collecting traffic data. In addition to field data evaluation, the CORSIM Version 5.0 simulation software was used to simulate traffic operations in the corridor. The corridor was simulated using the collected field data on highway geometrics and vehicle characteristics at various times of the day. The simulation involved determining the effect of travel time and speeds of the simulated corridor of the different scenarios that take into account traffic volume, vehicle type distribution, time of the day, and other factors. The effects of these operational factors were analyzed under various scenarios of restricting trucks during the daytime only, and also 24 hours restriction.

CRASH ANALYSIS

Crashes occurring in the corridor were reviewed. In the review process crashes were categorized by type of crashes, severity of crashes, contributing causes, drivers' violation behavior, and type of the vehicle involved in the crash. The crash analysis also examined crashes by time of occurrence—i.e., day or night. The crash data on the I-75 corridor for the years 1999 and 2000 were acquired and summarized using Highway Safety Analysis (HSA) software. A total of 426 crashes were reported for the two-year period involving 715 vehicles of which 105 vehicles (15%) were trucks and 610 vehicles (85%) were passenger cars. Trucks accounted for only 14.7% of the vehicles involved in crashes while accounting for 20% of the observed traffic in the corridor. Although it seems that the passenger cars were over-represented in the crashes, the overall severity of these crashes was low. The major types of crashes reported in this corridor were rear-end, ran-off-roadway, and sideswipe. The data further showed that there were more daytime than nighttime crashes partly due to higher volumes and higher speeds during daytime as the operational analysis will later show. The most-reported driver violation behavior was executing an improper lane change possibly to pass a slow moving vehicle or merge/exit on freeway ramps. The data showed that truck drivers were at fault in 58 crashes (66%) that involved trucks.

OPERATIONS ANALYSIS

Traffic characteristics that were analyzed include traffic volume, speed characteristics, headways, delays, and lane changes. The analysis was based on field data collected throughout the corridor as discussed earlier. In addition, operating characteristics were simulated and the results are reported later.

Traffic Volume

The volume data were extracted from a telemetered traffic monitoring site located at milepost 374 in the southern end of the study corridor. The average hourly weekday traffic and average hourly weekend traffic data for the year 2001 were analyzed. The plot of average hourly volumes for weekdays and weekends showed a similar pattern of traffic peaks although weekends had more traffic than weekdays in both northbound and southbound directions. Because of similarities in temporal volume distribution between week-ends and weekdays, a typical weekday was selected for further analysis of traffic characteristics. The data showed that in the south-bound direction, truck volumes were more evenly distributed throughout the day with a slightly noticeable peak volume of about 340 trucks per hour from 9 a.m. to 10 a m. Passenger car volume was relatively high, peaking around 3 p.m. to 4 p m. at 2,600 passenger car per hour (pcph). In the northbound direction, the volume of trucks was slightly higher while the volume of passenger cars was lower compared to the traffic volume in the southbound direction.

There was a coincidence of peak hours for trucks and passenger cars in the northbound direction, which took place between 10 a.m. and 11 a.m. with a peak hour volume of 520 and 1,880 vehicles per hour for trucks and passenger cars, respectively. Note that the traffic data analyzed was already summarized in one-hour volume and thus the peak hour factor (PHF), as measure of traffic congestion, could not be calculated. However, the capacity analysis of 24-hour data in both northbound and southbound directions for weekends and weekdays showed that the level of service — a measure of a driver's freedom to maneuver in a traffic stream—in this corridor was not less than B in the season that the data were acquired.

In addition, data showed that on the average 29%, 47%, and 24% of passenger cars that were recorded were traveling in the median, middle, and shoulder lanes, respectively. Further analysis showed that 1%, 41%, and 58% of trucks that were recorded were traveling in the median, middle, and shoulder lanes, re-spectively. The 1% of heavy vehicles recorded in the median lane in violation of the truck restriction policy were distributed as follows: 64% were Class 5 vehicles (2-axle single unit trucks, dual rear wheel), 5% were Class 6 (3-axle single unit trucks), and 31% were Class 8 and 9 which are a combination of tractor-trailers and a 3-axle single unit truck pulling a 2-axle trailer.

