

Impacts of Left Lane Truck Restrictions on Urban Freeways



Institute of Transportation Studies
University of California, Irvine
Graduate Student Researcher :ChoonHeon Yang



Background

- Demand for trucking services continue to increase
- This increase will have significant negative influence



- Various truck management strategies have been studied



Objectives

Main Part

- 1. Provide insights into restrictions under which traffic conditions would work**
- 2. Identify the number of lanes to restrict and shows that this is an important factor**
- 3. Perform a case study**

Through a case study, we investigate the full impacts of left lane truck restrictions using various performance measures



Descriptions

- **Definition of truck lane restrictions**
 - ☞ **Trucks are only allowed to travel in certain lanes whereas other vehicles are allowed to use all lanes**
 - ☞ **The main objective is to separate trucks from other traffic**
 - ☞ **Two types of restrictions**
 - Rightmost lane restriction/ Leftmost lane restriction**
- **Require low costs, ease to implement, and high public acceptance**



Previous studies

Researcher	Restriction Scenarios	Study Site	Analysis Tool	Performance Measurements
Graber and Gardiraju	Right lane and Speed limits	Rural Urban	CORSIM	Traffic flow and Speeds Headways and Accident patterns
Mannering	Left lane	Urban	Field Data	Volume and Flow rate Speed and Headway Accident data
Zavoina and Urbanik	Left lane	Rural	Field Data	Speeds and Time Gap
Mugarula and Mussa	Median lane	Rural	SIMAN	Travel time and Delay Lane-Change
Hoel and Peek	Right and left lane	Rural Urban	FRESIM	Density and Speed Differential Lane-Change
Cate and Urbanik II	Left lane	Rural	VISSIM	Speed and Level of Service Speed Differential Lane-Change
Gan and Jo	Left lane	Hypothetic	CORSIM	Average Speed and Throughput Lane-Change Speed Differential
Rakha et. al	Right and left Extra lane Exclusive lane	Rural Urban	INTEGRATION	Speed and Travel Time Delay and Emission Source



Experimental Study

Feasible Scenarios

- **Do-nothing: No strategy implemented**
- **Alternative 1: Trucks restricted from the one left most lane**
- **Alternative 2: Trucks restricted from the two left most lane**

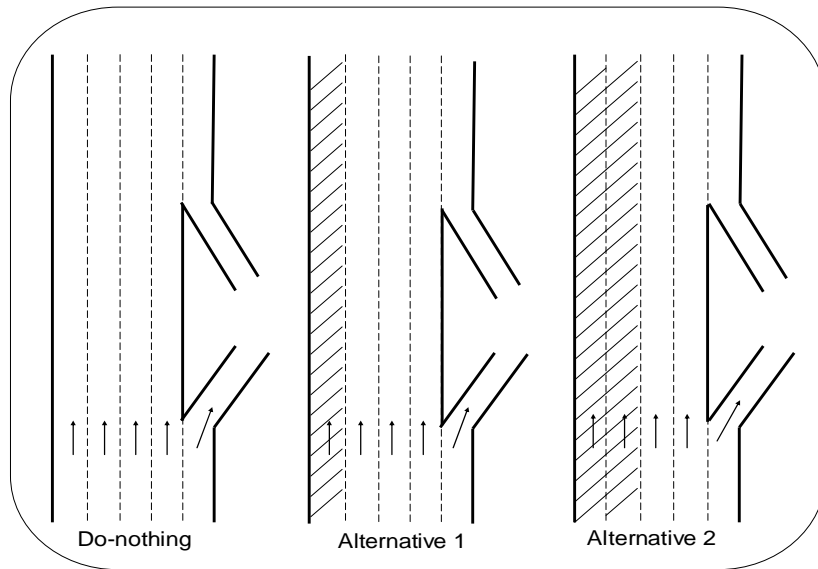
Traffic Flow Components

- **Average Speed (mph)**
- **The frequency of lane changes (frequency/veh)**
- **Throughput (veh/hr)**

