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An Evaluation of the Impact of Lane Use Restrictions for Large Trucks Along I-40 near Knoxville

Vasin Kiattikomol
University of Tennessee - Knoxville

To the Graduate Council:

I am submitting herewith a thesis written by Vasin Kiattikomol entitled "An Evaluation of the Impact of Lane Use Restrictions for Large Trucks Along I-40 near Knoxville." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Civil Engineering.

Arun Chatterjee, Major Professor

We have read this thesis and recommend its acceptance:

Frederick J. Wegmann, Lee D. Han

Accepted for the Council:
Dixie L. Thompson

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

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An Evaluation of the Impact of Lane Use Restrictions for Large Trucks Along I-40 near Knoxville

A Thesis
Presented for the
Master of Science
Degree
The University of Tennessee, Knoxville

Vasin Kiattikomol
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Abstract

This thesis is concerned with studies on an effectiveness and impact of lane restriction for large trucks from a left lane on Interstate 40 near Knoxville. The data collection was conducted in July to August 2001 and March to April 2002. The restriction was implemented on August 13, 2001. The lane distribution and individual speed of large trucks in each lane were then gathered to obtain patterns and characteristics of large trucks 'before' and 'after' the implementation. A database was developed, a data comparison was conducted, and a statistical test was applied. The findings reveal several significant changes of lane distributions and speeds of large trucks and are concluded in the form that can provide the Tennessee department of transportation information in order to make a decision on an existing and future lane use restriction plan.

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Chapter 1 Introduction

Opportunities for solving traffic congestion problems by building more new highways are becoming less than before, and highway engineers now have to rely on improving the existing ones in order to provide a better level of service and safer operation. There exist many strategies for this purpose depending on the nature of the existing problem and the characteristics and volume of traffic at each location as well as the behavior of road users in the area.

One of the frequently encountered issues that highway engineers have to deal with involves truck traffic along the freeways through urban areas. These usually are large trucks that travel long distances for interstate commerce. These trucks contribute not only to traffic congestion but also cause highway safety problems.

Data for 1999 show that about 5,362 people died and 142,000 people were injured in crashes involving large trucks in USA. Of these crashes, 20% of fatal crashes and 17% of injury crashes are resulted from trucks running over the speed limit. About 26% of fatal crashes involving large trucks occurred in work zones, as in FMCSA's report (1). Trucks contributed about 49,896 million vehicle-miles of travel on rural Interstates and approximately 30,193 million vehicle-miles on urban Interstates in 1998, as in BTS's report (2), and truck travel is continuing to increase. Better control of truck operation on freeways can improve safety on the existing facilities.

One strategy that has been used in many states with respect to truck travel is to restrict their travel only on certain designated lanes. Truck lane use restrictions have been implemented in more than 25 states. There are different reasons for imposing a truck lane use restriction. Unfortunately, there are only few studies concerning the impact of these restrictions on operation and safety. Highway engineers must be careful in imposing these restrictions. All situations are not alike. There are differences in traffic volume at each site, differences in traffic volume distribution over lanes, percentage of trucks, and differences curvature and grade. This study has been conducted in order to provide Tennessee Department of Transportation (TDOT) with first-hand information on the consequences of restricting large trucks from the left-most lane of urban freeways based

on an actual experimental project along two stretches of I-40 in and near Knoxville. One of the stretches is on the east side of Knoxville, and this 25 miles long stretch lies between milepost 395 and 420. The other one is on the west side of Knoxville between milepost 369 and 379 and it is only 10 miles long. The purpose of the study is to study on the effectiveness of truck lane restriction on the Interstate stretches near Knoxville and assess the impact of truck lane restrictions along these stretches of highway on traffic flow in terms of the following:

- lane distribution of large trucks
- speed of large trucks
- potential of increasing merging conflict at an entrance ramp

The findings will help TDOT decide whether the restrictions should be continuously implemented or discontinued, and also whether similar restrictions should be used in other areas.

It should be pointed out that a lane use restriction for trucks usually is applied along a highway for a long continuous stretch through an urban area or on a statewide basis. In the case of Knoxville, the restriction was discontinued through the central part of the city because of construction projects.

Chapter 2 Literature Review

Truck lane restrictions are normally introduced for the purpose of better traffic operational, longer structure longevity and higher highway safety for both highway commuters and workers in construction zones. Jasek, Shafer, Picha, and Urbanik (3) mention from their literature review and survey that several types of restrictions are implemented in more than 25 states and have a positive response since in 1986. Those reasons for implementing are improving highway operation (14 states), reducing accidents (8 states), considering on pavement structure (7 states), and restricting in construction zone (7 states). There are four alternative types of truck restrictions to improve safety and operation.

- Lane restrictions are for safety and congestion improvement.
- Route restrictions are for hazardous materials carriers and oversize/overweight vehicles.
- Time-of-Day restrictions are for noise avoidance in residential areas.
- Speed restrictions

The study of truck lane use restrictions has been conducting by several researchers for different reasons. There are two major reasons for the study, to reveal the impact of truck lane use restriction and to guide the State Department of Transportation on the strategy of segregating trucks from the traffic on highways. The studies were conducted in both numerical and alphabetical aspects. However, all of the researchers believe that the truck lane use restriction is one of the solutions to reduce conflict between trucks and cars, increase traffic flow, improve level of safety, and increase structural longevity of highway.

Previous Study Methodologies

Hoel and Peek (8) and Zavoina, Urbanik, and Hinshaw (9) studied on the impact of truck lane use restrictions in Virginia and Texas respectively by using the similar data

collection method, loop detectors and tapeswitches detectors in both before and after the restrictions while Jasek, Shafer, Picha, and Urbanik (3), TDOT (11), and Koehne, Mannering, and Hallenbeck (7) studied on the impact of truck lane use restrictions by reviewing literatures, surveying, and interview for opinions methods.

Hoel and Peek (8) analyzed the data by using the Federal Highway Administration's Freeway Simulation Model (FRESIM) to interpret results from the traffic count for changes of three parameters, changes in lane changes per vehicle, changes in speed differential between average speeds of cars and the average speeds of trucks, and changes in a density, an important parameter in determining a level of service. And they use a paired – sample t test to measure the significant differences of those three parameters between before and after the restriction. , Zavoina, Urbanik, and Hinshaw (9) tested the significances of colleted data between before and after the restriction by using Chi-square for the significance in lane distribution of trucks and cars and using a t-test for the significant mean speeds and time gaps.

Results from Previous Studies

The study by Hoel and Peek (8) reveals that restricting trucks from the left lane with steep grades around 4% causes an increase in the speed differential and decrease density and the number of lane changes. And restricting trucks from the right lane increases the number of lane changes for sites without exit and entry ramps. This is because trucks are forced to shift to the left lanes under the restrictions and have to additionally change to accommodate passing cars in the left lane. The study concludes that the scenario analysis and the case studied do not produce negative effect from truck lane restrictions so that the use of left lane restrictions can be continued at the exiting site.

Zavoina, Urbanik, and Hinshaw (9) separated collected data into peak and non-peak period. Before data reveals that truck lane restrictions would be the best operational strategy for some reasons

- There are very few trucks using the left-most lane, about 1.3% of all traffic
- Trucks in the left lane are exceeding the speed limit up to 10 miles per hour

- Trucks might impede the free-flow ability of cars. However, the speed of cars following cars is not significantly different (α=0.05) from that of cars following trucks

A survey is conducted in the same study after the implementation of the restriction and gives the following results.

- 32% of motorists and 24% of truckers do not see the signs.
- 12% of motorists and 27% of truckers do not fully understand the sign.
- 45% of motorists feel that the restriction had improved operations.
- 20% of truckers feel the better operational improvement.

And the results from analyzing by Chi-square test and t-test show that

- At α=0.05, the directional distribution of trucks significantly change after the restriction.
- A truck percentage significantly decreases in the left lane at all sites
- A truck percentage significantly increases in the right lane of each direction of I-20 and in the right two lanes of each direction of I-35E.
- The redistribution of trucks does not effect changes in the distribution of cars.
- Only 3% of trucks remain in the left lane.
- Time gaps of trucks following trucks are significantly less than those of trucks following cars.
- Grade significantly affects the speed of trucks.

The study concludes that the significant changes of the lane distribution of trucks due to the lane use restriction has no effect to the lane distribution of cars, speed changes of either cars or trucks, or time gaps between vehicles. And there is no evidence to support the conclusion on an improvement of capacity and safety of highway from the truck restriction.

A literature review and survey on the truck lane restriction for Nashville's freeway system, by TDOT (11) ends up with the results that

- The restrictions have a conflict problem to the Nashville's Interstate having left exits.

- Accident potential may increase with high truck percentage and high traffic volume.
- Lane restrictions are appropriate on steep grades section.
- There are about 29 interchanges having spacing less than two miles and about 17 interchanges having spacing equal to or less than a half mile. Currently, operational effects of merging traffic are heaviest in the right two lanes. So restricting trucks to the right lane would increase more merging problem.
- Restrictions give benefit on rural interstate, but may increase congestion and accident problems on urban interstate.
- Enforcement of speed limit might be more effective than lane restriction in order to improve safety.
- There are no significant benefits gained from lane restrictions according to a study by Federal Highway Administration.

An interview survey by Koehne, Mannering, and Hallenbeck (7) on the motorist' opinions to the truck lane use restriction on two sections of I-5 in Puget Sound, Washington shows that most of the truckers especially for longer licensed drivers feel reluctant with the restriction that a lane restriction is unnecessary because trucks rarely use left lane on ascending grade. Two-third of truckers changes lane due to a rough pavement. Some of them are unclear about the restriction sign. Some states determine vehicle types to be restricted as any vehicles bearing truck plate. And only small number of truckers wants to keep the restriction. On the other hand, motorists feel that the lane restrictions will improve highway operation and increase safety. Currently, most of the motorists are sometimes and often avoiding being followed by a truck and traveling next to a truck. There is more favorable for those who changed lanes often while being followed by trucks. The survey found that about 31% of truckers disobeyed the restriction.

For the evaluation on the efficiency of truck lane restrictions to the accident improvement, a literature review by Jasek, Shafer, Picha, and Urbanik (3) states that the proportion of accidents involving trucks with three or more axles on I-95 in Broward

County, Florida decrease during the hour of restrictions. However, the lane restrictions for trucks on I-95 section of Washington D.C., capital belt increase the crash rate.

However, many urban areas still are continuing using truck lane use restrictions even though they have not been concluded to significantly reduce crashes on freeway as in surveys by Jasek, Shafer, Picha, and Urbanik (3).

Recommendations from Previous Studies

The agencies responding in the lane restrictions have to realize that these restrictions are not the solution for all problems; on the other hand, it might create other problems according to the physical characteristics of freeway, behavior of drivers, and traffic pattern and volume in the areas. Hoel and Peek (8) suggest that modeling of each site is necessary when determining if lane restrictions should be implemented. The restrictions are proved to be efficient in the steep grade that it could increase speed differential thus may resulting in lower density and lower number of lane changes. However, the restrictions are not recommended in high merging areas and on freeway with quite a few of right exit ramps. This might generate conflict problem resulting in more potential of crashes. Jasek, Shafer, Picha, and Urbanik (3) recommend that truck lane restrictions should not be implemented on a two-lane rural freeway. In many states, truck lane restrictions are intended to force those few trucks running in the left-most lane on freeways with the exceeding speed limit to slow down by shifting the operation in the slower lanes. Sometimes, trucks are restricted from right lane according to the purpose of providing more uniform pavement wear, protecting workers in construction zones, and increasing visibility of signing along freeway, but this might increase number of lane change because trucks have to shift the lanes back and forth to accommodate passing passenger vehicles. FHWA (5) suggests the limitation of truck lane use restriction that it could be difficult to enforce, accelerate pavement deteriorations, reduce visibility of signing, and will be limited by lane drops at freeway-freeway interchange.

Chapter 3 Study Methodology

Develop a Detailed Plan for Data Collection

A plan was developed in consultation with Tennessee Department of Transportation (TDOT) traffic engineers of Region 1 and Nashville offices for gathering data for all components of the study, which include the following traffic flow characteristics:

- Lane distribution of large trucks
- Speed of large trucks
- Merging maneuver at on-ramps

The details of data collection plan are given below:

- Determine time period of data collection:
  - Data are to be collected in both 'before' and 'after' periods of the lane use restriction
  - Data are to be collected during AM and PM peak hours and one mid-day hour. The preferred times were 7.30-8.30 am, 16.30-17.30pm, and 12.00-13.00 pm
  - Data are to be collected on weekdays excluding some weeks having holidays which may cause abnormal traffic patterns.
- Select locations for data collection: Four sites were selected. The recording equipment is to be set up on an overpass at each of the four sites, two on the east side and two on the west side of Knoxville. There are two directions for recording data, east and west, at each location.
- Procure equipment for data collection: It was decided that the video cameras and tripods will be used to record all traffic at each location. A set of special equipment, Remote Traffic Microwave Sensor (RTMS), is installed on the west side for collecting traffic related data for another project. The data collected by these RTMS units represent another source for the study that will be explored.

- The restriction areas are set to be between mileposts 369 and 379 on the west side and between mileposts 395 and 420 on the east side of Knoxville as demonstrated in figure 3-01.
- For determining the speed at which trucks are traveling at each site, two white paint marks were placed on the shoulders 200 feet apart from each other. TDOT arranged to have this work done. The times of travel through these speed zones were determined from video.

Execute Data Collection Plan

Data collection is divided into two phases, 'before' and 'after' the implementation of truck lane use restrictions.

The 'before' data were collected during June and July of 2001 for the lane distribution and speed data. Since the traffic pattern in the first week of July usually is different from normal patterns because of a holiday, this week was not covered.

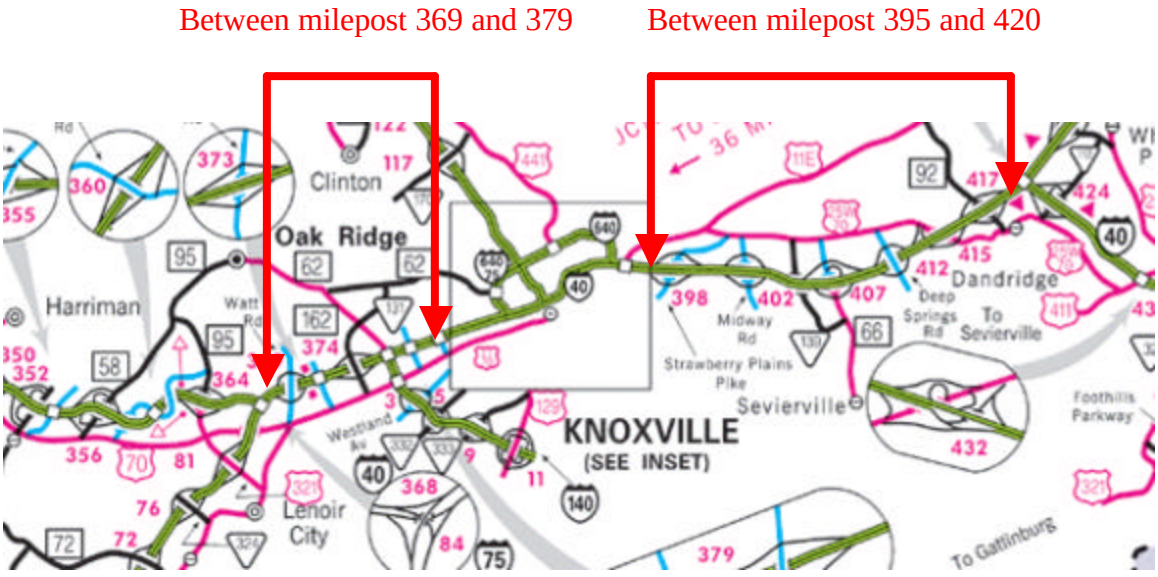


Figure 3-01. Proposed restriction areas on west and east side of Knoxville

Source: The Official 2002 Highway Map, Tennessee Department of Transportation

The restriction was implemented on August 13, 2001. The 'after' data were collected after several months, in March and April of 2002, from the implementation period to allow the traffic pattern to stabilize.

The detailed descriptions of restricted areas were graphically illustrated in figure 3-02 for the westside of Knoxville and in figure 3-03 for the eastside of Knoxville.

Extracting Data from Videotapes and RTMS Units

The 'before' data extraction required a few different steps. Some of the videotapes were read directly on the screen mounted on the video cameras. Others had to be converted into VHS format and read by normal video players.

The data collection 'after' the implementation of truck lane use restriction utilized two methods. The Remote Traffic Microwave Sensor (RTMS) and video taping were employed for detecting both lane distribution and speed of trucks in the traffic stream on the west side of Knoxville. The 'after' data for the east side of Knoxville was collected by using the same video taping method as used for the 'before' data.