Those opposed to the 24-hour truck restriction have argued that the restriction be lifted at night, purportedly when traffic volumes are low. Therefore, it is useful to analyze nighttime conditions in this corridor. The data showed that the volume of truck traffic remained high at night almost at levels similar to daytime. While the volume of passenger cars decreased at night, significant decrease did not happen until midnight and began to increase appreciably at around 5 a.m. Based on these data, if daytime-only restriction was to be considered for implementation in this corridor, it would be difficult to define the daytime—that is, restricting from 5 a.m. to midnight is awkward, would be confusing to truck drivers, and would be difficult to enforce. In addition, the safety implications of such a strategy need to be analyzed using field headway data, as well as by simulation as reported in the next sections.

Additional traffic data were extracted from the telemetered traffic monitoring site at milepost 428 in the northern end of the study corridor. The analysis of data from this site revealed trends similar to those downloaded from the telemetered traffic monitoring site at milepost 374. Moreover, data were collected manually at various other sites within the study corridor. The sampled data showed minimal variation of traffic characteristics and it can be surmised that the trends from these sampled data were similar to those downloaded from continuous count stations. This suggests that the majority of traffic in this I-75 corridor is primarily through traffic with a very small proportion of vehicles entering or exiting the freeway at the 23 interchanges located in the study corridor.

Passing Opportunities for Trucks

Further analysis was conducted to determine the availability of passing opportunity for trucks in the middle lane during congested hours of operation. The peak hour was deduced from the volume distribution. The cumulative time headway distribution was plotted for the peak hour. Time headway is defined as the difference between the time of passage between the corresponding points of two consecutive vehicles at a specific point on a highway. For example, time of passage of the front tire of the lead vehicle to the time of passage of the front tire of the trailing vehicle.

Literature search did not reveal a specific time headway needed by a truck to initiate a passing maneuver, thus, a range of time headways were assumed for this purpose. The geometric probability distribution was used in determining the number of vehicles that will pass in the middle lane before a truck gets a passing opportunity. This is a discrete probability distribution that describes the probability that a Bernoulli experiment (a stochastic process consisting of a finite or infinite sequence of independent random variables with each variable having a possibility of either failure or success) will have its first success on the *n*th trial. The mathematical expression of the geometric probability distribution is

(1) $$P(X = n) = p(1 - p)^{n-1}$$

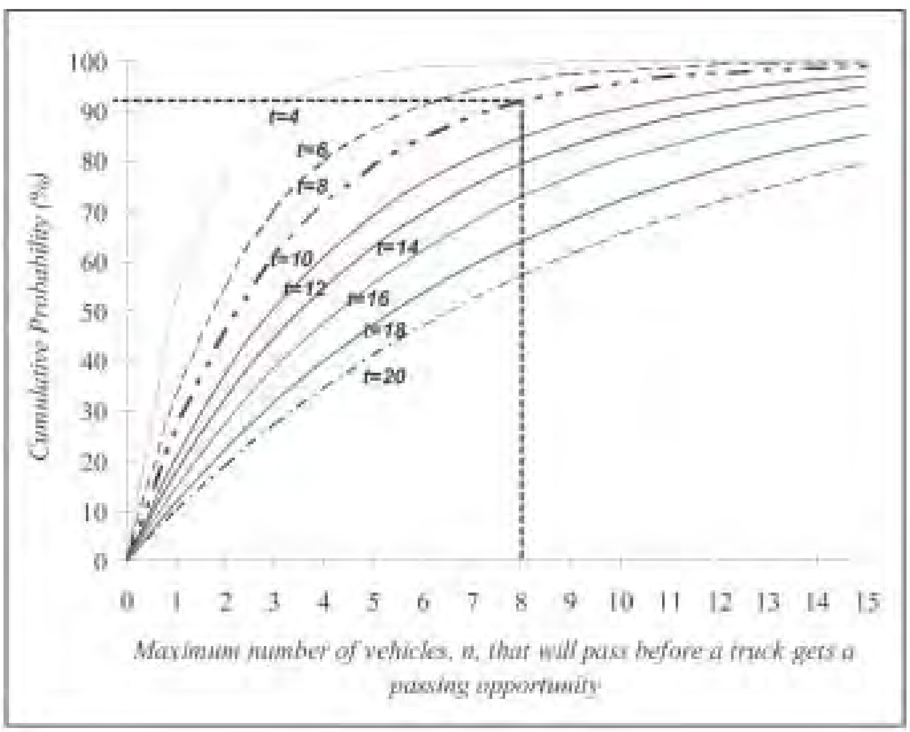
where *P(X=n)* denotes the probability of *n* vehicles passing before a truck gets a passing opportunity, *p* is the probability of the headway to be greater or equal to the headway required for a truck to pass, and *n* is the number of vehicles that will pass before a truck gets a passing opportunity. The cumulative probabilities, which is a sum of individual *P(X*=n), were plotted against number of vehicles *n* for different assumed values of time headway *t*, in seconds, required by a truck driver to make the passing maneuver. Figure 1 shows the plot of the cumulative probabilities of passing opportunities.