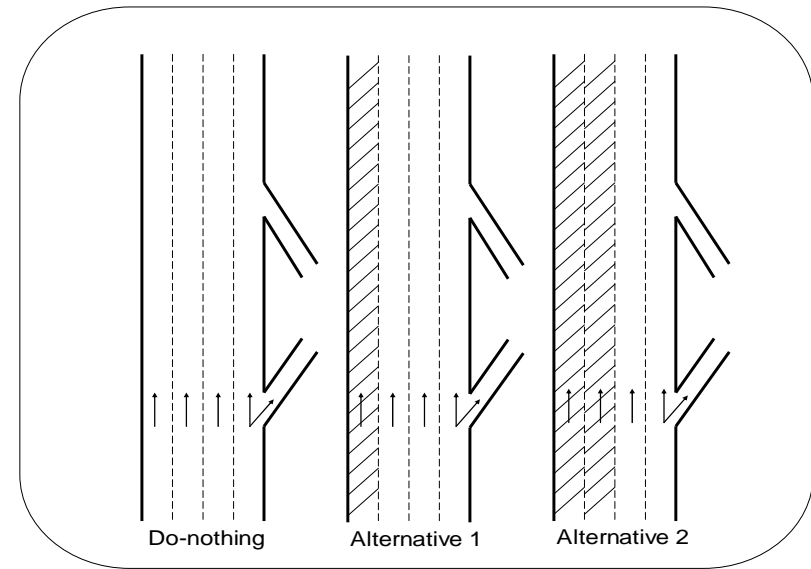


Experimental Study (con't)

□ Hypothetical Cases



Case A



Case B

□ Variables setting

- ☞ **Truck proportion: 5%~20%**
- ☞ **Traffic conditions: LOS criteria for multilane highways (HCM)**
- ☞ **Vehicle type: Trucks and Non-trucks**



Experimental Study (con't)

□ Statistical Analysis (Case A)

☞ ANOVA test

☞ All statistical tests are conducted with a 95% confidence interval

P-values of Case A

MSF (vphpl)	Truck Percentage											
	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 throughput in order



Experimental Study (con't)

Tukey's HSD test of Case A

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



Experimental Study (con't)

Tukey's HSD test of Case A

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



Experimental Study (con't)

Tukey's HSD test of Case A

Throughput		Multiple Comparison of Case B			
MSF		Truck Percentage			
1300 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.000	0.824(13.6)	0.527(63.2)	0.992(7.4)
Do-noting	Alternative 2	0.000	0.992(-2.8)	0.987(-8.8)	0.052(-165)
Alternative 1	Alternative 2	0.000	0.756(-16.4)	0.441(-72.0)	0.04(-172.4*)
1600 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.656 (69.2)	0.92(-30.4)	0.086(-141.0)	0.993(-6.2)
Do-noting	Alternative 2	0.149 (-157.2)	0.082(-185.4)	0.002(-276.5*)	0.03(-155.6*)
Alternative 1	Alternative 2	0.032(-26.4*)	0.157(-155.0)	0.1(-135.0)	0.04(-149.4*)
2000 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.176(-119.0)	0.334(-108.0)	0.995(-5.4)	0.994(-8.6)
Do-noting	Alternative 2	0.071(-152.8)	0.015(-244.4*)	0.014(-185.4*)	0.02(-255.0*)
Alternative 1	Alternative 2	0.851(-33.8)	0.190(-136.4)	0.016(-180.0*)	0.03(-246.4*)



Experimental Study (con't)

□ Statistical Analysis (Case B)

☞ ANOVA test

☞ All statistical tests are conducted with a 95% confidence interval

P-values of Case B

MSF (vphpl)	Truck Percentage											
	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	0.000	0.000	0.000	0.000
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 throughput in order



Experimental Study (con't)

Tukey's HSD test of Case B

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



Experimental Study (con't)

Tukey's HSD test of Case B

Frequency of lane changes		Multiple Comparison of Case B			
MSF (vphpl)		Truck Percentage			
1000 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.001 (-0.27*)	0.000 (-0.47*)	0.000 (-0.58*)	0.000 (-0.59*)
Do-noting	Alternative 2	0.129 (-0.11)	0.051 (-0.16)	0.028 (-0.22*)	0.467 (-0.11)
Alternative 1	Alternative 2	0.024 (0.16*)	0.001 (0.30*)	0.001 (0.36*)	0.001 (0.47*)
1300 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.512 (-0.32)	0.000 (-0.40*)	0.000 (-0.42*)	0.000 (-1.11*)
Do-noting	Alternative 2	0.951 (-0.08)	0.749 (-0.04)	0.268 (-0.07)	0.347 (0.30)
Alternative 1	Alternative 2	0.690 (0.238)	0.000 (0.36*)	0.000 (0.35*)	0.000 (1.41*)
1600 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.001 (-0.22*)	0.000 (-0.27*)	0.000(0.47*)	0.086(0.19)
Do-noting	Alternative 2	0.835 (0.02)	0.002 (0.10*)	0.000(0.76*)	0.000(0.688*)
Alternative 1	Alternative 2	0.000 (0.25*)	0.000 (0.38*)	0.000(0.28*)	0.000(0.498*)
2000 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.327 (-0.06)	0.000 (-0.17*)	0.004 (-0.11*)	0.000 (-0.17*)
Do-noting	Alternative 2	0.040 (0.11*)	0.001 (0.14*)	0.000 (0.25*)	0.000 (0.62*)
Alternative 1	Alternative 2	0003. (0.17*)	0.000 (0.31*)	0.000 (0.36*)	0.000 (0.80*)