Remote Traffic Microwave Sensor (RTMS)

The RTMS is a RAdio Detection And Ranging (RADAR) device and provides detection of vehicles in each lane. The ranging capability is achieved by Frequency Modulated Continuous Wave (FMCW) operation. The sensor transmits a microwave beam and receives energy reflected by targets, vehicles and stationary objects, in its path. An RTMS can cover up to 8 individual lanes for information on traffic volume, occupancy, average speed, and long vehicle count in the range of 10-600 seconds. A vehicle speed is calculated by measuring the transit time of each vehicle through the detection zone. The average speed is calculated based on small vehicles only. RTMS can be placed as side-fire mounting and forward-looking mounting. The side-fire configuration is to mount the RTMS on the side of the road with the oval footprint at a right angle to the traffic lanes. The forward-looking mounting is to mount the RTMS in a

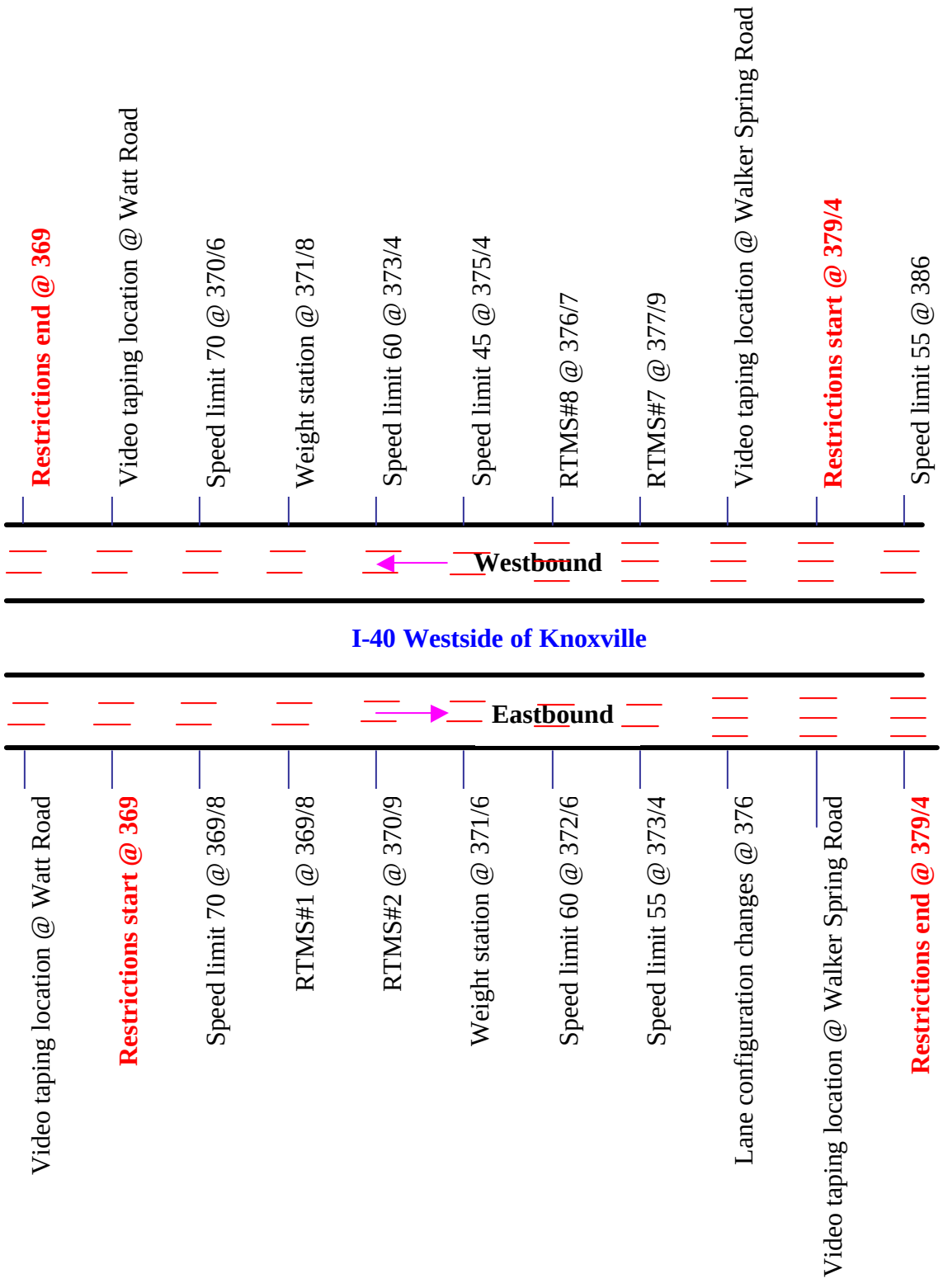


Figure 3-02. Demographic of signs and constrains along I-40 westside of Knoxville

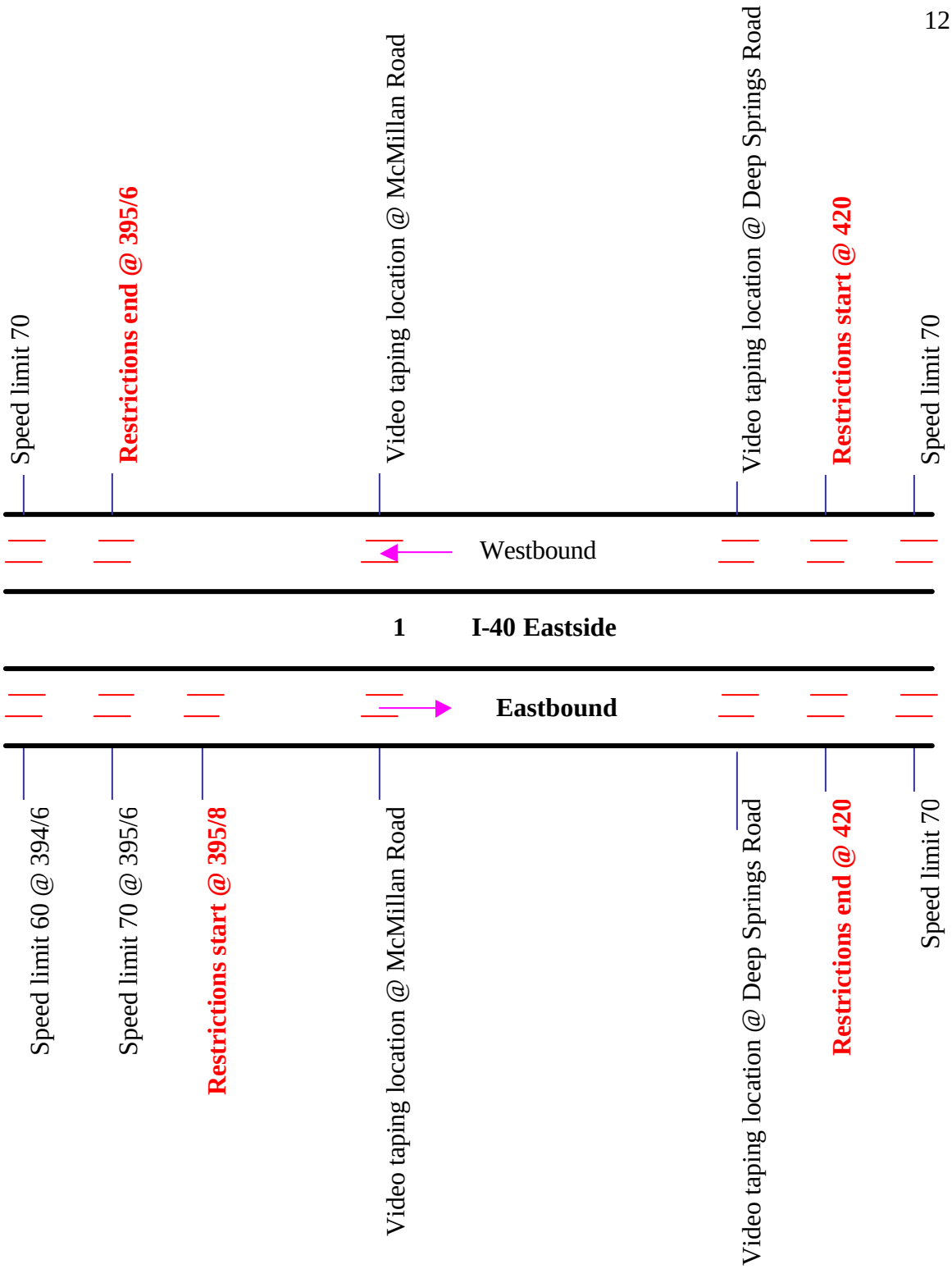


Figure 3-03. Demographic of signs and constrains along I-40 eastside of Knoxville

forward-looking configuration with the detection zones aligned along the direction of travel. Roadside pole-mounted side-fired RTMS stations can deliver their data directly via modem to the Traffic Operation Center (TOC) without a controller, as described in RTMS manual (4). Figure 3-04 shows the picture of RTMS installed on Westside of Knoxville.

Results and Comparisons

The 'before' and 'after' observed data were individually summarized and then compared to determine if the results are significantly different. A statistical test was used to determine if the differences in each case are significant or not. The major concern of the comparisons is to test for the differences among the lane distributions and speeds of trucks in 'before' and 'after' the implementation of the lane use restrictions.

Figure 3-04. RTMS unit#1 on I-40E at milepost 369 (near Watt road overpass)

Chapter 4 Data Collection and Analysis 'Before' the Restrictions

The 'before' and 'after' data contain information on the total traffic consisting of all types of vehicles. However, this study's primary interest is large trucks in the traffic stream and the truck information was extracted from the collected data. The main statistics of interest are distribution of trucks and their speeds in each lane. A comparison of 'before' and 'after' distributions can show if the truck lane use restrictions indeed changed the percentages of trucks traveling along different lanes. The 'before' and 'after' speeds of travel of trucks would help understand what impact the lane use restriction has had on traffic flow characteristics.

Data Collection Locations

The study locations include four sites: two on the west side of Knoxville on I-40 at exit 369, Watt road overpass and exit 379, Walker Spring road overpass; and two on the east side at exit 412, Deep Springs road overpass, and McMillan Road overpass. The McMillan road overpass at milepost 399 is not a part of an interchange that is there are no on/off ramps. It may be pointed out the two data collection sites on the west side are very near the termini of the restricted zone, whereas the two sites on the eastside are near the middle of the restricted stretch. The Watt road location was chosen because the Lovell road and Pellissippi Parkway locations could not be used due to construction projects. Further, the interchange at Campbell Station road did not have an overpass needed for observation. The eight locations of video camera settings on the different overpasses are as follows:

1. Walker Springs Road (on I-40 east) (Figure 4-01 and 4-02)
2. Walker Springs Road (on I-40 west) (Figure 4-01 and 4-03)
3. Watt Road (on I-40 east) (Figure 4-01 and 4-04)
4. Watt Road (on I-40 west) (Figure 4-01 and 4-05)
5. McMillan Road (on I-40 east) (Figure 4-01and 4-06)

6. McMillan Road (on I-40 west) (Figure 4-01 and 4-07)
7. Deep Springs Road (on I-40 east) (Figure 4-01 and 4-08)
8. Deep Springs Road (on I-40 west) (Figure 4-01 and 4-09)

Data Extraction/Retrieval

As discussed earlier the volume of trucks and their speeds were captured by the video recording method. To estimate the speed of trucks by video tapping, white paint markers were put on the shoulders of I-40 at each location (Figure 4-02 to 4-09) with a 200 feet spacing at each site. The time that trucks used to pass a pair of markers was used to calculate speed. These markers were done by TDOT.

The video recording was done by switching back and forth between the west side and the east side of Knoxville, one week at a time. On the same side of east or west, the taping was switched between the location of Walker Spring Road overpass and Watt Road overpass on the west side; the same switching process was done between McMillan Road overpass and Deep Springs Road overpass on the east side of Knoxville. These switching were done so that both sites on east and west were simultaneously surveyed as in table 4-01.

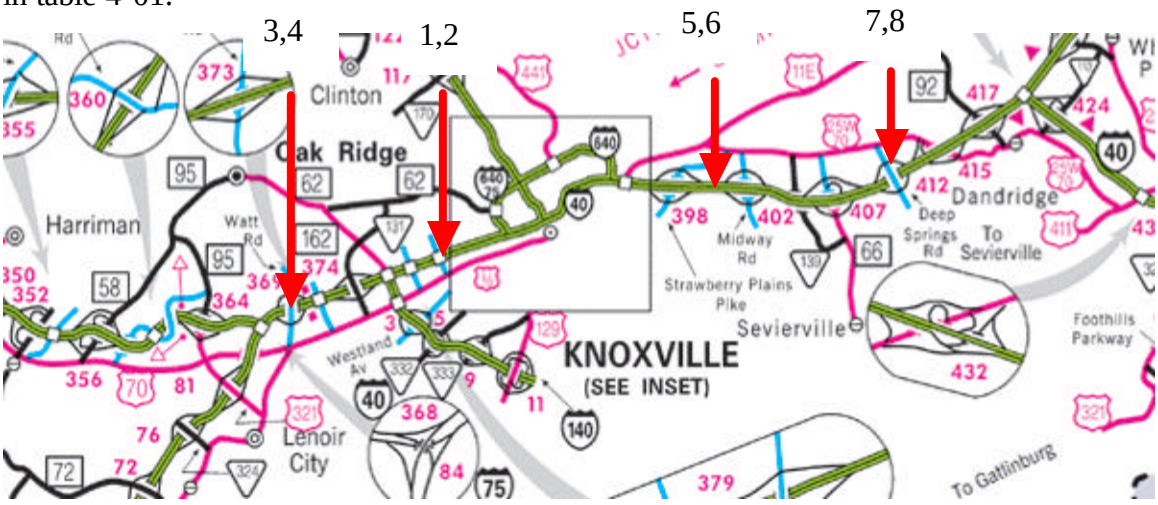


Figure 4-01. Data Collection Locations

Source: The Official 2002 Highway Map, Tennessee Department of Transportation

Figure 4-02. Walker Springs Road overpass (I-40 eastbound, looking west)

Figure 4-03. Walker Springs Road overpass (I-40 westbound, looking west)

Figure 4-04. Watt Road overpass (I-40 eastbound, looking east)

Figure 4-05. Watt Road overpass (I-40 westbound, looking east)

Figure 4-06. McMillan Road overpass (I-40 eastbound, looking west)

Figure 4-07. McMillan Road overpass (I-40 westbound, looking west)

Figure 4-08. Deep Springs Road overpass (I-40 eastbound, looking west)

Figure 4-09. Deep Springs Road overpass (I-40 westbound, looking west)

Table 4-01. 'Before' data collection times and locations

Date	Time		
	7.30 - 8.30	12.00 - 13.00	16.30 - 17.30
25-Jun-01	A	A	A
26-Jun-01	B	B	B
27-Jun-01	A	A	A
28-Jun-01	B	B	B
29-Jun-01	A B	A B	A B
9-Jul-01	D	D	D
10-Jul-01	C	C	C
11-Jul-01	D	D	D
12-Jul-01	C	C	C
13-Jul-01	C D	C D	C D
16-Jul-01	A	A	A
17-Jul-01	B	B	B
18-Jul-01	A	A	A
19-Jul-01	B	B	B
20-Jul-01	A B	A B	A B
23-Jul-01	D	D	D
24-Jul-01	C	C	C
25-Jul-01	D	D	D
26-Jul-01	C	C	C
27-Jul-01	C D	C D	C D

A = Walker Spring Road Overpass (I-40E and I-40W)
B = Watt Road Overpass (I-40E and I-40W)
C = McMillan Road Overpass (I-40E and I-40W)
D = Deep Springs Road Overpass (I-40E and I-40W)

It should be pointed out that some days of week and some weeks of a month were left out because of a holiday, accidents, or severe weather condition such as a heavy rain. These conditions usually result in altered travel patterns and would have given a picture different from the average condition.

Results from Video Collection

The data from each site were collected in multiple sets in a series of days during the week, they were combined into one set for each site per direction and per one hour periods as shown in Table 4-02. The data were collected by video cameras, so that nearly 100% of truck traffic in each lane of each location was counted and analyzed in the study. About 50,775 of all trucks were counted from all lanes, directions, and locations from the data collection before the restriction.

The numbers of lanes on I-40 at the Walker Springs Road location are four in each direction and the numbers of lanes at all other sites are three per each direction. Table 4-02 shows percentages of trucks in each lane for all data collection sites during three time periods, morning, midday, and evening. The percentages in the table are based only on the total number of trucks counted in the direction.

The 'before' data show that there was the highest percentage of trucks in the right two lanes and lowest in the left lane for a section of three lanes per direction. And there was the highest percentage of trucks in the middle two lanes and lowest in either the left or right lanes for a section of four lanes per direction.

Table 4-03 shows the 85^{th} percentile speed of trucks considered all locations and both directions together. It was observed that the 85^{th} percentile speed of truck in all locations and both directions was highest in the left most lane. There is only one location having 4 lanes per each direction, Walker Spring Road Overpass. The overall 85^{th} percentile truck speeds for a four-lane section were lowest in the middle left lane. However, the overall observed 85^{th} percentile truck speeds were high since the maximum speed limit is only 70 mph.