Figure 1 shows that if a truck accepts a gap of 10 seconds to pass then there is a 92% probability that a maximum number of eight vehicles will pass before a truck gets a passing opportunity[1]. Figure 1 can be used to find the probability and the number of vehicles that will pass before a truck gets an opportunity to pass on the middle lane at the congested period of the day using any reasonably assumed value of acceptable gap, *t*. Because peak hours for trucks and passenger cars were not exactly the same as discussed earlier, the same analysis was done for headway distributions when the truck volume was slightly higher than other periods of the day but the results were very close to those shown in Figure 1.

Speed Analysis

The operating speed of an individual vehicle is an important measure of how a road serves the traveling public. Long-distance travelers on limited-access highways tend to maximize their speeds—often within the limits of speed regulation—in order to minimize their travel time. Thus, it is important to analyze how the regulation of restricting trucks from using

Figure 1: Cumulative Distribution of P(X=n) During the Peak Hour



the median lane on this stretch of I-75 affects individual vehicle speeds for both passenger cars and trucks. A full day of individual vehicle records was downloaded from a telemetered traffic monitoring site at milepost 374 on Tuesday, April 30, 2002. The data were time-stamped to show the time the vehicle was recorded. The individual vehicle speed, vehicle classification, and the lane of passage were also recorded. A total of 49,126 vehicles were recorded in the 24-hour period. Table 1 shows the average vehicle speeds categorized by time-of-day, vehicle type, and by lane. The time-of-day data are shown in blocks of three hours for brevity because the hourly data did not show much variation from the three-hour averages. The data are for northbound direction only because the southbound direction had trends similar to those shown in Table 1.

The data in Table 1 shows that, on the average, the difference between passenger car and truck speeds (passenger car speed minus truck speed) is 2.7 mph and 2.6 mph for the middle and shoulder lanes, respectively. These differences were found not to be statistically significant ($p=0.13$ for the middle lane and $p=0.11$ for the shoulder lane). The 85th percentile speeds for passenger cars were 79.2 mph and 76.3 mph for the middle and shoulder lanes, respectively. For trucks, the 85th percentile speeds were 77.9 mph and 75.1 mph for the middle and shoulder lanes, respectively. These values are significantly higher than the speed limit of 70 mph posted throughout this section of I-75. The 10-mph pace (the 10 mph range with the highest number of observa-tions) for passenger cars and trucks in the middle lane are 69.5 to 79.5 mph and 68.5 to 78.5 mph, respectively. The percentages of vehicles within these ranges were 72% and 68% for passenger cars and trucks, respectively. For the shoulder lane, the 10-mph pace are 67.2 to 77.2 mph and 64.5 to 74.5 mph for passenger cars and trucks, respectively. The percentages of vehicles within these ranges were 67% and 65% for passenger cars and trucks, respectively.