Experimental Study (con't)

Tukey's HSD test of Case B

Throughput		Multiple Comparison of Case B			
MSF		Truck Percentage			
1300 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.000	0.000	0.162 (-95.2)	0.000
Do-noting	Alternative 2	0.000	0.000	0.000(-273.4*)	0.00(-680.6*)
Alternative 1	Alternative 2	0.000	0.000	0.008(-178.2*)	0.00(-680.6*)
1600 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.000	0.537(-25.2)	0.00(-989.6*)	0.00(-681.4*)
Do-noting	Alternative 2	0.967(-8.0)	0.006(-88.4*)	0.00(-965.0*)	0.00(-825.2*)
Alternative 1	Alternative 2	0.967(-8.0)	0.044(-63.2*)	0.575(24.6)	0.249(-143.8)
2000 vphpl		5%	10%	15%	20%
Do-noting	Alternative 1	0.712(-21.4)	0.4(-38.4)	0.267(-39.6)	0.726(-19.4)
Do-noting	Alternative 2	0.221(-47.6)	0.003(-119.6*)	0.000(-130.0*)	0.00(-562.0*)
Alternative 1	Alternative 2	0.606(-26.2)	0.037(-81.2*)	0.007(-90.4*)	0.00(-542.6*)



Experimental Study (con't)

□ Results Summary

- **Alternative 1 and 2 appear to lead to an increase in average speeds**
- **The frequency of lane changes would vary according to geometric conditions**
- **Throughput is likely to increase under restrictions**
- **Lane restrictions would work when traffic conditions is more than 1300 vphpl and truck traffic is over 10%**
- **Each alternative-pair shows statistically different results**



Case Study

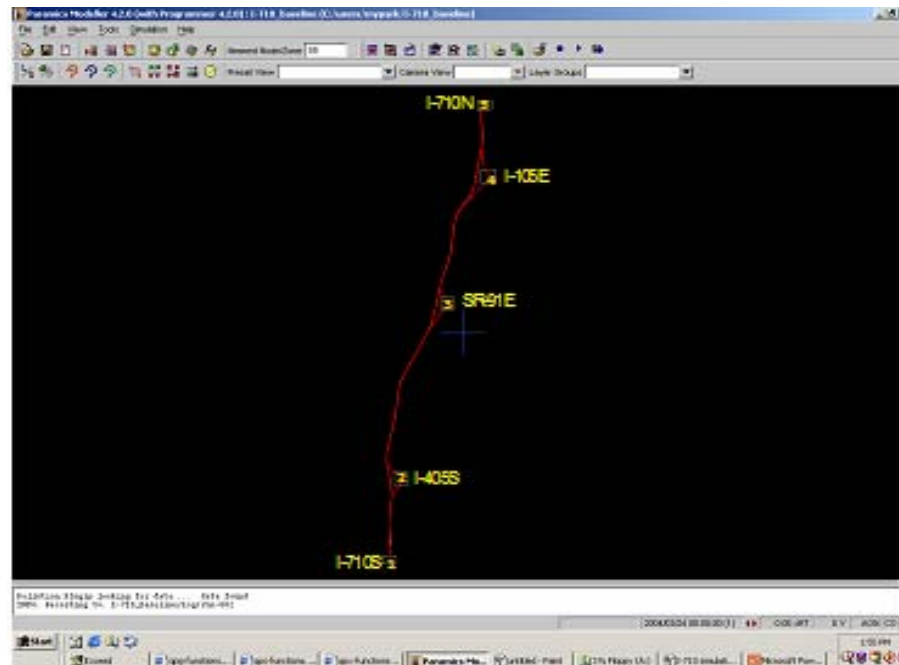
- ❑ **Study Site (I-710 corridor)**
 - **A high percentage of truck volume**
 - **Major route to the Ports of LA and Long Beach (truck mobility problems)**