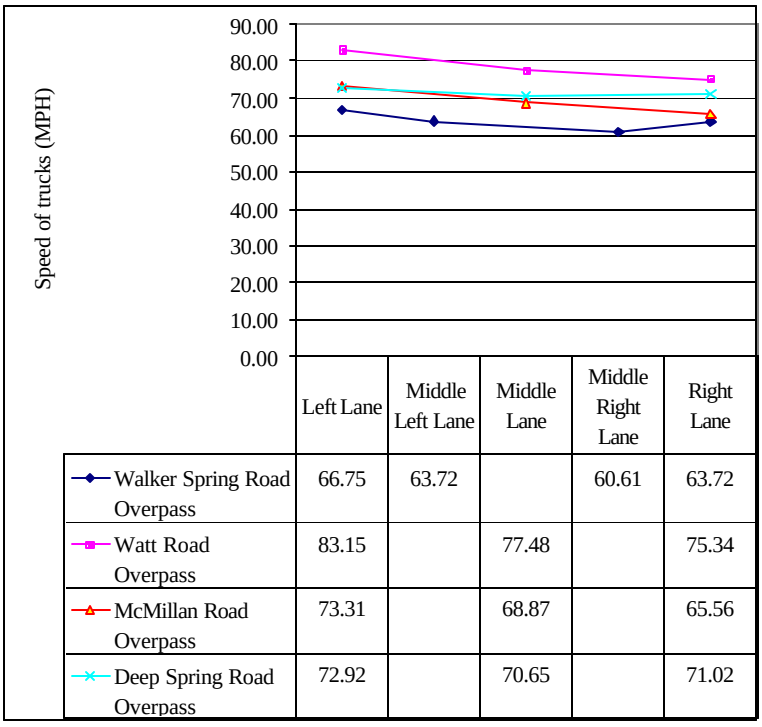
Table 4-02. Lane distribution of trucks before the restrictions

Direction	Time	Lane	Percentage of Truck Distribution (%)			
			Walker Spring Road Site	Watt Road Site	McMillan Road Site	Deep Springs Road Site
Eastbound	Morning (7.30-8.30)	Left Lane	6.26	2.73	9.03	6.17
		Middle Left Lane	44.78			
		Middle Lane		37.21	44.41	44.68
		Middle Right Lane	42.00			
		Right Lane	6.96	60.06	46.56	49.15
		Total	100.00	100.00	100.00	100
	Afternoon (12.00-13.00)	Left Lane	10.14	6.09	21.03	10.24
		Middle Left Lane	46.14			
		Middle Lane		41.33	43.10	44.40
		Middle Right Lane	37.57			
		Right Lane	6.15	52.58	35.87	45.36
		Total	100.00	100.00	100.00	100
	Evening (16.30-17.30)	Left Lane	11.71	4.89	14.10	11.26
		Middle Left Lane	45.59			
		Middle Lane		38.27	47.24	47.09
		Middle Right Lane	36.76			
		Right Lane	5.95	56.84	38.66	41.65
		Total	100.00	100.00	100.00	100
Westbound	Morning (7.30-8.30)	Left Lane	9.20	13.86	5.73	7.13
		Middle Left Lane	46.76			
		Middle Lane		56.73	40.19	42.53
		Middle Right Lane	32.76			
		Right Lane	11.28	29.40	54.08	50.34
		Total	100.00	100.00	100.00	100
	Afternoon (12.00-13.00)	Left Lane	9.38	14.46	11.76	7.70
		Middle Left Lane	45.51			
		Middle Lane		53.96	48.35	45.67
		Middle Right Lane	34.62			
		Right Lane	10.49	31.58	39.90	46.63
		Total	100.00	100.00	100.00	100
	Evening (16.30-17.30)	Left Lane	11.66	14.28	7.74	11.01
		Middle Left Lane	47.74			
		Middle Lane		51.69	45.71	44.02
		Middle Right Lane	34.37			
		Right Lane	6.24	34.03	46.55	44.97
		Total	100.00	100.00	100.00	100

Table 4-03. Truck speeds by lane before the restrictions

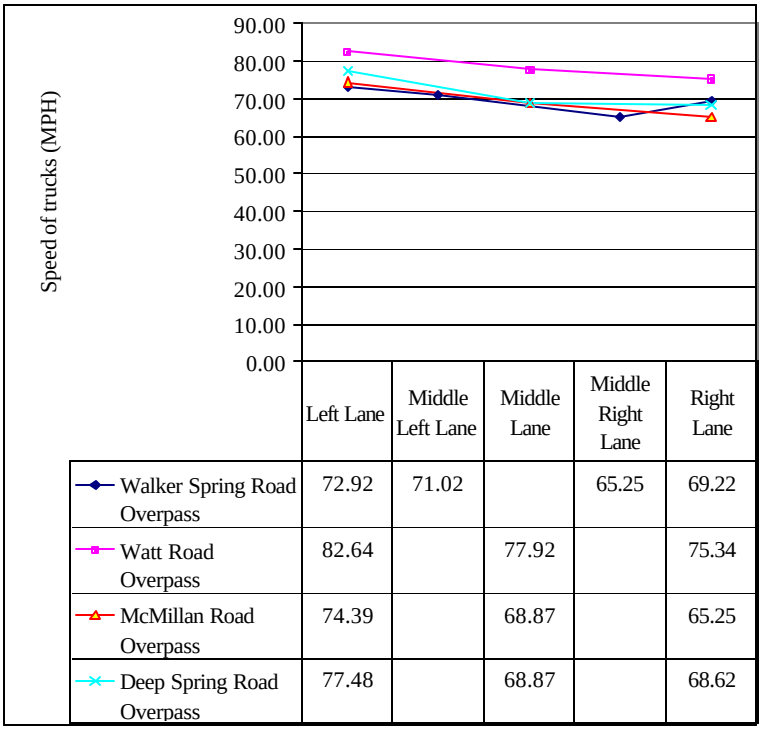
Lane	Time	Total Counted Number of Trucks (å = 50,775)	85th Percentile Speed (MPH)
Right Lane	7.30-8.30	5434	72.92
	12.00-13.00	5737	72.92
	16.30-17.30	6177	72.92
Middle Right Lane	7.30-8.30	1513	68.87
	12.00-13.00	1917	68.87
	16.30-17.30	1634	67.17
Middle Lane	7.30-8.30	4685	75.34
	12.00-13.00	6049	73.31
	16.30-17.30	6071	75.34
Middle Left Lane	7.30-8.30	2079	71.02
	12.00-13.00	2237	75.34
	16.30-17.30	2152	71.02
Left Lane	7.30-8.30	1201	77.48
	12.00-13.00	1986	77.48
	16.30-17.30	1903	77.48

Figure 4-10 through 4-15 shows the variation of 85th percentile speed of trucks in each direction at all four sites. Figure 4-10, 4-11, and 4-12 represent the truck speeds in the morning, midday, and evening time period respectively in the an eastbound direction. Figure 4-13, 4-14, and 4-15 also represent the truck speeds in those three hours, but for the westbound direction. It was observed that the patterns of truck speed variations across the lanes were similar. The speed of trucks was highest in the left lane and as high as more than 80 mph for some locations. The speeds of trucks operating in the middle lanes were higher than those in the right lanes for almost all locations. However, for Walker Spring road site that has four lanes per direction, the speeds of trucks appeared to be lowest in either one or both of middle lanes in the eastbound direction. It is interesting that the overall speed of trucks was quite high at all locations. The variations of truck speeds in each lane of all data collection locations were higher in the eastbound direction, as in figure 4-10 through 4-12, than those in the westbound direction, as in figure 4-13 through 4-15.



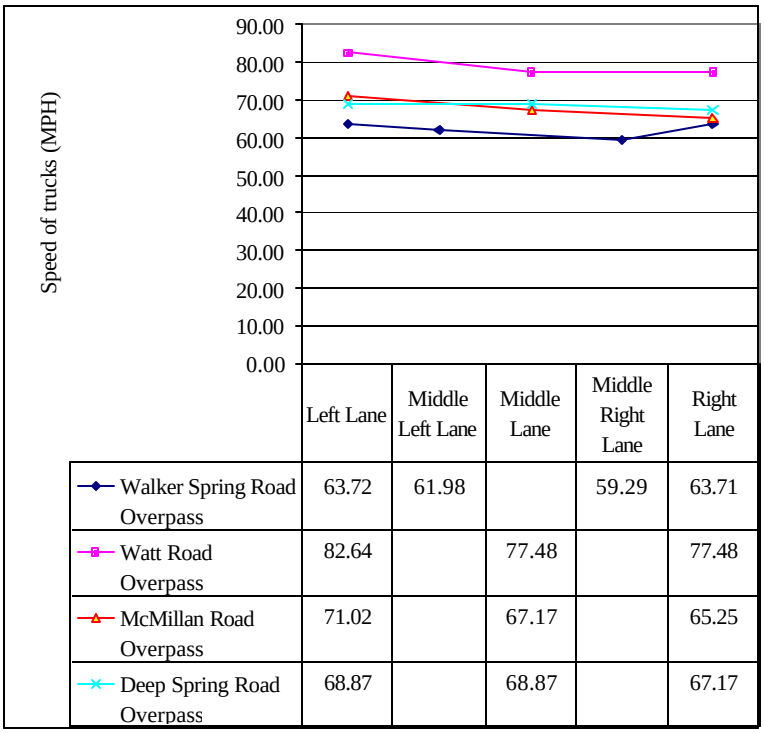
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	66.75	63.72		60.61	63.72
Watt Road Overpass	83.15		77.48		75.34
McMillan Road Overpass	73.31		68.87		65.56
Deep Spring Road Overpass	72.92		70.65		71.02

Figure 4-10. A speed differential of trucks on eastbound in the morning period



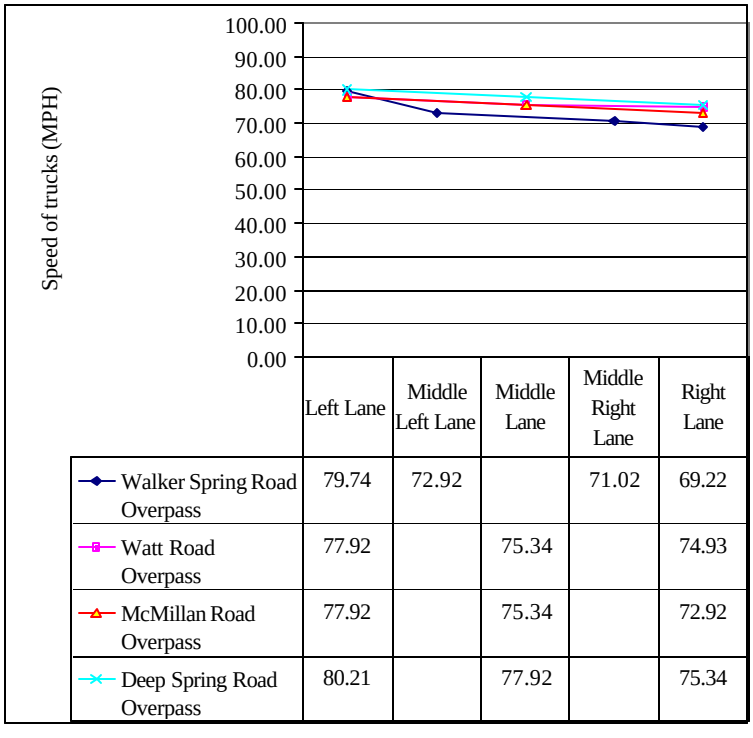
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	72.92	71.02		65.25	69.22
Watt Road Overpass	82.64		77.92		75.34
McMillan Road Overpass	74.39		68.87		65.25
Deep Spring Road Overpass	77.48		68.87		68.62

Figure 4-11. A speed differential of trucks on eastbound in the midday period



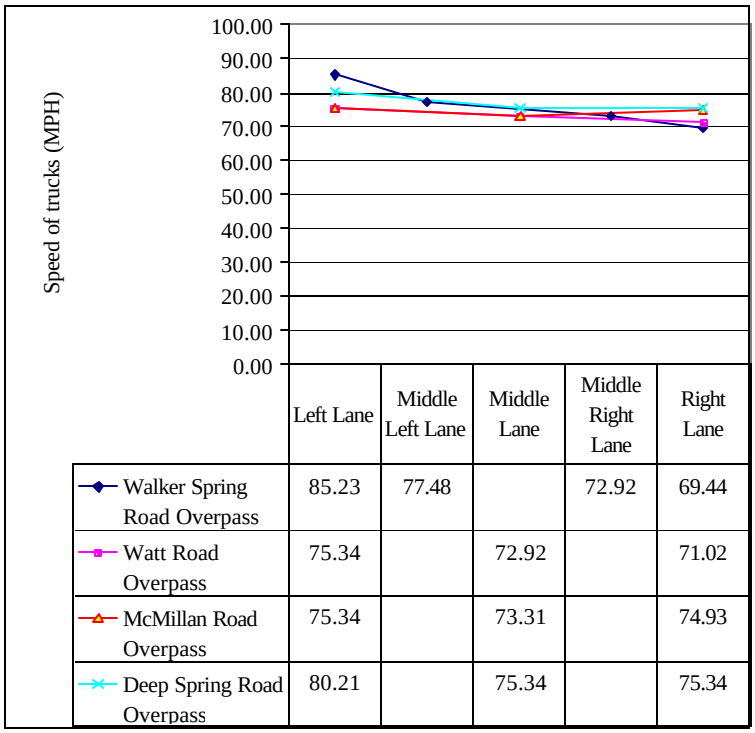
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	63.72	61.98		59.29	63.71
Watt Road Overpass	82.64		77.48		77.48
McMillan Road Overpass	71.02		67.17		65.25
Deep Spring Road Overpass	68.87		68.87		67.17

Figure 4-12. A speed differential of trucks on eastbound in the evening period



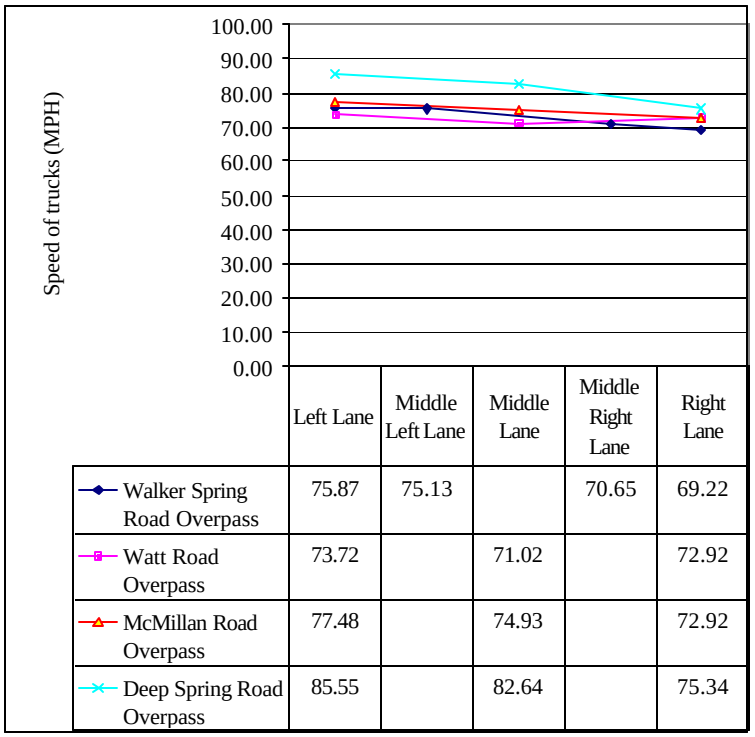
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	79.74	72.92		71.02	69.22
Watt Road Overpass	77.92		75.34		74.93
McMillan Road Overpass	77.92		75.34		72.92
Deep Spring Road Overpass	80.21		77.92		75.34

Figure 4-13. A speed differential of trucks on westbound in the morning period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	85.23	77.48		72.92	69.44
Watt Road Overpass	75.34		72.92		71.02
McMillan Road Overpass	75.34		73.31		74.93
Deep Spring Road Overpass	80.21		75.34		75.34

Figure 4-14. A speed differential of trucks on westbound in the midday period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	75.87	75.13		70.65	69.22
Watt Road Overpass	73.72		71.02		72.92
McMillan Road Overpass	77.48		74.93		72.92
Deep Spring Road Overpass	85.55		82.64		75.34

Figure 4-15. A speed differential of trucks on westbound in the evening period

Chapter 5 Data Collection and Analysis 'After' the Restrictions

The truck lane use restriction was introduced along the stretches of I-40 in Knoxville area on August 13, 2001. The restriction sign "Trucks Use Right 2 Lanes" was installed in both west and east side of the study areas. The first sign at the beginning of a stretch with restriction is equipped with orange flags to make it more noticeable to truck drivers. The parameters of interest for the after data are the same as those for the before data, and so the two sets of data can be compared to assess the difference in the lane distribution of large trucks as well as travel speeds of trucks. The restriction signs at the beginning, within, and end of restriction zones are shown in figure 5-01 to figure 5-03.

Data Collection Locations

The primary study locations for 'after' data collection are the same as those for the 'before' data collection, but the after data collection covered some other locations on the west side of Knoxville where few special equipment, Remote Traffic Microwave Sensors (RTMS) were installed for another study. The 12 units of RTMS are installed along both eastbound and westbound directions on Interstate 40 between Bridgewater Road and Watt Road as described below.

- Eastbound Interstate 40
    - RTMS# 1, Milepost: 369.8, East of Watt Road interchange
    - RTMS# 2, Milepost 370.9, Crest of hill between Watt Road and weigh station
    - RTMS# 3, Milepost 371.6, At weigh station, behind guardrail
    - RTMS# 4, Milepost 372.9, At Campbell Station interchange, at east end of overpass
    - RTMS# 5, Milepost 373.6, At Crest of Hill between Campbell Station and Lovell Road

Figure 5-01. A sign at the beginning of a restriction zone

Figure 5-02. A sign within a restriction zone

Figure 5-03. A sign at the end of a restriction zone

  - RTMS# 6, Milepost 374.2, At Baptist Hospital West Sign (near off ramp to Lovell Road)

- Westbound Interstate 40
  - RTMS# 7, Milepost 377.9, At on ramp from northbound Cedar Bluff to westbound Interstate 40
  - RTMS# 8, Milepost 376.7, At Pellissippi Parkway on final overhead sign bridge (use sign support)
  - RTMS# 9, Milepost 376.0, At Pellissippi Parkway overpass
  - RTMS# 10, Milepost 375.5, At end of onramp from Pellissippi Parkway to westbound Interstate 40
  - RTMS# 11, Milepost 375.1, Near earthen mound
  - RTMS# 12, Milepost 374.9, Between mounds, near bushes

Data Collection

The 'after' data collection utilized both video cameras and RTMS units. The RTMS units are installed and operated since November 2001 for seven days a week. Each unit covers the traffic in all lanes in a specific direction and sends a message to the control station every minute. The RTMS units can separately count the trucks in the traffic stream in each lane.