The median lane, which trucks are restricted from using, is analyzed next. A small number of heavy vehicles were recorded in this lane as shown in brackets in column 3 of Table 1. The majority of the heavy vehicles recorded were trucks violating the lane restriction but some were buses and trucks with less than six wheels but with vehicle dimensions similar to the types that are restricted from using this lane. Comparison of the average passenger car speeds on the median and middle lane shows that overall the passenger cars in the median lane travel faster by 1.1 mph. This difference, however, was found not to be statistically significant

Table 1: Average Speed Characteristics, in Miles Per Hour (MPH)

Time-of-day	Median Lane		Middle Lane		Shoulder Lane	
	Cars	**Trucks**	**Cars**	**Trucks**	**Cars**	**Trucks**
00:00 – 3:00	72.7	73.0(*n=4*)	73.4	70.6	66.7	66.1
03:01 – 06:00	73.5	73.8(*n=6*)	73.0	70.2	67.9	65.5
06:01 – 09:00	75.5	73.7(*n=11*)	74.3	70.5	69.4	65.8
09:01 – 12:00	75.1	73.9(*n=12*)	73.5	70.8	68.6	65.0
12:01 – 15:00	74.8	73.4(*n=19*)	73.2	69.9	68.0	64.8
15:01 – 18:00	75.5	73.2(*n=18*)	73.6	71.7	68.6	65.7
18:01 – 21:00	76.0	73.1(*n=18*)	74.4	72.3	69.3	66.2
21:01 – 00:00	74.6	72.0(*n=6*)	73.0	71.1	67.6	66.8
Daily Avg.	74.7	73.3(*n=13*)	73.6	70.9	68.3	65.7

(p=0.22). The 10-mph pace for passenger cars in this lane was 71.3 to 81.3 mph while for trucks it was 68.2 mph to 78.2 mph. The percentages of vehicles within these ranges were 80% and 76% for passenger cars and trucks, respectively.

A careful evaluation of speeds reveals that the majority of passenger cars and trucks travel at very high speeds close to and exceeding the speed limit of 70 mph as made evident by the percentage of vehicles in the pace ranges shown above. The high operating speed of trucks in both day and night clearly shows that the lane restriction does not negatively impact speeds of trucks in this stretch of I-75. However, the speed data analyzed and displayed in Table 1 are mean speeds at various times that one can argue do not accurately depict overall travel time differences between passenger cars and trucks in the study corridor. To determine the travel times in the corridor and other operational measures such as the number of lane changes with or without lane restrictions, a simulation analysis was conducted, the results of which are reported in the next section.

SIMULATION ANALYSIS

The difference between operating characteristics of passenger cars and trucks was analyzed using CORSIM—which stands for CORridor SIMulation—software. CORSIM is a microscopic, time-stepping, stochastic simulation model capable of simulating corridors containing freeways and surface streets. The CORSIM model was reviewed to determine its capability and limitations in simulating the I-75 corridor. Of importance to the simulation study was the theory used by CORSIM to generate vehicles in the corridor, to space vehicles, and to initiate a lane change. It was also important to understand how truck lane restriction is handled in CORSIM.

CORSIM typically generates vehicles from entry links and source links non-stochastically (at a uniform rate) or the user can specify a random number seed to generate stochastic vehicle entry headways using either the normal or Erlang distribution (Halati et al. 1997). CORSIM randomly assigns the gen-erated vehicle to a lane as long as the minimum headway requirement is not violated. The FRESIM component of CORSIM uses the PITT car-following model, which is founded on a combination of the Northwestern car-following, and the UTCS-1 collision avoidance procedures (Halati et al. 1997). The mathematical expression of the model is

$$(2)\quad h_{n+1} = L + 10 + k\dot{x}_{n+1} + bk(\dot{x}_n - \dot{x}_{n+1})^2$$

where h_{n+1} denotes space headway, $\dot{x}_{n+1}$ is the speed of the following vehicle at time *t*, $\dot{x}_n$ is the speed of the lead vehicle at time *t*, *L* is the length of the leading vehicle, *b* is constant, and *k* denotes driver sensitivity. The time headway between vehicles is directly proportional to the driver sensitivity factor, *k*, and therefore the higher the value of *k*, the lower the capacity of the roadway being simulated. The PITT car following model is of the form: *response*=func(*sensitivity*, *stimuli*), the response is the acceleration of the following vehicle, the stimuli is the space headway, and sensitivity is the driver characteristics.