- ❑ **Feasible truck management strategies**
 - **Currently, no strategy implemented**
 - **Truck exclusive lanes were considered but ruled out**
 - **Build alternatives were selected but eliminated due to cost**
 - **Management strategies can only be considered**



Case Study

- ❑ **I-710 Corridor**
- ☞ **23 mile section of urban freeway**
- ☞ **Pavement: concrete surface with flat terrain**
- ☞ **Ramp configuration compounds case A and B**
- ☞ **Number of lanes varies but mostly 4 lanes**





Case Study

☐ Traffic Data

☞ Used the year 2005 (PeMS)

Northbound	Average Flow Rate	Truck Percentage	Average Speed
AM	1246 vphpl	7.9%	47.88 mile/hr
MD	1422 vphpl	13%	53.99mile/hr
PM	1168 vphpl	8.4%	41.14mile/hr
Southbound	Average Flow Rate	Truck Percentage	Average Speed
AM	1513 vphpl	8.1%	56.00mile/hr
MD	1136 vphpl	11.4%	57.94mile/hr
PM	986 vphpl	7.8%	39.26mile/hr

☞ 973~1950 veh/hr/lane during MD time period on northbound

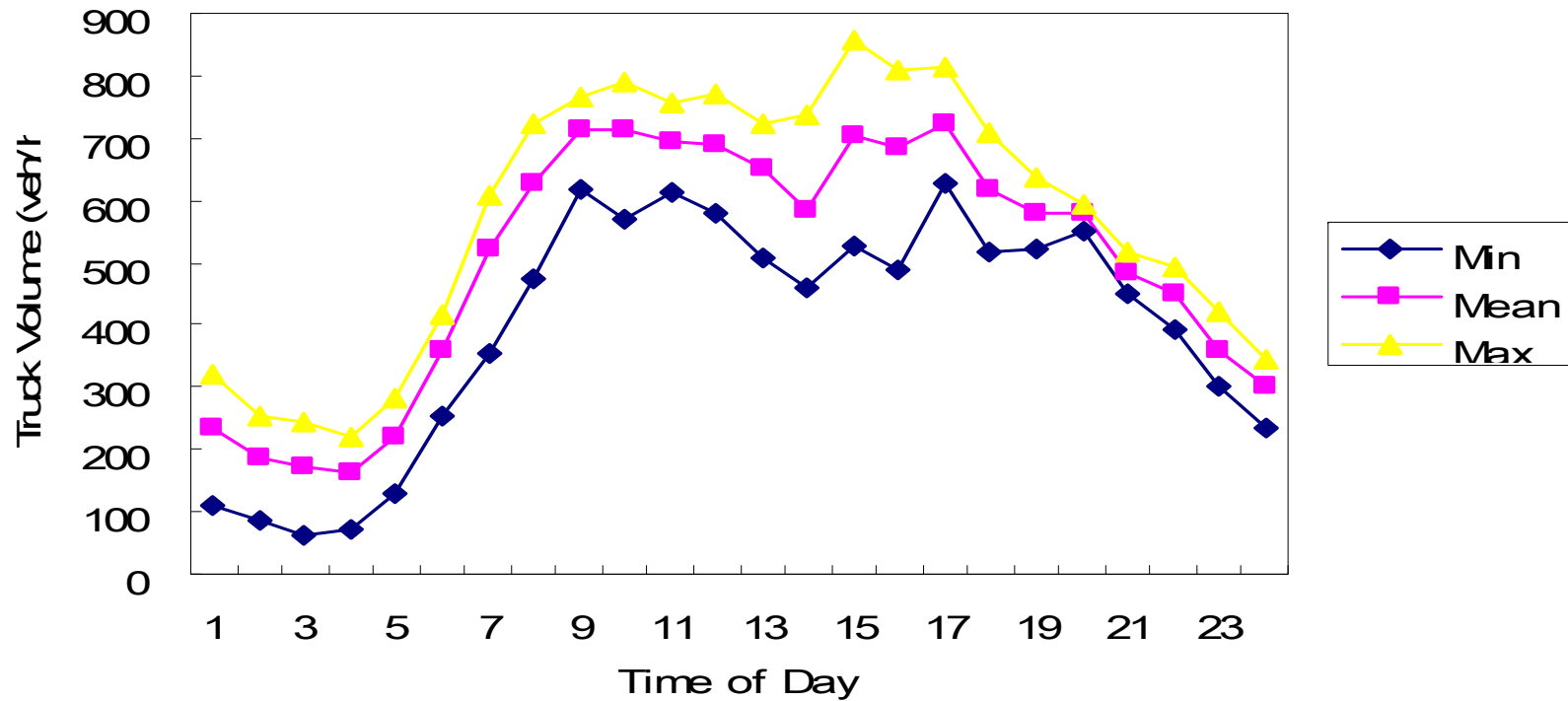
☞ 13% trucks and 87% non-trucks

☞ Independent count of truck frequency were performed



Case Study

Truck Volume (CA 11.00mile)

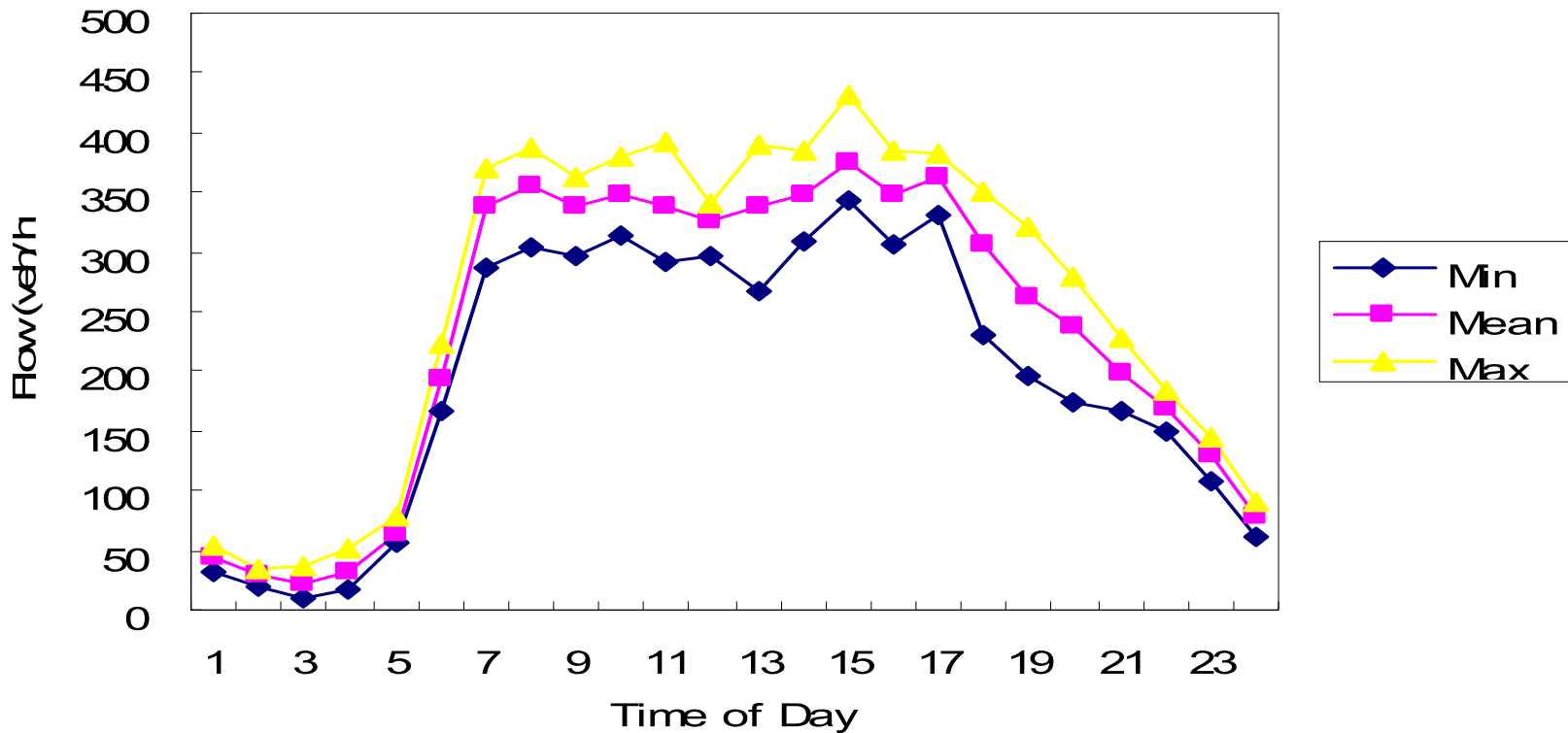


Truck volume at 11 mile from the LB Port



Case Study

Truck Flow (CA. 23.71mile)