The RTMS are installed only in the west side of Knoxville to supplement the data from video cameras. The data collection for the east side relied on video cameras only similar to the before period. The video data collection was held between March 17, 2002 and April 8, 2002. The data collection took two weeks for the east side and one week for the west side of Knoxville.

Results from RTMS for Truck Volume

The RTMS units started operating in November 2001 and worked seven days a week. To get the traffic pattern only during weekdays, the data collected from RTMS are

filtered out for Saturdays and Sundays and holiday periods. Further filtering helped in getting the data for only the same time periods as those used for the before data: one hour in the morning peak, one hour in the midday period, and one hour in the evening peak.

It should be pointed out that only a few RTMS units are located close to the 'before' data sites and only those were used for this study. The RTMS number one and two are to be counted for 'after' data in the eastbound direction and the RTMS units number seven and eight are to be counted for the data in the westbound direction. Tables5-01 and Table 5-02 include the percent distribution of trucks detected by RTMS units for each individual lane during interested hours in four months, November 2001 to February 2002, for both eastbound and westbound directions respectively. The percentages represented in both tables are based on only total number of trucks. After the lane restriction, the percentages of trucks in each lane detected by both those RTMS units confirm the same pattern as those from video data collection in 'before' the restriction period. However, the percentages of trucks in each lane were different between 'before' and 'after' the restriction and they will be tested in the later chapter. For the sites having three lanes three lanes per direction, the percentage of trucks was highest in the right lane and was lowest in the left lane. For Walker Spring road site, the only one having four lanes per direction, the percentages of trucks were highest in the two middle lanes and lowest in either left lane or right lane.

The lane use distributions of truck traffic during the selected hours in the morning, midday, and evening in the eastbound direction showed about the same pattern. Near Watt road, some trucks used the left lane when passing the first sensor and much fewer of them used the left lane while passing the second sensor. Since the first RTMS unit was installed near the beginning of the lane restriction on the west side of Knoxville, there might be not full compliance since trucks required some time to change the lanes to comply to the restriction. And the second RTMS was installed very near to the weigh station where trucks are required to use only a right lane to enter and exit the weigh station.

Table 5-01. Truck traffic counted by RTMS units in eastbound direction

RTMS ID	Lane	Morning (7.30 - 8.30)	Midday (12.00 - 13.00)	Evening (16.30 - 17.30)
		%	%	%
RTMS# 1	Left	9.57	7.85	9.67
	Middle	31.31	35.36	33.25
	Right	59.12	56.79	57.08
	Total	100	100	100
RTMS# 2	Left	0.61	1.21	1.40
	Middle	9.49	11.05	10.34
	Right	89.90	87.74	88.26
	Total	100	100	100

Table 5-02. Truck traffic counted by RTMS units in westbound direction

RTMS ID	Lane	Morning (7.30 - 8.30)	Midday (12.00 - 13.00)	Evening (16.30 - 17.30)
		%	%	%
RTMS# 7	Left	5.37	5.03	7.87
	Middle Left	23.77	22.56	26.73
	Middle Right	57.21	57.09	53.91
	Right	13.65	15.32	11.49
	Total	100	100	100
RTMS# 8	Left	4.26	3.81	8.49
	Middle Left	29.61	29.06	31.92
	Middle Right	61.37	60.50	54.21
	Right	4.75	6.63	5.38
	Total	100	100	100

Results from RTMS for Speeds

The RTMS units can give only the average speed of all traffic, both trucks and passenger vehicles combined. It could not give the speed of specific vehicle types in the section. So, the speed data obtained from RTMS units might not be representative of the speed of trucks only.

The results from RTMS may not be mentioned in the comparison of this study according to many limitations of RTMS themselves when comparing with the video collection format. So it is more accurate to use results only from video data collection in the comparison and analysis in this study.

Results from Video Data for Truck Volume

The 'after' data from the video cameras are valid only from seven locations, not eight as before for determining the effectiveness of the lane use restriction. Base on the location of restricted signs, the filming on I-40 eastbound at the Watt road location should be left out because this location is located just before the beginning of the restriction area. Besides, the results from Walker Spring road location in the westbound direction may not be accurate enough because the filming location was located very close to the beginning sign of restriction zone. However, the results from these locations are included in the report to see if there may be some differences between 'before' and 'after' situations due to the restriction. The total number of trucks collected in the 'after' period was about 33,211 of trucks.

Table 5-03 shows the lane distributions of trucks in percentages during 'after' the lane restriction period. Those percentages are based on only total number of trucks counted in each direction as same as that presented for distributions of trucks in the 'before' situation. The patterns of lane distributions of trucks across the lanes for the 'after' situation were similar to those the 'before' situation. For a section having four lanes per each direction, the observation after implementing the truck lane use restriction found that the percentages of trucks were highest in the two middle lanes and lowest in

the left lane. For the sites having three lanes per direction, the percentages of trucks were highest in either middle lane or right lane and lowest in the left lane as same as the patterns of truck lane distributions in the 'before' situation.

Results from Video Data for Truck Speeds

The truck speeds in table 5-04 were represented all truck speeds in both eastbound and westbound directions of all sites for each interested time period. The 85th percentile speed of trucks was interested instead of average speeds of trucks as same as the before data. The observation for the 'after' situation finds that about 85 percent of trucks traveled as high as 70.65 mph to 77.48 mph in all lanes of both directions as shown in table 5-04. Truck speeds in the left lanes and middle lanes were about equal while truck speeds in the right lane were slightly lower than those in the middle and left lanes. Like the observed truck speeds from the 'before' data, the truck speeds from the 'after' data also exceeded even the maximum speed limit.

Figure 5-04 through 5-06 present the speed of trucks in detailed for each lane of eastbound direction during morning, midday, and evening time period respectively. And figure 5-07 through 5-09 present the speed of trucks in each lane of the westbound direction. The results for truck speeds from all sites were presented as shown in each figure. The values shown in all figures refer to the 85th percentile speed of trucks. Each figure presents the truck speeds at all locations simultaneously. It is observed that the truck speeds measured from all location are more likely to have the same patterns across the lanes from a left lane to a right lane. Most of the highest speeds of trucks were in the left lane and most of the lowest truck speeds were in the right lane. Like the observation from the 'before' data, most of the truck speeds in each lane from the 'after' observation were very high at all locations.

Table 5-03. Lane distribution of trucks after the restrictions

Direction	Time	Lane	Percentage of Truck Distribution (%)			
			Walker Spring Road Site	Watt Road Site	McMillan Road Site	Deep Springs Road Site
Eastbound	Morning (7.30-8.30)	Left Lane	3.10	2.00	2.21	1.68
		Middle Left Lane	39.79			
		Middle Lane		39.06	46.18	41.65
		Middle Right Lane	48.77			
		Right Lane	8.34	58.94	51.61	56.67
		Total	100.00	100.00	100.00	100
	Afternoon (12.00-13.00)	Left Lane	1.20	4.06	2.39	1.40
		Middle Left Lane	39.71			
		Middle Lane		46.79	50.00	44.62
		Middle Right Lane	50.12			
		Right Lane	8.97	49.15	47.61	53.98
		Total	100.00	100.00	100.00	100
	Evening (16.30-17.30)	Left Lane	3.91	3.55	2.04	1.45
		Middle Left Lane	44.17			
		Middle Lane		51.47	50.71	45.03
		Middle Right Lane	43.01			
		Right Lane	8.91	44.98	47.24	53.52
		Total	100.00	100.00	100.00	100
Westbound	Morning (7.30-8.30)	Left Lane	3.03	6.72	1.27	0.99
		Middle Left Lane	36.89			
		Middle Lane		58.45	41.39	41.52
		Middle Right Lane	47.33			
		Right Lane	12.74	34.84	57.34	57.48
		Total	100.00	100.00	100.00	100
	Afternoon (12.00-13.00)	Left Lane	0.00	5.36	1.20	0.93
		Middle Left Lane	39.95			
		Middle Lane		53.41	44.08	43.61
		Middle Right Lane	46.09			
		Right Lane	13.96	41.23	54.72	55.46
		Total	100.00	100.00	100.00	100
	Evening (16.30-17.30)	Left Lane	6.76	9.09	1.02	1.05
		Middle Left Lane	41.90			
		Middle Lane		53.37	43.07	42.30
		Middle Right Lane	43.81			
		Right Lane	7.52	37.54	55.91	56.65
		Total	100.00	100.00	100.00	100

Table 5-04. Truck speed by lane after the restrictions

Lane	Time	Total Counted Number of Trucks (å = 33,211)	85th Percentile Speed (MPH)
Right Lane	7.30-8.30	4587	74.93
	12.00-1.00	5147	74.93
	4.30-5.30	5252	72.92
Middle Right Lane	7.30-8.30	845	72.92
	12.00-1.00	802	75.34
	4.30-5.30	1053	70.65
Middle Lane	7.30-8.30	3607	77.48
	12.00-1.00	4349	77.48
	4.30-5.30	4412	75.34
Middle Left Lane	7.30-8.30	676	72.92
	12.00-1.00	663	77.48
	4.30-5.30	1049	71.02
Left Lane	7.30-8.30	233	77.48
	12.00-1.00	240	77.48
	4.30-5.30	296	75.34

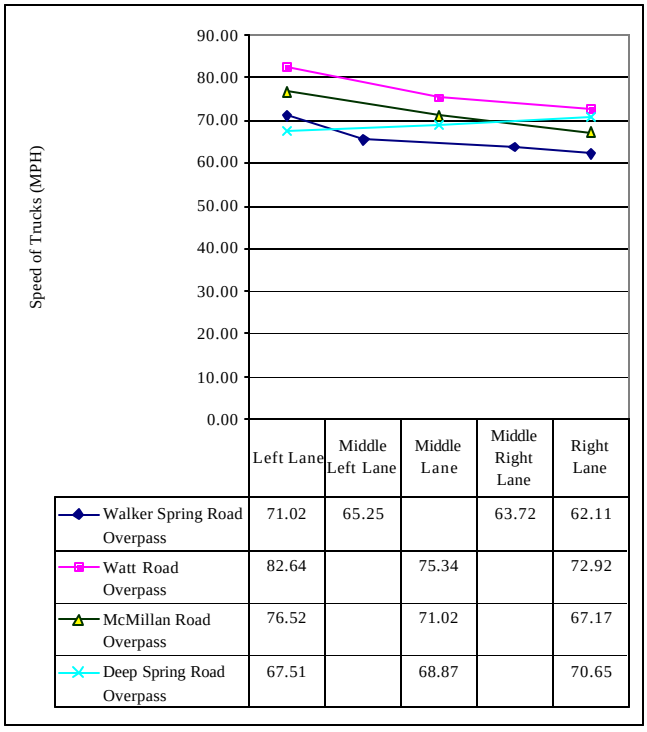
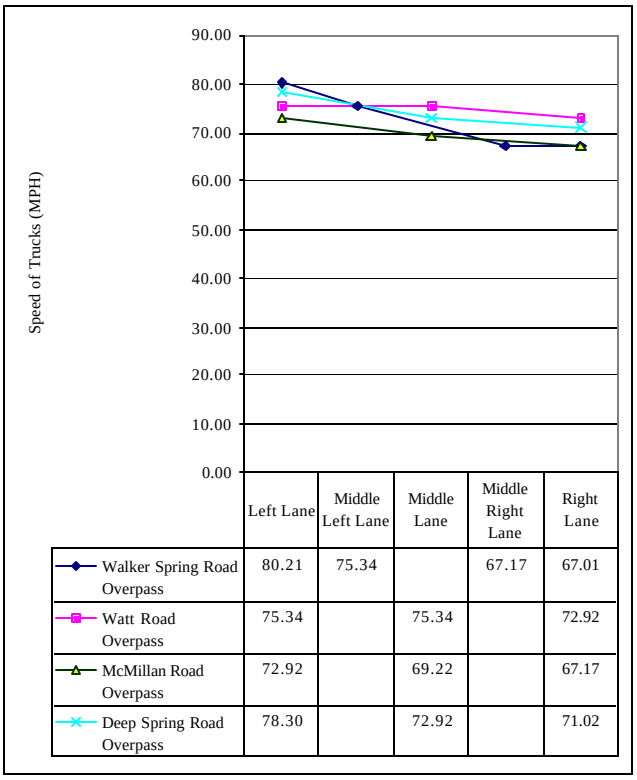
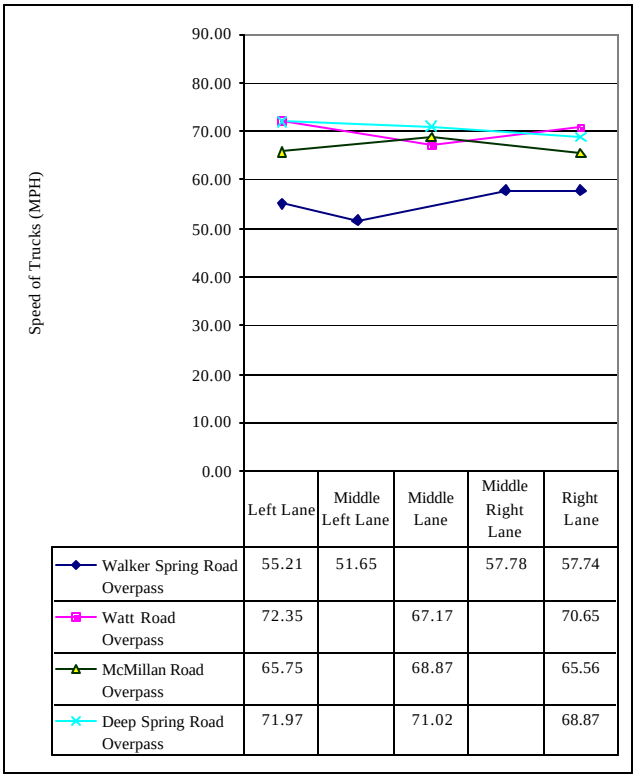


Figure 5-04. Speed differential of trucks in eastbound morning period



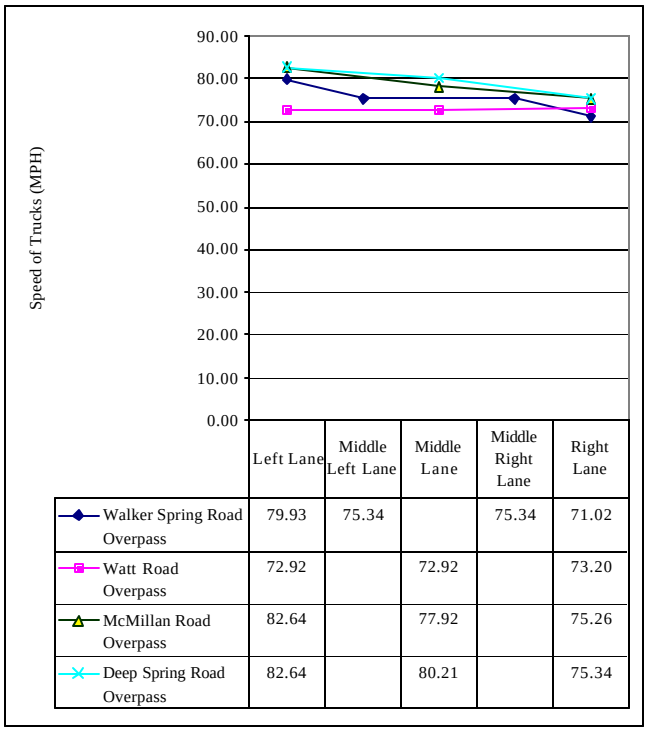
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	80.21	75.34		67.17	67.01
Watt Road Overpass	75.34		75.34		72.92
McMillan Road Overpass	72.92		69.22		67.17
Deep Spring Road Overpass	78.30		72.92		71.02

Figure 5-05. Speed differential of trucks in eastbound midday period



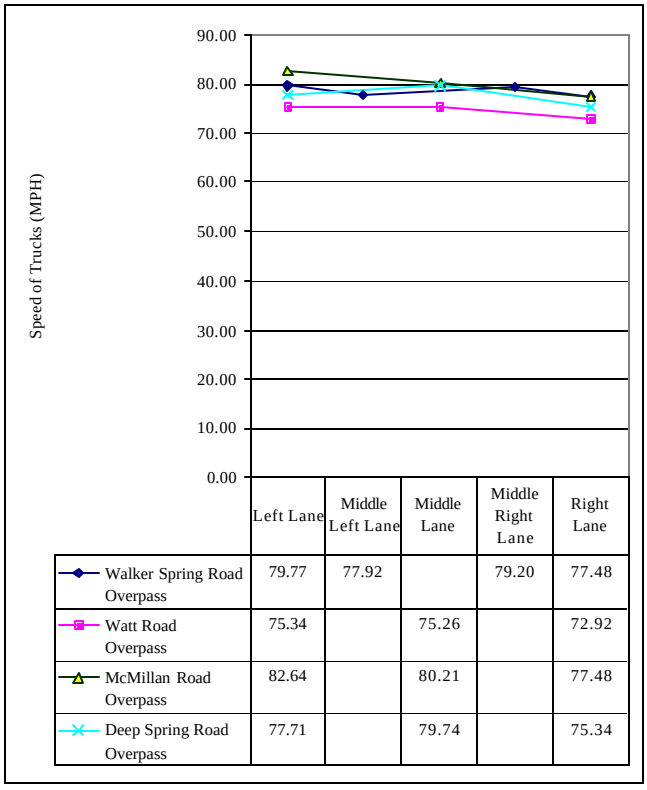
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	55.21	51.65		57.78	57.74
Watt Road Overpass	72.35		67.17		70.65
McMillan Road Overpass	65.75		68.87		65.56
Deep Spring Road Overpass	71.97		71.02		68.87