FRESIM models lane changing in three distinct categories: mandatory lane change, discretionary lane change, and anticipatory lane change. Of importance in this study, is the discretionary lane changing in which vehicles perform lane change to pass slow moving vehicles such as trucks. The FRESIM model assigns to each vehicle an intolerable speed, v_i, below which a driver is highly motivated to perform the lane change which is given by

$$(3)\quad v_i = v_{ff}(50 + 2c)/100$$

where v_{ff} is the desired free flow speed and *c* is the driver type factor which is a randomly assigned number between 1 and 10 with 10 representing the most aggressive driver and 1 representing the most timid driver (Halati *et al.* 1997). It is noteworthy that CORSIM does not allow the user to change any default value and functional relationships used in the discretionary lane changing model.

The geometrics of a 40-mile section of the I-75 corridor were coded in CORSIM. The geometric data were extracted from as-built drawings and condition diagrams derived from field visits. Efforts were made to include all geometrics that are likely to affect safety and operations including grades, median widths, deceleration and acceleration lanes, etc. The traffic data input was field data that was representative of the time of day being simulated. The times of day of interest were daytime and nighttime defined by average volumes during those times. The entrance and exit volumes as well as the percentage of trucks on each lane, exit, or entrance ramps were coded in CORSIM for each scenario. Ten scenarios representing a wide range of operating characteristics in the corridor were simulated. In each scenario, a different driver type and random number seeds were used. Several simulation runs were performed for each scenario. For each scenario, data on travel time and delay were recorded and averaged. Similarly, the number of lane changes was recorded. In order to increase the realism of the simulation, the CORSIM model was validated using field data which represent the lane restriction scenario as it exists in the field. A sensitivity analysis of driver input parameters in the CORSIM model was conducted and the influence of these parameters on CORSIM's measures of effectiveness was determined. The calibration involved adjusting values of these parameters until CORSIM's outputs, particularly average speed, were close to those observed in the field under similar geometric and traffic conditions.

Travel Time/Delay Analysis

Table 2 shows the comparison of average travel time and average delay in the corridor for a situation in which trucks are restricted from using the median lane and a situation in which all vehicles are allowed to use all lanes. The averages are for the ten scenarios described above. The numbers in parentheses are the standard deviations.

Table 2 shows that there is no significant difference in travel time on the freeway for restricted and unrestricted conditions for both daytime and nighttime. However, the delay analysis showed that there was no significant difference between restricted and unrestricted scenarios in the daytime. The daytime was defined as 7 a.m. to 7 p.m. while the nighttime was defined as 7 p m. to 7 a.m. The high *p*-values in Table 2 suggest that the travel times are not significantly affected by truck restriction on the median lane regardless of whether it is daytime or nighttime.

Table 2: Simulation Results of Travel Time and Delay in the Corridor

	Restricted $\overline{X}$ **(*s*)**	**Unrestricted** $\overline{X}$ **(*s*)**	***t* statistic**	***p-value***
Daytime				
Travel time, in *min/veh*	49.1 (0.26)	49.1 (0.25)	-0.6052	0.5498
Delay, in *sec/veh*	397 (316)	399 (284)	-1.1938	0.2422
Nighttime				
Travel time, in *min/veh*	48.9 (0.15)	48.5 (0.15)	-0.5187	0.6079
Delay, in *sec/veh*	224 (125)	214 (120)	-5.4222	0.0000

Lane Change Analysis

Table 3 shows the average number of lane changes for restricted and unrestricted conditions for both daytime and nighttime.