Truck volume at 23 mile from the LB Port



Case Study

OD Demand Data

- **SCAG data year 2000 traffic**
- **Highway OD extract using TransCAD**

Simulation Runs

- **The simulated traffic counts can be matched the known traffic counts**
- **GEH statistics**
- **The simulation duration 80-minute**
- **Simulation runs with the different seed numbers**



Quantitative Analysis

Traffic Congestion

☞ Average delay

☞ Average Travel rate

☞ Average Travel time

☞ Average delay rate

Simulation results

Performance Measures	Do-nothing	Alternative 1	Alternative 2
Average delay (min per veh)	11.88	11.79	11.55
Average travel rate (min per mile)	1.36	1.36	1.31
Average travel time (min)	33.59	33.54	33.43
Average delay rate (min per mile)	49.9	46.5	44.2

☞ A reduction in average delay 3%, average travel rate 4%, average travel time 0.5% and average delay rate 11% compared with do-nothing case



Case Study

☐ ANOVA test

Performance Measures	P-value	Significance
Average delay (min per veh)	0.158	Not significant
Average travel rate (min per mile)	0.001	Significant
Average link travel time (min)	0.001	Significant
Average delay rate (min per mile)	0.248	Not significant

☞ H_0 : All measures across scenarios are the same at the level of significance (0.05)

☞ Two measures statistically differ



Safety

- ☞ Average frequency of lane changes (frequency/veh)
- ☞ Average lane speed differential (mph)
- ☞ As these increase, the likelihood of vehicle interactions also increase

Simulation results

Safety Measures	Do-nothing	Alternative 1	Alternative 2
Average frequency of lane changes (frequency/veh)	9.78	11.08	11.60
Average lane speed differential (mile/hour)	10.89	13.31	13.35

- ☞ LC slightly increases 18.6% and 5% compared to do-nothing case and alternative 1



☐ ANOVA test

Performance Measures	P-value	Significance
Average frequency of lane changes (frequency/mile-veh)	0.000	Significant
Average lane speed differential (mph)	0.134	Not significant

☞ **Average frequency of lane changes are different**

☞ **No statistical difference in average lane speed differential**



Air quality

☞ **CO, CO₂, NO_x, HC, Fuel Consumption (Using CMEM)**

Simulation results

Emission rate (gram/veh)	CO	CO ₂	NO _x	HC	FC
Do-nothing	171.93	1369.3	6.37	4.40	521.51
Alternative 1	172.13	1354.1	6.40	4.39	513.90
Alternative 2	171.59	1353.1	6.39	4.38	510.36