Figure 5-06. Speed differential of trucks in eastbound evening period



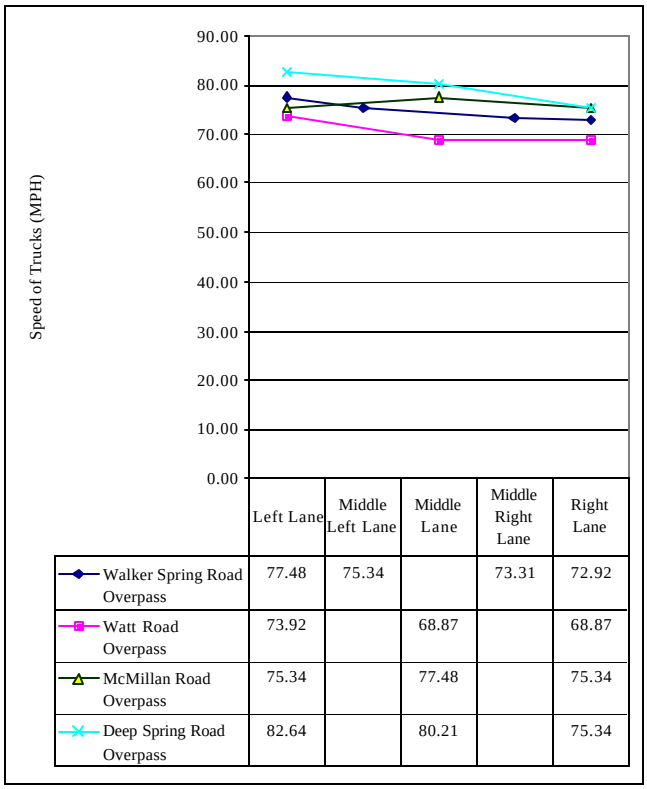
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	79.93	75.34		75.34	71.02
Watt Road Overpass	72.92		72.92		73.20
McMillan Road Overpass	82.64		77.92		75.26
Deep Spring Road Overpass	82.64		80.21		75.34

Figure 5-07. Speed differential of trucks in westbound morning period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	79.77	77.92		79.20	77.48
Watt Road Overpass	75.34		75.26		72.92
McMillan Road Overpass	82.64		80.21		77.48
Deep Spring Road Overpass	77.71		79.74		75.34

Figure 5-08. Speed differential of trucks in westbound afternoon period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass	77.48	75.34		73.31	72.92
Watt Road Overpass	73.92		68.87		68.87
McMillan Road Overpass	75.34		77.48		75.34
Deep Spring Road Overpass	82.64		80.21		75.34

Figure 5-09. Speed differential of trucks in westbound evening period

Chapter 6 Comparison of Results for the Lane Distribution of Trucks

The major information of interest in evaluating the effectiveness of truck lane restrictions is the percentage changes of the lane distribution of large trucks in the study area. The 'before' and 'after' percentages of lane distribution of large trucks are to be compared. And if the comparison shows significantly increased percentages of trucks in the right lanes, the lane restrictions may cause more conflicts between truck traffic and merging vehicles at on-ramps. The analysis of results for truck speeds will be mentioned in Chapter 7.

The comparison of 'before' and 'after' results of truck lane distribution is divided into two groups, I-40 stretch on westside and eastside of Knoxville. The westside, considered an urban Interstate, has two locations: Watt road overpass and Walker Spring road overpass. The eastside, considered a rural Interstate, has two locations: McMillan road overpass and Deep Springs road overpass. The comparison is mainly based on the video data for the 'before' and 'after' situations. The results from RTMS are treated as a supplement to the video data.

Method for a Statistical Test for the Lane Distribution of Trucks

The difference in the percentages of trucks in each lane in 'before' and 'after' periods was tested statistically by inferences concerning a difference between population proportions, as in Jay L. Devore (6), with a null hypothesis (H_0) $p_1 = p_2$, where p_1 = the percentage of trucks 'before' the restriction and p_2 = the percentage of trucks 'after' the restriction. The variables X and Y represent the number of trucks in each lane in 'before' and 'after' respectively. The variables m and n indicate the total number of trucks in each direction of each location in 'before' and 'after' respectively. The difference in population proportions ($p_1 - p_2$) is the corresponding difference in sample proportions

$\frac{X}{m} - \frac{Y}{n}$. With $\hat{p}_1 = \frac{X}{m}$ and $\hat{p}_2 = \frac{Y}{n}$, the estimator of p_1 - p_2 can be expressed as $\hat{p}_1 - \hat{p}_2$. When the null hypothesis that there is no difference between two proportions is to be tested, the test statistic will be z.

Test statistic value: $z = \frac{\hat{p}_1 - \hat{p}_2}{\sqrt{\hat{p}\hat{q}\left(\frac{1}{m} + \frac{1}{n}\right)}}$

Where $\hat{p} = \frac{X + Y}{m + n}$, $\hat{q} = 1 - \hat{p}$, $\sqrt{\hat{p}\hat{q}\left(\frac{1}{m} + \frac{1}{n}\right)}$ = standard error

Null hypothesis: $H_0: p_1 = p_2$

Alternative hypothesis: $H_a: p_1 \neq p_2$

Rejection region for approximation level α (=0.05) test: either $z \geq Z_{\alpha/2}$ or $z \leq -Z_{\alpha/2}$

When $\alpha = 0.05$, $Z_{\alpha/2} = 1.96$ and $-Z_{\alpha/2} = -1.96$

It is noted that the statistical test for truck lane distributions was done by using calculation steps according to the formulas and then comparing results with z value.

Comparison of the Lane Distribution of Trucks on Eastside of Knoxville

Although there is a truck stop on Deep Springs road and on Strawberry Plains Pike where is about one mile away from McMillan road overpass, those truck stops seem not to influence the lane distribution of trucks in the eastside locations.

The comparison shows that the number of trucks decreased in the left lane and increased in the right lane in both directions and at both locations in the eastside of Knoxville.

Figure 6-01 through figure 6-06, table 6-01, and table 6-02 show the comparison among the lane distribution of large trucks during ‘before’ and ‘after’ the lane restrictions and the statistical test results for both directions at Deep Springs road overpass. The

percentage of trucks in the left lane decreased for both directions and all time periods. The percentage of trucks in the middle lane also decreased for both directions and all time periods except for the midday time on eastbound direction that it slightly increased by 0.5%. The percentage of trucks in the right lane increased for both directions in all time periods. The percentage of trucks in the left lane decreased by 72.76% to 87.16% for eastbound direction and decreased by 86.12% to 90.46% for westbound direction. The percentage of trucks in the middle lane decreased by 4.36% in the evening time period and decreased about 6.77% in the morning time period for eastbound direction. The percentage of trucks in the middle lane decreased by 2.37% to 4.51% for westbound direction. The percentage of trucks in the right lane increased by 15.29% to 28.50% for eastbound direction and increased by 14.18% to 25.97% for westbound direction. The statistical test shows that the percentage of trucks in the left lane was significantly decreased for both directions during all time periods except for morning time in the eastbound directions ($\alpha = 0.05$). And there were no significant changes in the middle lane and right lane according to the lane use restriction at this location. The detailed results of statistical tests are shown in table 6-01 and table 6-02 for the eastbound and the westbound direction respectively.

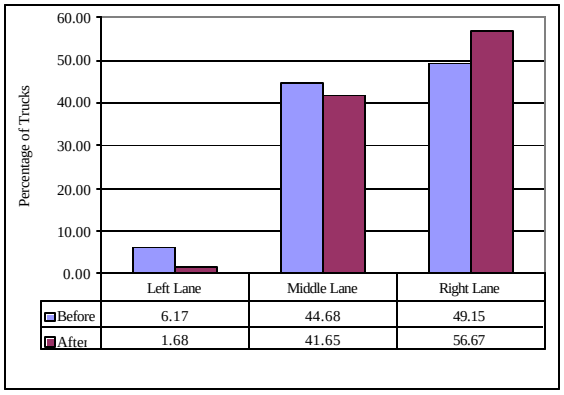


Figure 6-01. A comparison of truck lane distribution in eastbound at Deep Springs road overpass (morning period)

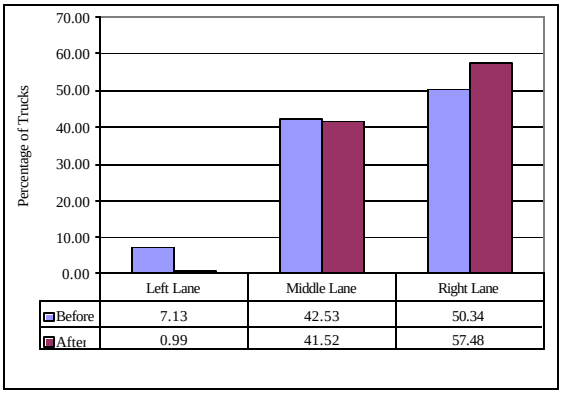


Figure 6-02. A comparison of truck lane distribution in westbound at Deep Springs road overpass (morning period)

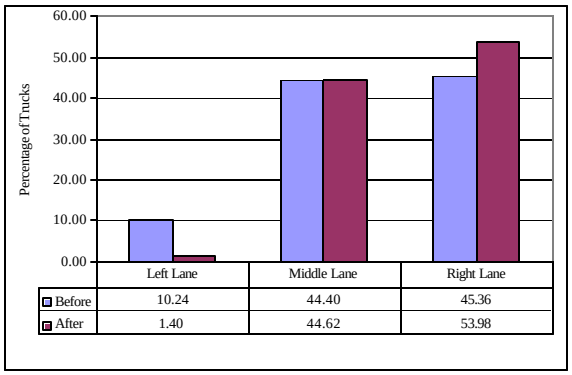


Figure 6-03. A comparison of truck lane distribution in eastbound at Deep Springs road overpass (mid day period)

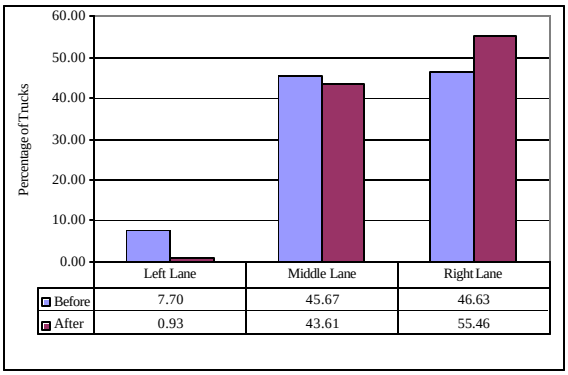


Figure 6-04. A comparison of truck lane distribution in westbound at Deep Springs road overpass (mid day period)

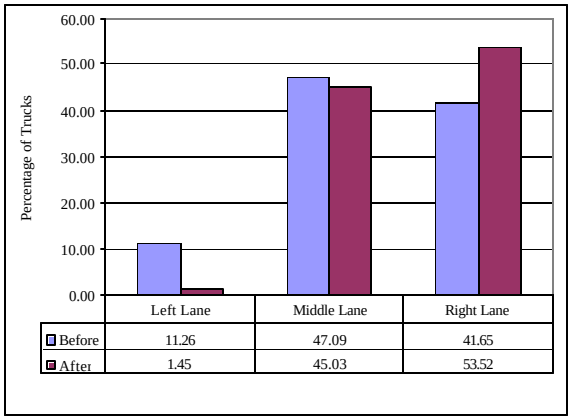


Figure 6-05. A comparison of truck lane distribution in eastbound at Deep Springs road overpass (evening period)

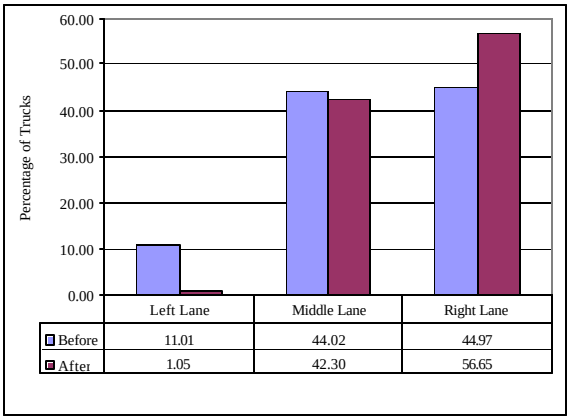


Figure 6-06. A comparison of truck lane distribution in westbound at Deep Springs road overpass (evening period)

Table 6-01. A statistical test for the difference of lane distribution between 'before' and 'after' the restrictions in eastbound at Deep Springs road location

Direction	Time	Lane	Deep Springs Road Overpass			
			Before (%)	After (%)	Percent change (%)	Significantly change
Eastbound	Morning (7.30-8.30)	Left Lane	6.17	1.68	-72.76	Not Significant
		Middle Lane	44.68	41.65	-6.77	Not Significant
		Right Lane	49.15	56.67	+15.29	Not Significant
	Afternoon (12.00-13.00)	Left Lane	10.24	1.40	-86.33	Significant
		Middle Lane	44.40	44.62	+0.50	Not Significant
		Right Lane	45.36	53.98	+19.00	Not Significant
	Evening (16.30-17.30)	Left Lane	11.26	1.45	-87.16	Significant
		Middle Lane	47.09	45.03	-4.36	Not Significant
		Right Lane	41.65	53.52	+28.50	Not Significant

Table 6-02. A statistical test for the difference of lane distribution between 'before' and 'after' the restrictions in westbound at Deep Springs road location

Direction	Time	Lane	Deep Springs Road Overpass			
			Before (%)	After (%)	Percent change (%)	Significantly change
Westbound	Morning (7.30-8.30)	Left Lane	7.13	0.99	-86.12	Significant
		Middle Lane	42.53	41.52	-2.37	Not Significant
		Right Lane	50.34	57.48	+14.18	Not Significant
	Afternoon (12.00-13.00)	Left Lane	7.70	0.93	-87.92	Significant
		Middle Lane	45.67	43.61	-4.51	Not Significant
		Right Lane	46.63	55.46	+18.94	Not Significant
	Evening (16.30-17.30)	Left Lane	11.01	1.05	-90.46	Significant
		Middle Lane	44.02	42.30	-3.91	Not Significant
		Right Lane	44.97	56.65	+25.97	Not Significant

Figure 6-07 through figure 6-12, table 6-03, and table 6-04 show the comparison among the lane distributions of large trucks 'before' and 'after' the lane restrictions and the statistical test results for both directions at McMillan road overpass. Unlike the others, this location is not an interchange having entrance and exit ramps thus there was no merging and diverging traffic influence at this location. The percentage of trucks in the left lane decreased for both directions and all time periods. The percentage of trucks in the middle lane increased in both direction for all time periods except for midday time period and evening time period on westbound direction. And the percentage of trucks in the right lane increased in both directions for all time periods. The percentage of trucks in the left lane decreased by 75.55% to 88.63% for eastbound direction and decreased by 77.84% to 89.80% for westbound direction. The percentage of trucks in the middle lane increased by 3.99% to 16.01% for eastbound direction and increased only the morning time period by 2.99% for westbound direction. And the percentage of trucks in the right lane increased by 10.85% to 32.73% for eastbound direction and increased by 6.03% to 37.14% for westbound direction. The lane restrictions caused a significant decreased of the percentage of trucks in the left lane in both directions for all time periods except for morning time period on westbound direction (α =0.05). The lane use restriction caused a significant increasing of number of trucks in the right lane only one observed time during midday period in westbound direction (α =0.05).