The results in Table 3 show that there were consistently fewer lane changes at night compared to the daytime whether or not the median lane was restricted. This is due to the fact that the volume level simulated to represent nighttime conditions was lower than the daytime volume; consequently, there is less platooning of vehicles moving at speeds slower than $v_i = v_{ff}(50 + 2c)/100$ which would trigger the desire to change lanes. However, the data show that the average number of lane changes increased significantly in both day and night when trucks are allowed to use all three lanes. This result might have safety implications. The increase in the number of lane changes suggest that impatient drivers are performing an increasing number of discretionary lane changing to maximize their speeds. This would inevitably increase the likelihood of conflicts between vehicles in the traffic stream leading to the potential for more crashes in this corridor.

SUMMARY

This study suggests that the truck restriction policy on this corridor might be having safety benefits. This is revealed by considering the results of the simulation analysis. The simulation analysis of lane changes showed that the number of lane changes would significantly increase if the median lane were to be opened to trucks. Frequent lane changes is a good predictor of the potential for increase in vehicular conflicts which could lead to crashes. And indeed the crash analysis showed that lane changing was one of the major contributing causes for crashes that occurred in this corridor. The field results show that the current 24-hour median lane restriction policy does not have statistically significant negative effects on truck speeds. The 85th percentile speed of both passenger cars and trucks in the middle and shoulder lanes were in excess of 75 mph, which is 5 mph above the posted speed limit of 70 mph. Further simulation analysis to determine the travel time across a 40-mile section of the corridor showed that there was no significant difference between the travel times for all vehicles whether all lanes were opened to trucks or the median lane was closed to trucks. This result suggests that with the current traffic flow levels and mix, there is not much to be gained for trucks or passenger cars if the policy is rescinded. It should be noted, however, that the capacity analysis of the corridor showed that the level of service is B or better throughout the day; thus, this is a relatively uncongested corridor and the results reported herein should be interpreted as such.

Table 3: Simulation Results for the Number of Lane Changes in the Corridor

	Restricted $\bar{X}$ **(*s*)**	**Unrestricted** $\bar{X}$ **(*s*)**	***t* statistic**	***p*-value**
Daytime				
Number of lane changes	12,693 (3,824)	13,484 (4,238)	7.022	0.0000
Nighttime				
Number of lane changes	9,300 (2,224)	10,275 (2,785)	4.734	0.0000

Endnote

1. Using the standard probability level of 90% would have resulted in a non-whole number of vehicles (7.8).

References

A.T. Kearney, Inc. *Urban Goods Movement Demonstration Project Design Study*. Prepared for Urban Mass Transportation Administration, November 1975.

Florida Department of Transportation. *An Evaluation of the I-95 Truck Restriction in Broward County*. Tallahassee, FL, November 1982.

Halati, A., H. Lieu, and S. Walker. *CORSIM—Corridor Traffic Simulation Model*. Paper presented at the 76th Annual Meeting of the Transportation Research Board, Washington, D.C., 1997.

Hoel, L.A. and J.L. Peek. *A Simulation Analysis of Traffic Flow Elements for Restricted Lanes on Interstate Highways in Virginia*. Virginia Department of Transportation, January 1999.

Mannering, F.L., J.L. Koehne, and J. Araucto. *Truck Restriction Evaluation: The Puget Sound Experience*, Washington State Department of Transportation, August 1993.

Stokes, R.W. and W.R. McCasland. *Truck Operations and Regulations on Urban Freeways in Texas.* Research Report 338-1F, Texas Transportation Institute, August 1984.

Transportation Research Board. *Special Report 211: Twin Trailer Trucks.* National Research Council, Washington, D.C., 1986.

Wishart, H.L. and L.A. Hoel. *Analysis and Evaluation of Truck Traffic Restrictions and Separation Methods on Interstate Highways.* Report No. UVA/529242/CE96/104, University of Virginia, Charlottesville, VA, June 1996.

Renatus Mussa *is an associate professor of civil engineering at the FAMU-FSU College of Engineering where he teaches undergraduate and graduate courses as well as supervising research projects in transportation. His research interests include traffic operations and control, highway safety analysis, and Intelligent Transportation Systems.*