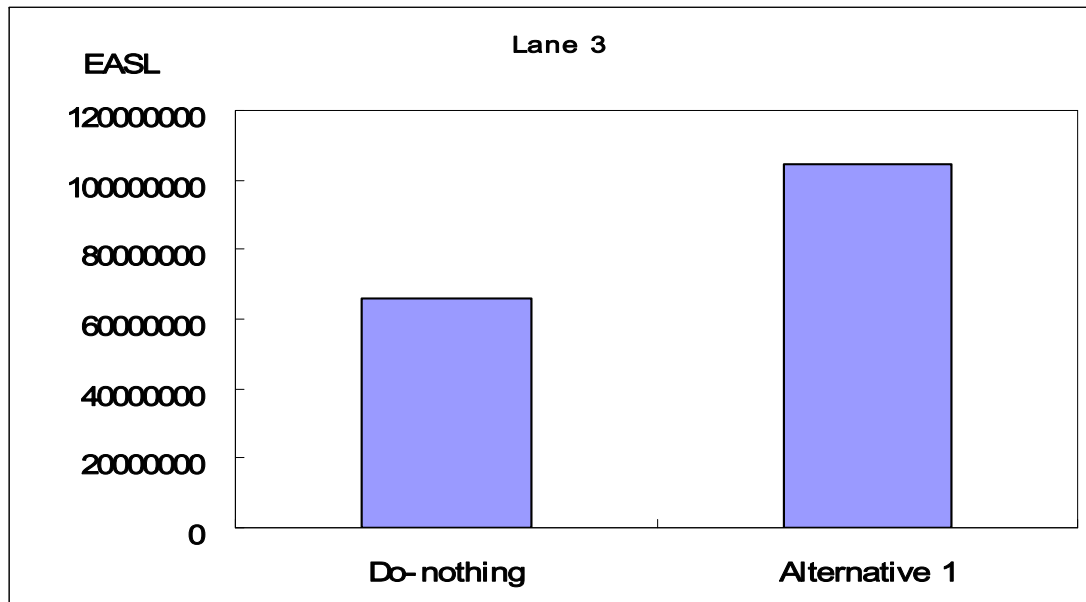
ANOVA test

Emission Sources	P-value	Significance
CO	0.066	Not significant
CO ₂	0.414	Not significant
NO _x	0.894	Not significant
HC	0.897	Not significant
FC	0.031	Significant

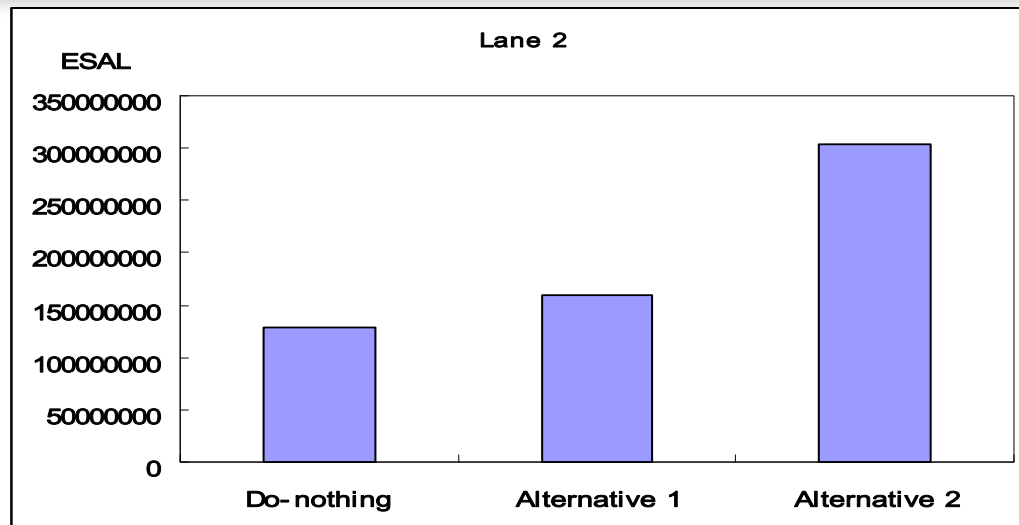


□ Pavement deterioration

☞ Equivalent Single Axle Load (ESAL)



☞ Under alternative 1, lane 3 needs repair from fatigue loading approximately 38% faster than under the do-nothing case



- ☞ **Lane 2 needs repair about 19% under alternative 1 and 58% under alternative 2**
- ☞ **It is easy to understand that trucks are forced to move unrestricted lanes and thus those lanes more have fatigue loading than restricted lanes**



□ Reliability

☞ Percent variation

☞ Travel time window

➤ In practice, it has to be measured in the field over a number of days

□ Travel time standard deviation (min)

	Do-nothing	Alternative 1	Alternative 2
All vehicles	0.74	0.71	0.55
Non-trucks	2.56	0.67	0.48
Trucks	1.24	1.01	0.83

☞ Alternative 2 is relatively less variability in travel time



Travel time window (min)