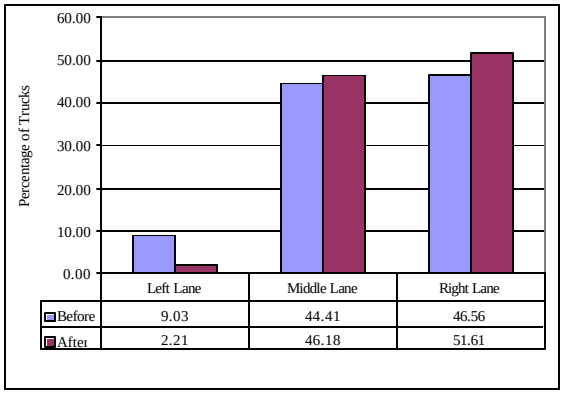


Figure 6-07. A comparison of truck lane distribution in eastbound at McMillan road overpass (morning period)

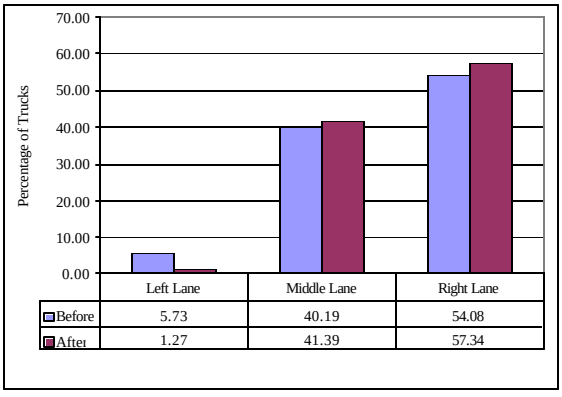


Figure 6-08. A comparison of truck lane distribution in westbound at McMillan road overpass (morning period)

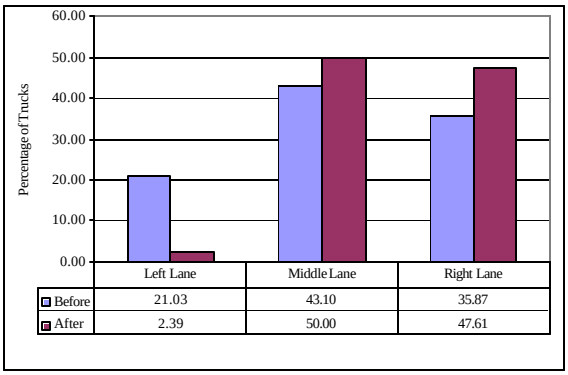


Figure 6-09. A comparison of truck lane distribution in eastbound at McMillan road overpass (mid day period)

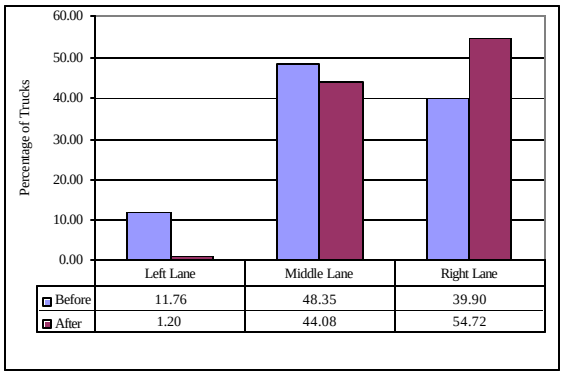


Figure 6-10. A comparison of truck lane distribution in westbound at McMillan road overpass (mid day period)

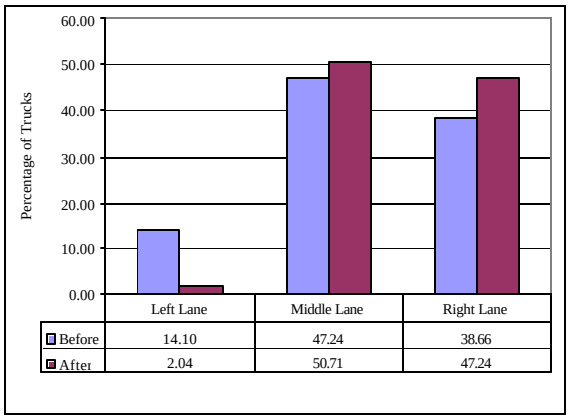


Figure 6-11. A comparison of truck lane distribution in eastbound at McMillan road overpass (evening period)

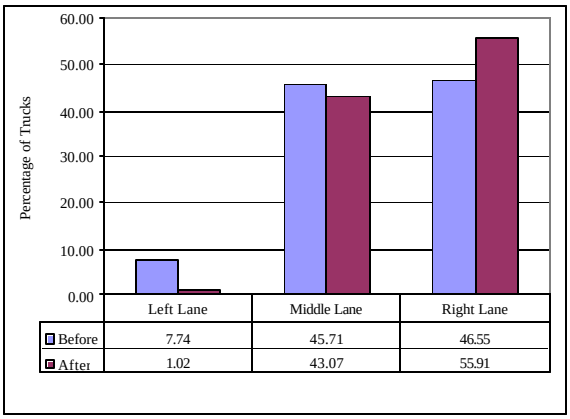


Figure 6-12. A comparison of truck lane distribution in westbound at McMillan road overpass (evening period)

Table 6-03. A statistical test for the difference of lane distribution between 'before' and 'after' the restrictions in eastbound at McMillan road location

Direction	Time	Lane	McMillan Road Overpass			
			Before (%)	After (%)	Percent change (%)	Significantly change
Eastbound	Morning (7.30-8.30)	Left Lane	9.03	2.21	-75.55	Significant
		Middle Lane	44.41	46.18	+3.99	Not Significant
		Right Lane	46.56	51.61	+10.85	Not Significant
	Afternoon (12.00-13.00)	Left Lane	21.03	2.39	-88.63	Significant
		Middle Lane	43.10	50.00	+16.01	Not Significant
		Right Lane	35.87	47.61	+32.73	Not Significant
	Evening (16.30-17.30)	Left Lane	14.10	2.04	-85.53	Significant
		Middle Lane	47.24	50.71	+7.35	Not Significant
		Right Lane	38.66	47.24	+22.21	Not Significant

Table 6-04. A statistical test for the difference of lane distribution between 'before' and 'after' the restrictions in westbound at McMillan road location

Direction	Time	Lane	McMillan Road Overpass			
			Before (%)	After (%)	Percent change (%)	Significantly change
Westbound	Morning (7.30-8.30)	Left Lane	5.73	1.27	-77.84	Not Significant
		Middle Lane	40.19	41.39	+2.99	Not Significant
		Right Lane	54.08	57.34	+6.03	Not Significant
	Afternoon (12.00-13.00)	Left Lane	11.76	1.20	-89.80	Significant
		Middle Lane	48.35	44.08	-8.83	Not Significant
		Right Lane	39.90	54.72	+37.14	Significant
	Evening (16.30-17.30)	Left Lane	7.74	1.02	-86.82	Significant
		Middle Lane	45.71	43.07	-5.78	Not Significant
		Right Lane	46.55	55.91	+20.11	Not Significant

Comparison of the Lane Distribution of Trucks on Westside of Knoxville

It should be acknowledged that the lane distributions and speeds of trucks along the West side between the interchanges with Watt Road and Campbell Station Road may be effected by factors in addition to the lane use restriction signs. There is a truck weigh station in both eastbound and westbound directions located a few miles east of the Watt Road interchange. These stations are located between Campbell Station Road and Watt Road interchanges. Further, there is sign located in advance of these weight stations urging trucks to use the right lane only. Usually, most of the truck drivers know in advance where weigh stations are located and are aware of the possibility that they will have to enter these stations where weigh-in-motion (WIM) scales are set up. Therefore, many large trucks approaching these weigh stations are likely to move to the right lanes well in advance of the exact locations of the stations. Trucks exiting a weigh station also are expected to stay in the right lane until they move far enough for changing lane. Another factors affecting lane distribution involves two major truck stops located near the Watt Road interchange, which are used by a large number of trucks. Both the exiting and entering trucks are expected to stay on the right lane in the vicinity of the Watt Road interchange.

The comparison of results shows that after the lane use restriction signs were installed, the number of trucks at Watt road location decreased in the left lane and right lane and increased in the middle lane on eastbound direction while it decreased in the left lane and increased in the middle lane and right lane on westbound direction. At the Walker Spring location, the number of trucks decreased in the left two lanes and increased in the right two lanes in both directions.

Figure 6-13 through figure 6-18, table 6-05, and table 6-06 show the comparison of the lane distributions of large trucks during ‘before’ and ‘after’ the lane restrictions and the statistical test results for both directions at Walker Spring road overpass. The percentage of trucks decreased in the left two lanes and increased in the right two lanes on this section as seen in all figures. The percentage of trucks decreased about 50.48% to 88.17% in the left lane for eastbound direction, and decreased about 42.02% to 100% in

the left lane for westbound direction. The percentage of truck decreased about 3.11% to 13.94% in the middle left lane for eastbound direction and decreased about 12.22% to 21.11% in the middle left lane for westbound direction. The percentage of trucks increased by 16.12% to 33.40% in the middle right lane for eastbound direction and increased by 27.47% to 44.47% in the middle right lane for westbound direction. The percentage of trucks increased by 19.83% to 49.75% in the right lane for eastbound direction and increased about 12.94% to 33.08% in the right lane for westbound direction. Statistical tests confirm that the percentage of truck in the left lane on eastbound direction decreased significantly during midday time and evening time period while that on westbound direction only decreased significantly during midday time (α = 0.05) as shown in table 6-05 and table 6-06. Further, this location, the percentage of trucks increased significantly in the middle right lane on westbound direction during morning time period (α = 0.05) as shown in table 6-06. And there were no significant changes for the number of trucks in the right lane of both directions. It appears that the lane use restriction signs have been effective only in the eastbound direction at this location. It is noted that the 'before' and 'after' legends in all following figures represent the video data and 'RTMS' legends represent counted data from RTMS.

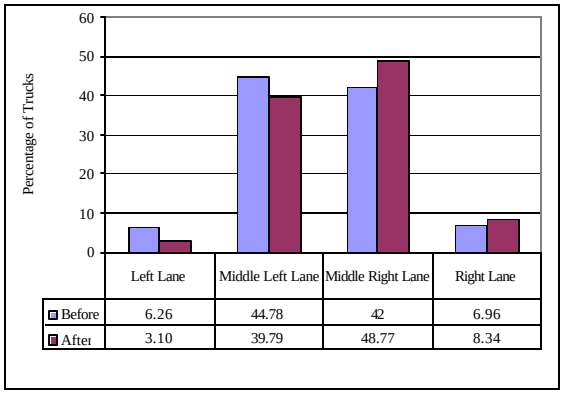


Figure 6-13. A comparison of truck lane distribution in eastbound at Walker Spring road overpass (morning period)

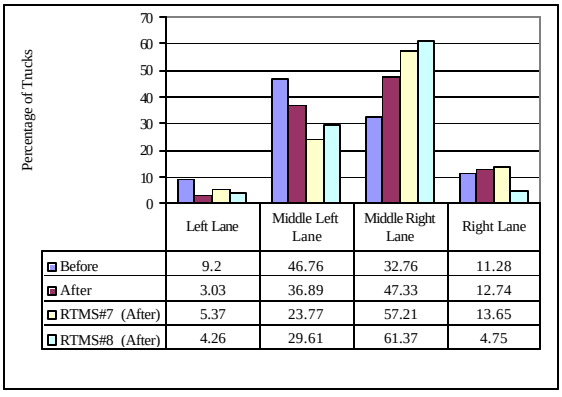


Figure 6-14. A comparison of truck lane distribution in westbound at Walker Spring road overpass (morning period)

Figure 6-15. A comparison of truck lane distribution in eastbound at Walker Spring road overpass (mid day period)

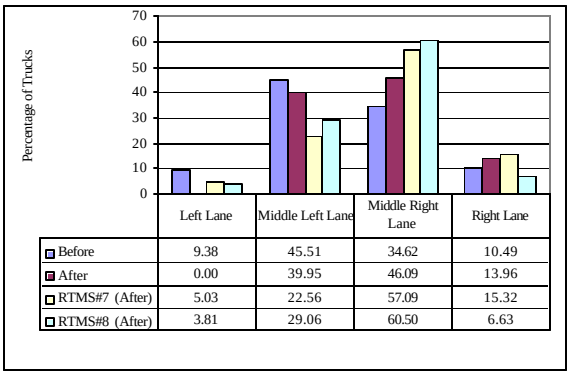


Figure 6-16. A comparison of truck lane distribution in westbound at Walker Spring road overpass (mid day period)

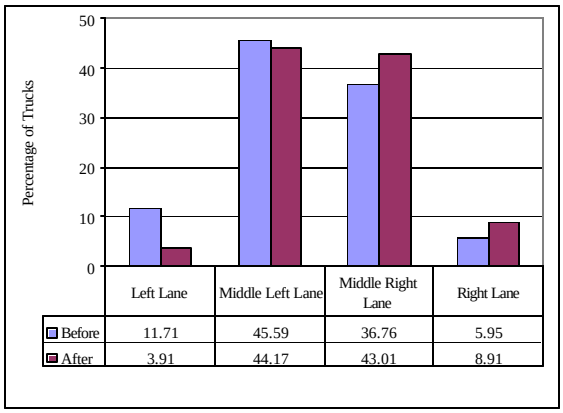


Figure 6-17. A comparison of truck lane distribution in eastbound at Walker Spring road overpass (evening period)

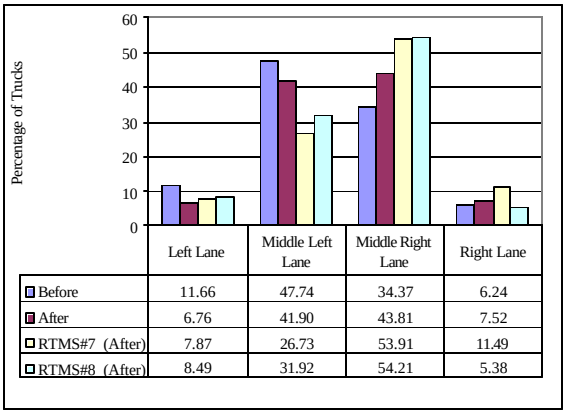


Figure 6-18. A comparison of truck lane distribution in westbound at Walker Spring road overpass (evening period)

Table 6-05. Statistical test for the difference of lane distribution between 'before' and 'after' the restrictions in eastbound at Walker Spring road location

Direction	Time	Lane	Walker Spring Road Overpass			
			Before (%)	After (%)	Percent change (%)	Significantly change
Eastbound	Morning (7.30-8.30)	Left Lane	6.26	3.10	-50.48	Not Significant
		Middle Left Lane	44.78	39.79	-11.14	Not Significant
		Middle Right Lane	42	48.77	+16.12	Not Significant
		Right Lane	6.96	8.34	+19.83	Not Significant
	Afternoon (12.00-13.00)	Left Lane	10.14	1.20	-88.17	Significant
		Middle Left Lane	46.14	39.71	-13.94	Not Significant
		Middle Right Lane	37.57	50.12	+33.40	Not Significant
		Right Lane	6.15	8.97	+45.85	Not Significant
	Evening (16.30-17.30)	Left Lane	11.71	3.91	-66.61	Significant
		Middle Left Lane	45.59	44.17	-3.11	Not Significant
		Middle Right Lane	36.76	43.01	+17.00	Not Significant
		Right Lane	5.95	8.91	+49.75	Not Significant

Table 6-06. Statistical test for the difference of lane distribution between 'before' and 'after' the restrictions in westbound at Walker Spring road location

Direction	Time	Lane	Walker Spring Road Overpass			
			Before (%)	After (%)	Percent change (%)	Significantly change
Westbound	Morning (7.30-8.30)	Left Lane	9.2	3.03	-67.07	Not Significant
		Middle Left Lane	46.76	36.89	-21.11	Not Significant
		Middle Right Lane	32.76	47.33	+44.47	Significant
		Right Lane	11.28	12.74	+12.94	Not Significant
	Afternoon (12.00-13.00)	Left Lane	9.38	0.00	-100.00	Significant
		Middle Left Lane	45.51	39.95	-12.22	Not Significant
		Middle Right Lane	34.62	46.09	+33.13	Not Significant
		Right Lane	10.49	13.96	+33.08	Not Significant
	Evening (16.30-17.30)	Left Lane	11.66	6.76	-42.02	Not Significant
		Middle Left Lane	47.74	41.90	-12.23	Not Significant
		Middle Right Lane	34.37	43.81	+27.47	Not Significant
		Right Lane	6.24	7.52	+20.51	Not Significant

Figure 6-19 through figure 6-24, table 6-07, and table 6-08 show the comparison of the lane distributions of large trucks 'before' and 'after' the lane restrictions and the statistical test results for both directions at the Watt road overpass. The percentage of trucks in the left lane decreased in all time period of the eastbound direction. According to the statistical test for the lane distributions, there was no significant change in the percentage of large trucks in the left lane in eastbound direction of Watt road location ($\alpha = 0.05$). And there were no significant changes for the percentages of trucks in all other lanes in the same direction at Watt road location ($\alpha = 0.05$). In westbound direction, the percentage of trucks in the left lane decreased about 36.34% to 51.52% during the observed time periods. However, the statistical test shows that there was only one significant decrease in percentage of trucks in the left lane during midday time period in the westbound direction ($\alpha = 0.05$). Results for all other lanes show no significant changes of percentage of trucks at any time ($\alpha = 0.05$). It is noted that the 'before' and 'after' legends in all following figures represent the video data and 'RTMS' legends represent data from RTMS.

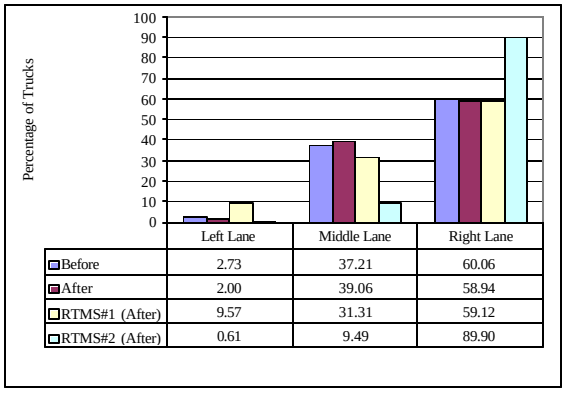


Figure 6-19. A comparison of truck lane distribution in eastbound at Watt road overpass (morning period)

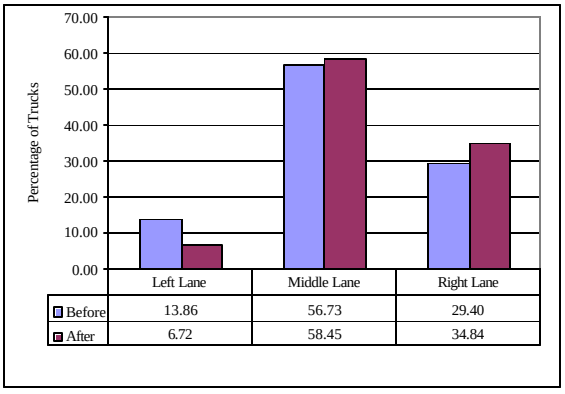


Figure 6-20. A comparison of truck lane distribution in westbound at Watt road overpass (morning period)

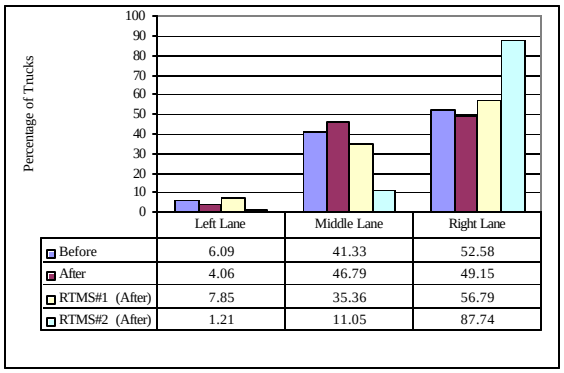


Figure 6-21. A comparison of truck lane distribution in eastbound at Watt road overpass (mid day period)

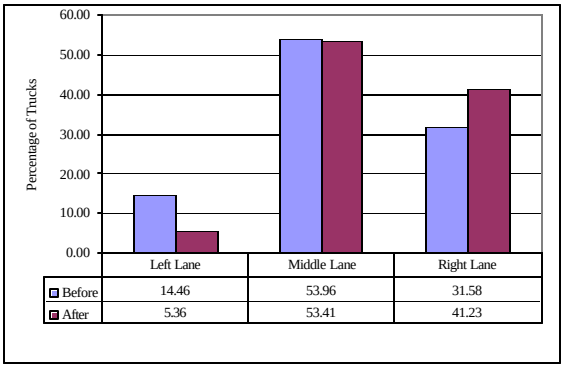


Figure 6-22. A comparison of truck lane distribution in westbound at Watt road overpass (mid day period)

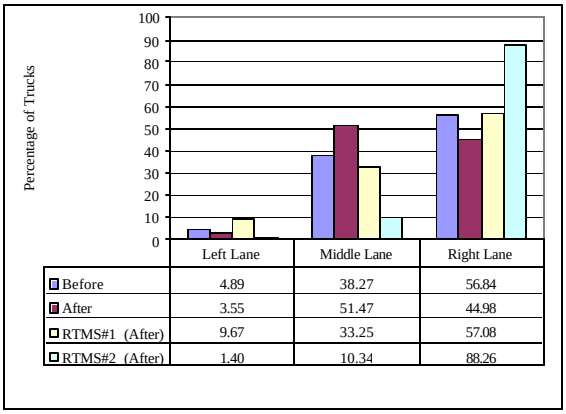


Figure 6-23. A comparison of truck lane distribution in eastbound at Watt road overpass (evening period)

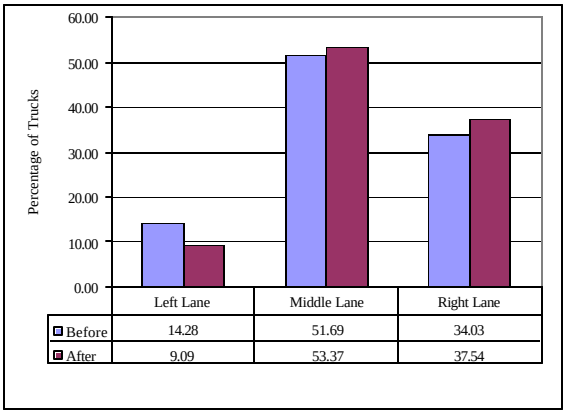


Figure 6-24. A comparison of truck lane distribution in westbound at Watt road overpass (evening period)

Table 6-07. Statistical test for the difference of lane distribution between 'before' and 'after' the restrictions in eastbound at Watt road location

Direction	Time	Lane	Watt Road Overpass			
			Before (%)	After (%)	Percent change (%)	Significantly change
Eastbound	Morning (7.30-8.30)	Left Lane	2.73	2.00	-26.74	Not Significant
		Middle Lane	37.21	39.06	+4.97	Not Significant
		Right Lane	60.06	58.94	-1.86	Not Significant
	Afternoon (12.00-13.00)	Left Lane	6.09	4.06	-33.33	Not Significant
		Middle Lane	41.33	46.79	+13.21	Not Significant
		Right Lane	52.58	49.15	-6.52	Not Significant
	Evening (16.30-17.30)	Left Lane	4.89	3.55	-27.40	Not Significant
		Middle Lane	38.27	51.47	+34.49	Not Significant
		Right Lane	56.84	44.98	-20.87	Not Significant

Table 6-08. Statistical test for the difference of lane distribution between 'before' and 'after' the restrictions in westbound at Watt road location

Direction	Time	Lane	Watt Road Overpass			
			Before (%)	After (%)	Percent change (%)	Significantly change
Westbound	Morning (7.30-8.30)	Left Lane	13.86	6.72	-51.52	Not Significant
		Middle Lane	56.73	58.45	+3.03	Not Significant
		Right Lane	29.4	34.84	+18.50	Not Significant
	Afternoon (12.00-13.00)	Left Lane	14.46	5.36	-62.93	Significant
		Middle Lane	53.96	53.41	-1.02	Not Significant
		Right Lane	31.58	41.23	+30.56	Not Significant
	Evening (16.30-17.30)	Left Lane	14.28	9.09	-36.34	Not Significant
		Middle Lane	51.69	53.37	+3.25	Not Significant
		Right Lane	34.03	37.54	+10.31	Not Significant

Chapter 7 Comparison of Results for Truck Speeds

A comparison of truck speeds is also used in evaluating the impact of lane use restriction. Besides the evaluation based on the lane distribution of large trucks, a comparison of truck speeds can also determine if lane use restrictions cause changes in travel characteristics. It is observed from both the 'before' and the 'after' data that most of the trucks in each lane traveled at very high speed. Moreover, trucks in the left lanes travel at speeds that are even much higher than the speed limit. If those trucks complied with the lane restrictions and did not reduce their speed after shifting to the right two lanes, they would potentially cause more hazards in those lanes. On the other hand, truck drivers may not satisfy if the restrictions cause them to loose their operational speeds thus resulting in less productivity.

Method for a Statistical Test for the Truck Speeds

The comparison of the differences between truck speeds 'before' and 'after' the restriction was based on t-test for independent samples. There are several methods involved in testing inferences about two population central value ($\mu_1 - \mu_2$) of independent samples where μ_1 = mean of population one and μ_2 = mean of population two. R. Lyman Ott and Michael Longnecker (10) classified the test methods according to the sample conditions that,

If population distributions are normally distributed, the sample sizes are equal, and the population variances are equal, a pooled-variance t method would be applied.

If both population distribution are normally distributed, but sample sizes and variances are unequal, a separate-variance t' method should be introduced.

If the conditions of normality and equal variance are not valid, but the sample sizes are large (normally $n \geq 30$), the results from t or t' are approximately correct

For the pooled-variance t method, population distributions are normal with equal variances, the following statistical test is used.

Null hypothesis: $H_0: \mu_1 = \mu_2$

Alternative hypothesis: $H_a: \mu_1 \neq \mu_2$

Test statistic value $t = \dfrac{\bar{y}_1 - \bar{y}_2}{S_p\sqrt{\dfrac{1}{n_1} + \dfrac{1}{n_2}}}$

$\bar{y}_1$ = mean of sample one (before)

$\bar{y}_2$ = mean of sample two (after)

Sp = estimated standard deviation = $\sqrt{\dfrac{(n_1 - 1)S_1^{\,2} + (n_2 - 1)S_2^{\,2}}{n_1 + n_2 - 2}}$

$S_1^{\,2}$ = variance of sample one (before)

$S_2^{\,2}$ = variance of sample two (after)

n_1 = sample size one

n_2 = sample size two

degree of freedom (df) = $n_1 + n_2 - 2$

Reject H_0 if $|t| \geq t_{\alpha/2}$

For the separate-variance t' method, population distribution are normal with unequal variances, the following statistical test is used.

Null hypothesis: $H_0: \mu_1 = \mu_2$

Alternative hypothesis: $H_a: \mu_1 \neq \mu_2$

Test statistic value $t' = \dfrac{\bar{y}_1 - \bar{y}_2}{\sqrt{\dfrac{S_1^{\,2}}{n_1} + \dfrac{S_2^{\,2}}{n_2}}}$

$\bar{y}_1$ = mean of sample one (before)

$\bar{y}_2$ = mean of sample two (after)

$S_1^{\,2}$ = variance of sample one (before)

$S_2^{\,2}$ = variance of sample two (after)

n_1 = sample size one

n_2 = sample size two

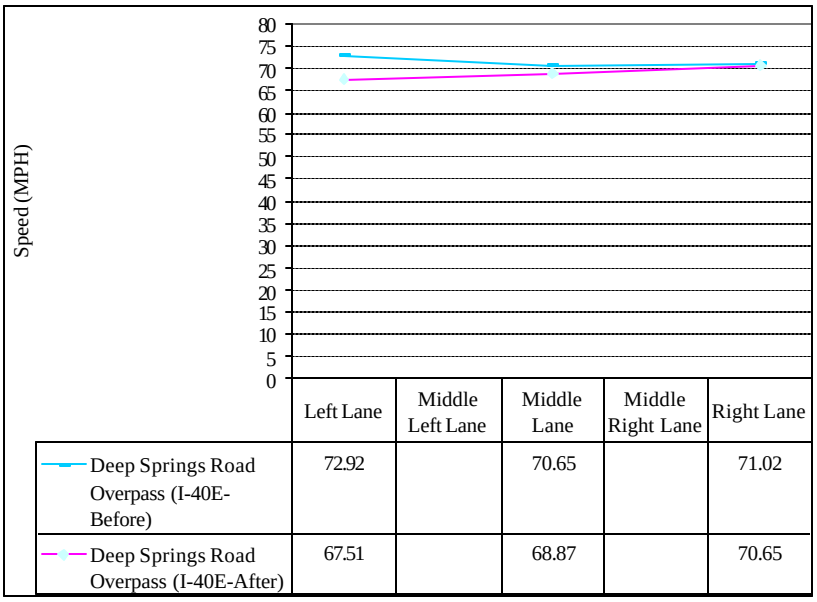
$$\text{degree of freedom (df)} = \frac{(n_1 - 1)(n_2 - 1)}{(1-c)^2(n_1 - 1) + c^2(n_2 - 1)},\ c = \frac{\frac{S_1^2}{n_1}}{\frac{S_1^2}{n_1} + \frac{S_2^2}{n_2}}$$

Reject H_0 if $|t'| \geq t_{\alpha/2}$

The statistical test for truck speed was done in statistical program, SAS. A normality of data samples and the equality of variances of data samples were calculated within the program. The Levine test was introduced to identify the equality of variances among data samples since this method does not restrict the population distribution or the sample size. To decide if the truck speeds were different between 'before' and 'after' periods, a level of significant (or p-value) from SAS program was used as acceptance criterion. If the p-value from the test was less than α (0.05), the truck speeds between 'before' and 'after' were concluded to be significantly different. All the p-values from the statistical test of truck speeds are included in the appendix.

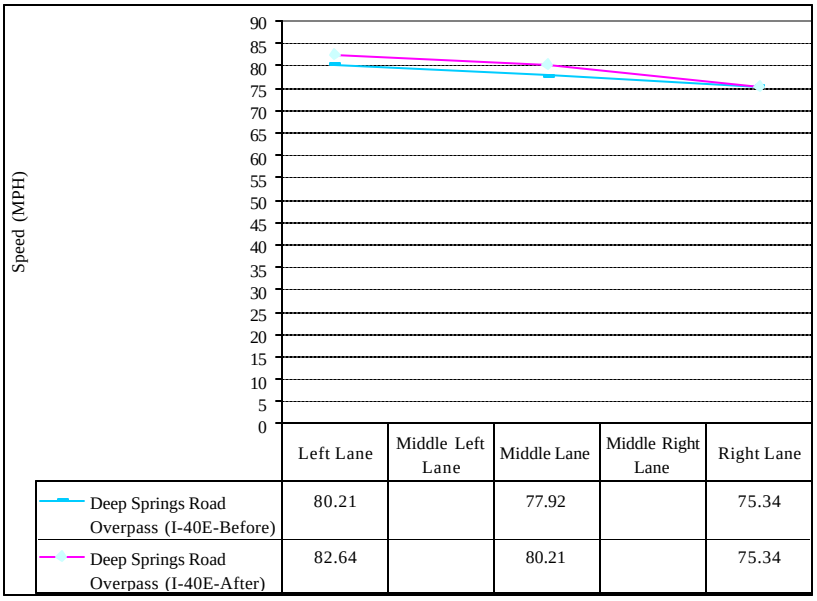
Comparison of Truck Speeds on Eastside of Knoxville

Figure 7-01 through figure 7-06 show the comparison of 85th percentile speed of trucks 'before' and 'after' the lane restrictions for each lane at Deep Springs road overpass location. The changes of the 85th percentile truck speeds in the left lane and middle lane at this location were fluctuate according to the time period after the restriction while the truck speeds in the right lane were more likely to remain the same between the 'before' and 'after' situation.



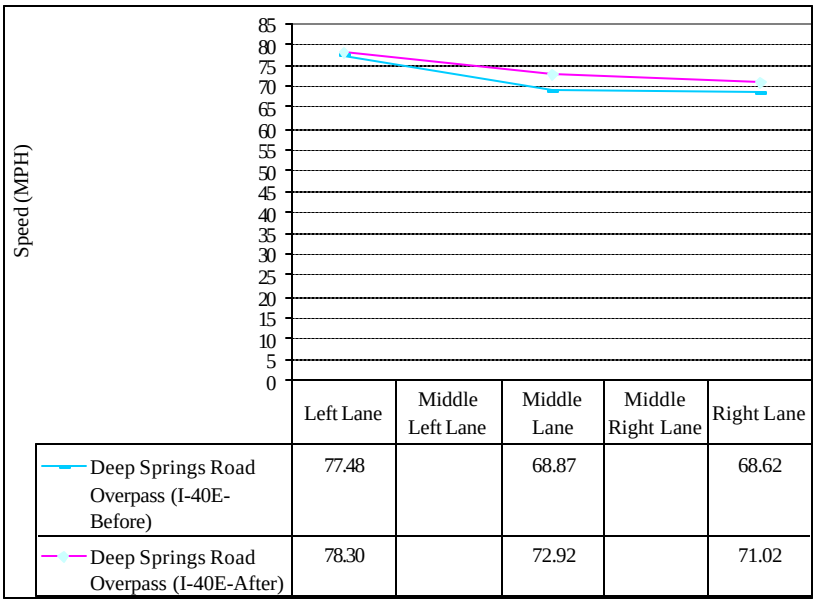
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Deep Springs Road Overpass (I-40E-Before)	72.92		70.65		71.02
Deep Springs Road Overpass (I-40E-After)	67.51		68.87		70.65

Figure 7-01. Truck speed in eastbound direction at Deep Springs road overpass in morning time period



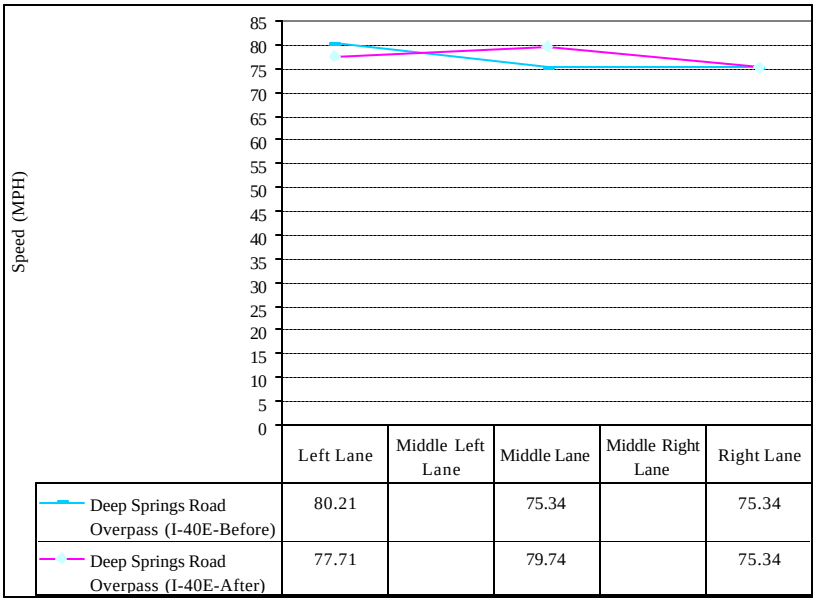
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Deep Springs Road Overpass (I-40E-Before)	80.21		77.92		75.34
Deep Springs Road Overpass (I-40E-After)	82.64		80.21		75.34

Figure 7-02. Truck speed in westbound direction at Deep Springs road overpass in morning time period