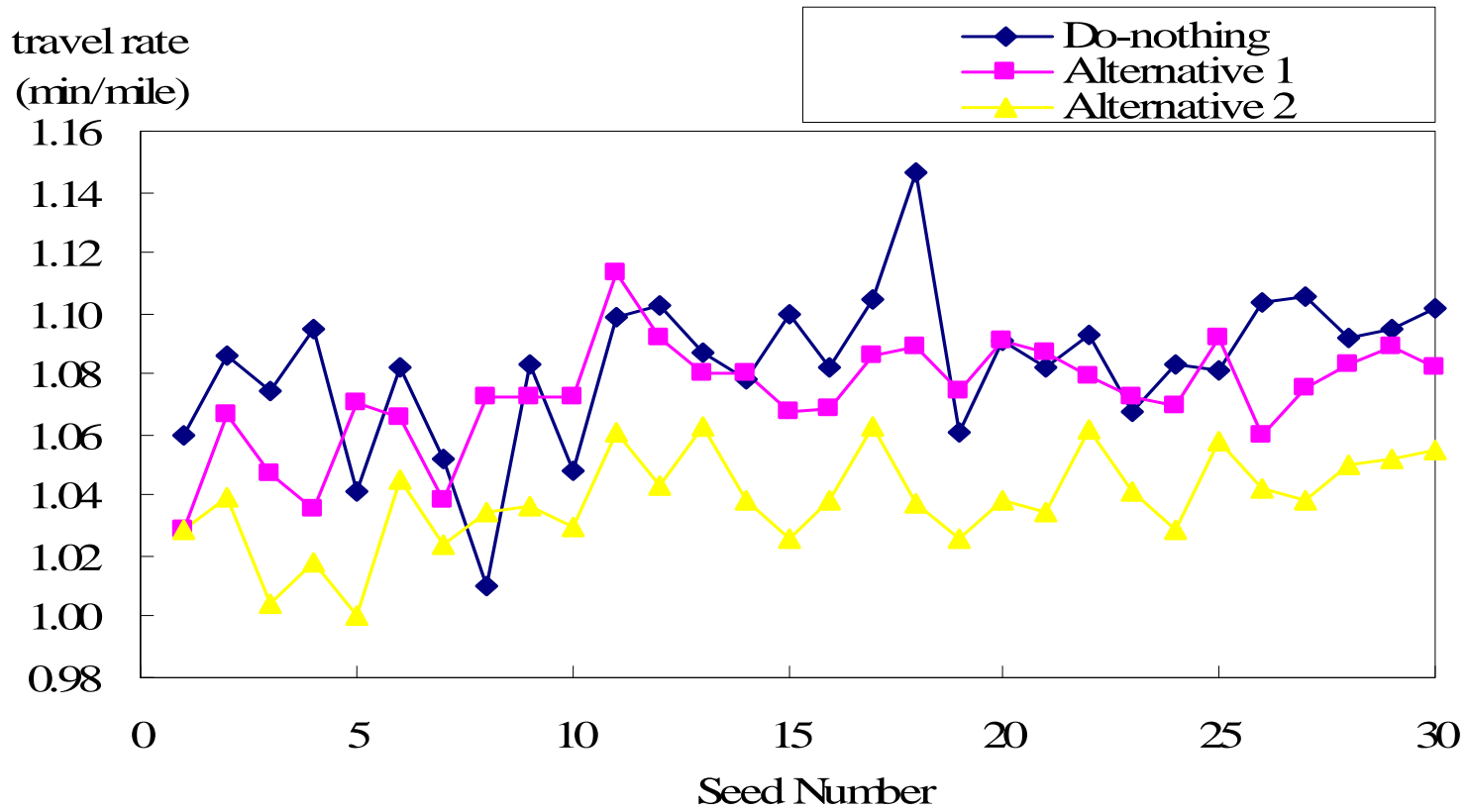
Do-nothing	Alternative 1	Alternative 2
34.60 ± 0.74	34.56 ± 0.71	33.43 ± 0.55

- 👉 Drawing from the research by Texas Transportation Institute
- 👉 would provide clear picture how much travel time differ

Percent variation

Do-nothing	Alternative 1	Alternative 2
2.06%	2.14%	1.70%

- 👉 A statistical measure and the same form of a coefficient of variation





Productivity

☞ **Truck travel time**

Simulation results

Do-nothing	Alternative 1	Alternative 2
40.84 min	43.50 min	45.59 min

☞ **Average truck speeds are likely to decrease as more lanes are restricted**

ANOVA test

Performance Measure	P-value	Significance
Average truck travel time (min)	0.000	Significant



Conclusion

□ Summary

- ☞ **Even though the impacts of lane restrictions on freeway facilities have been performed in the previous research, their evaluations have been focused on operational and safety issues**
- ☞ **The focus of our study is on quantifying the impacts, including the public and private sector standpoints using various performance measures**
- ☞ **Lane restrictions may provide benefits in terms of flow of traffic and fuel savings of vehicles on this site**



- ☞ However, safety benefits under restrictions do not appear to be considerable compared with the do-nothing case**
- ☞ Impacts for pavement deterioration under restrictions seem to be unpromising since truck are re-distributed**
- ☞ Nonetheless, truck lane restrictions are promising to manage truck traffic in terms of improving flow of traffic**