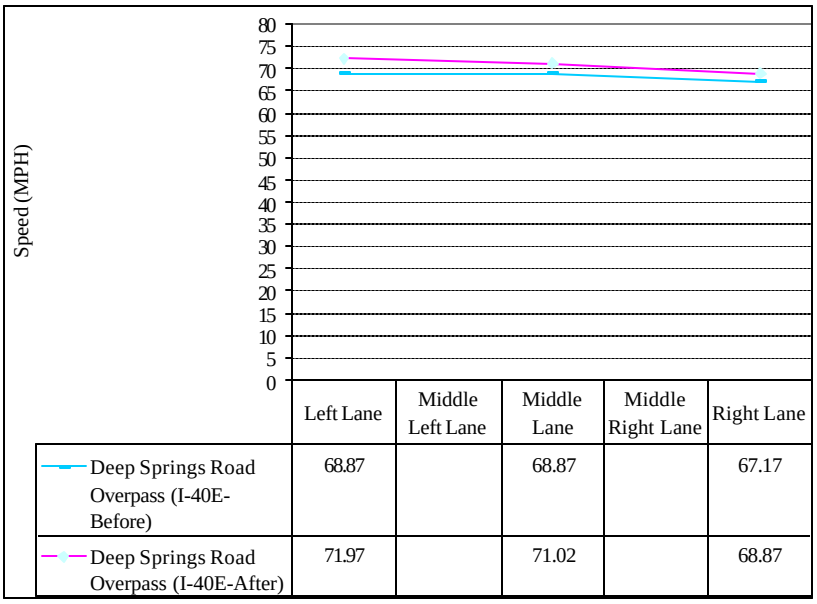
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Deep Springs Road Overpass (I-40E-Before)	77.48		68.87		68.62
Deep Springs Road Overpass (I-40E-After)	78.30		72.92		71.02

Figure 7-03. Truck speed in eastbound direction at Deep Springs road overpass in midday time period



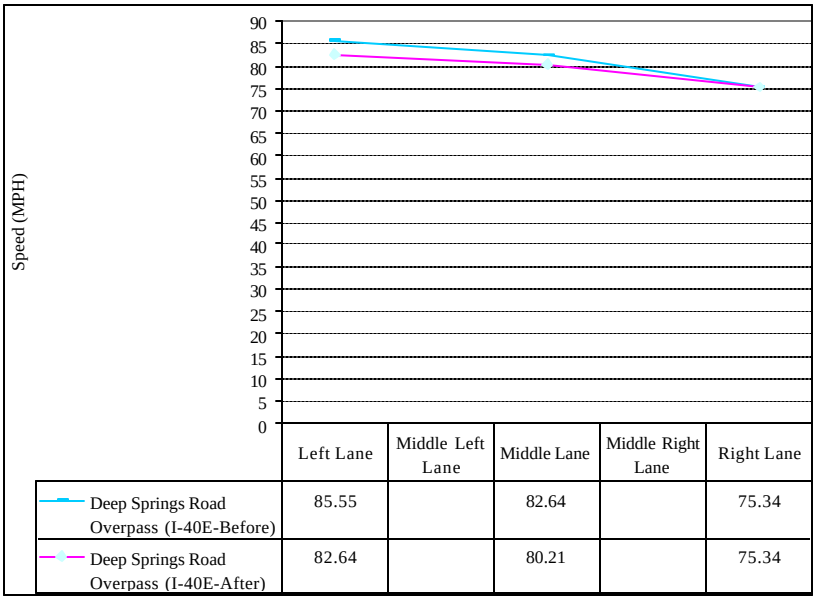
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Deep Springs Road Overpass (I-40E-Before)	80.21		75.34		75.34
Deep Springs Road Overpass (I-40E-After)	77.71		79.74		75.34

Figure 7-04. Truck speed in westbound direction at Deep Springs road overpass in midday time period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Deep Springs Road Overpass (I-40E-Before)	68.87		68.87		67.17
Deep Springs Road Overpass (I-40E-After)	71.97		71.02		68.87

Figure 7-05. Truck speed in eastbound direction at Deep Springs road overpass in evening time period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Deep Springs Road Overpass (I-40E-Before)	85.55		82.64		75.34
Deep Springs Road Overpass (I-40E-After)	82.64		80.21		75.34

Figure 7-06. Truck speed in westbound direction at Deep Springs road overpass in evening time period

Table 7-01 shows the comparison of 85th percentile speed of trucks and table 7-02 shows the statistical test results for speed of trucks between 'before' and 'after' the lane restriction in direction basis at Deep Springs road location. Base on the 85th percentile speed, the truck speed increased for both directions during midday time period and evening time period of eastbound direction and during midday time period of westbound direction. The 85th percentile truck speed decreased during morning time period on eastbound direction and evening time period on westbound direction and did not change during morning time period on westbound direction. However, the 85th percentile speed of trucks was not used in the statistical test for their significant differences. The statistical test is based on comparing the average speed of trucks between the 'before' and the 'after' situation, not 85th percentile speeds of trucks. So table 7-02 represents the test results for differences between the average speeds of trucks. The results in Table 7-02 show that truck speeds significantly changed up during midday time and evening time on eastbound direction, and midday time on westbound direction ($\alpha = 0.05$). And truck speeds significantly changed down during morning time on eastbound and westbound direction and evening time on westbound direction ($\alpha = 0.05$).

Figure 7-07 through figure 7-12 show the comparison speed of trucks 'before' and 'after' the lane restrictions for each lane at McMillan road overpass location. It is observed that the truck speeds in each lane in the 'after' situation were somewhat higher than those in the 'before' situation at this location. For both situations, the highest speed of trucks mostly appeared in the left lane while the lowest one mostly appeared in the right lane. All the speeds represented in the figures are considered as the 85th percentile speed of trucks measured from this site. The table in each figure represents the 85th percentile truck speeds from a left lane to a right lane for 'before' and 'after' situation.

Table 7-01. Change of 85th percentile speed of trucks at Deep Springs road location

Deep Springs Road						
Time	Eastbound			Westbound		
	Speed (Before)	Speed (After)	Percent change	Speed (Before)	Speed (After)	Percent change
AM	71.02	69.22	-2.53	77.48	77.48	0.00
Noon	68.87	71.02	+3.12	75.34	77.48	+2.84
PM	67.17	71.02	+5.73	80.21	77.92	-2.86

Table 7-02. Statistical test for truck speeds at Deep Springs road location

Deep Springs Road								
Time	Eastbound				Westbound			
	Average Speed (Before)	Average Speed (After)	Percent change	Signifi cantly change	Average Speed (Before)	Speed (After)	Percent change	Signifi cantly change
AM	64.70	63.32	-2.13	Yes	70.77	69.98	-1.12	Yes
Noon	63.17	64.92	+2.77	Yes	69.41	70.04	+0.91	Yes
PM	62.52	63.52	+1.60	Yes	71.69	70.83	-1.20	Yes

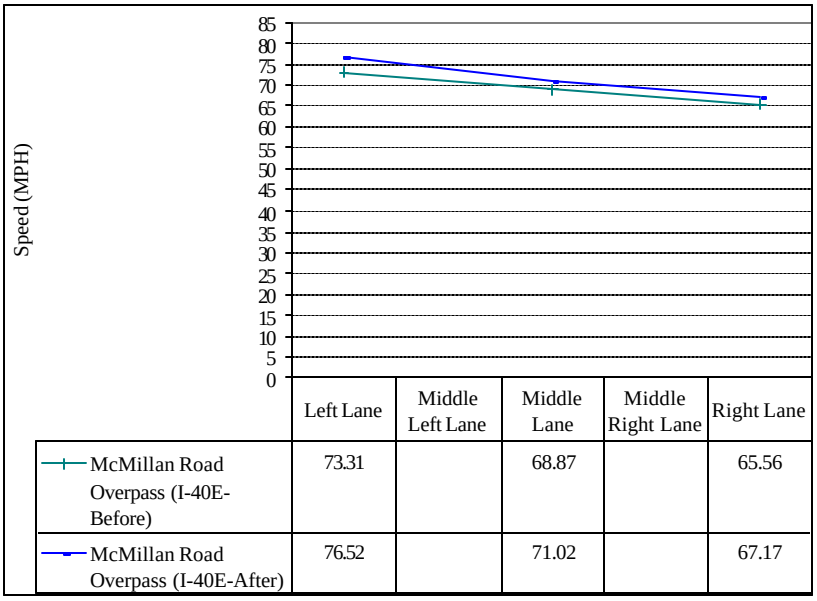
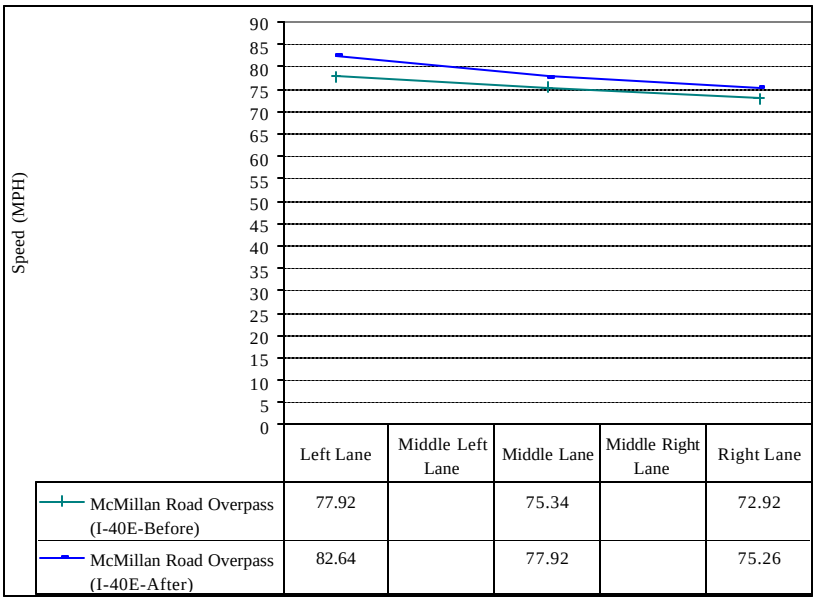
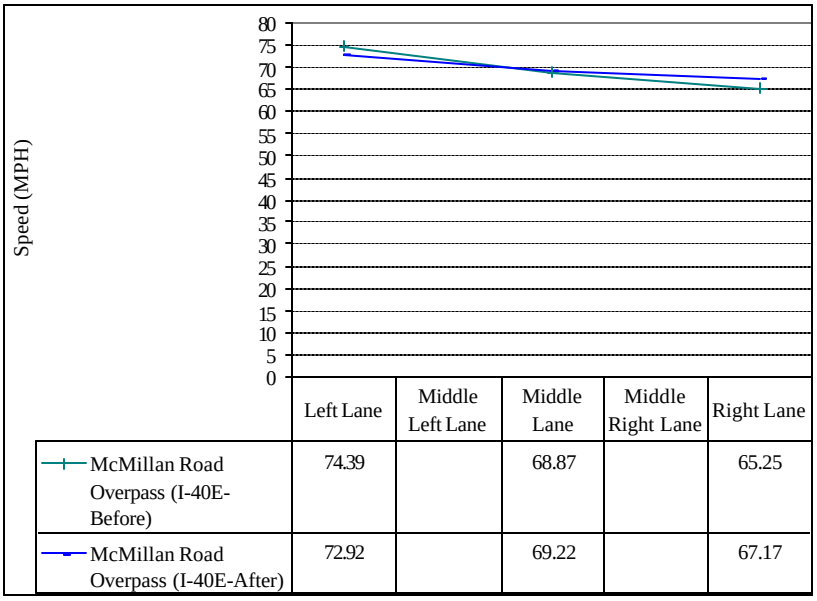


Figure 7-07. Truck speeds in eastbound direction at McMillan road overpass in the morning time period



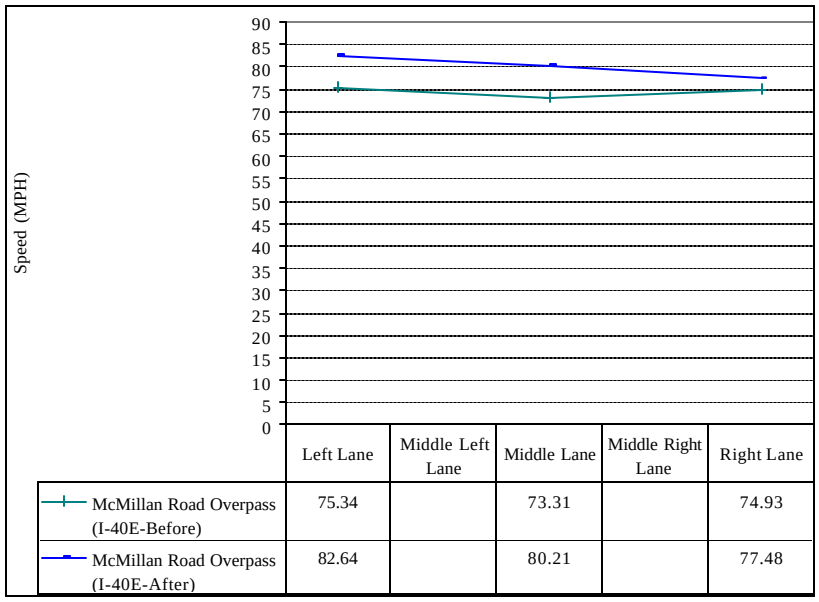
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
McMillan Road Overpass (I-40E-Before)	77.92		75.34		72.92
McMillan Road Overpass (I-40E-After)	82.64		77.92		75.26

Figure 7-08. Truck speeds in westbound direction at McMillan road overpass in the morning time period



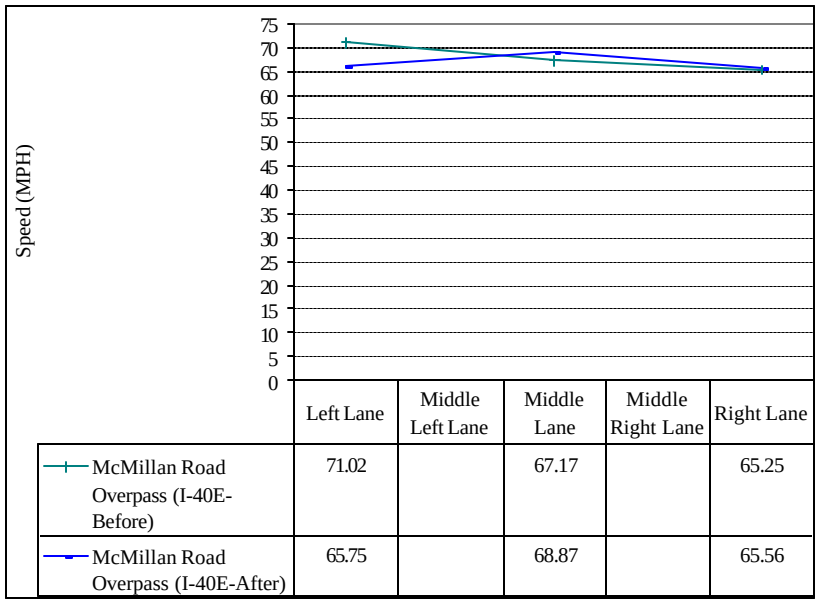
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
McMillan Road Overpass (I-40E-Before)	74.39		68.87		65.25
McMillan Road Overpass (I-40E-After)	72.92		69.22		67.17

Figure 7-09. Truck speeds in eastbound direction at McMillan road overpass in the midday time period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
McMillan Road Overpass (I-40E-Before)	75.34		73.31		74.93
McMillan Road Overpass (I-40E-After)	82.64		80.21		77.48

Figure 7-10. Truck speeds in westbound direction at McMillan road overpass in the midday time period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
McMillan Road Overpass (I-40E-Before)	71.02		67.17		65.25
McMillan Road Overpass (I-40E-After)	65.75		68.87		65.56

Figure 7-11. Truck speeds in eastbound direction at McMillan road overpass in the evening time period

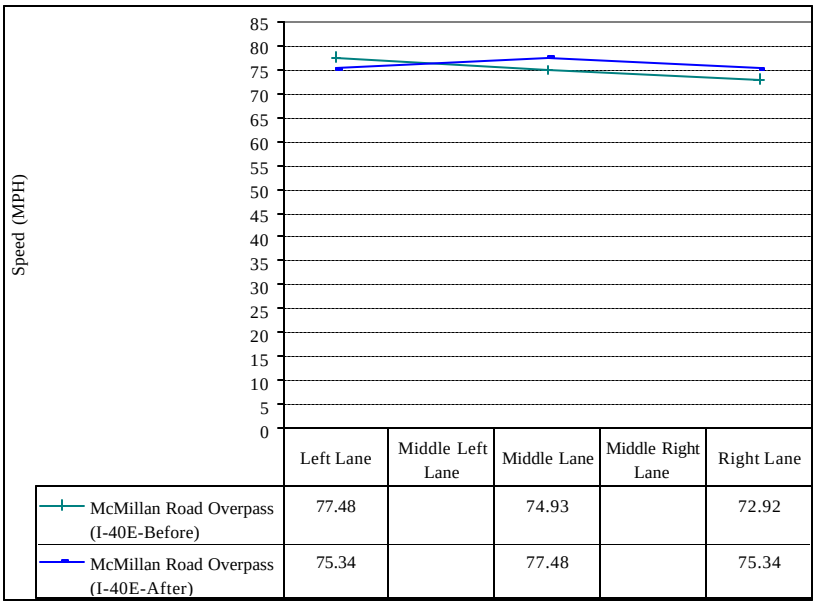


Figure 7-12. Truck speeds in westbound direction at McMillan road overpass in the evening time period

Table 7-03 shows the comparison of 85th percentile speed of trucks and table 7-04 shows the statistical test results for speed of trucks between 'before' and 'after' the lane restriction in directional basis at McMillan road location. Base on the 85th percentile speed, the overall truck speeds increased for both directions except for during midday time period and evening time period of eastbound direction that the truck speeds were about the same for both before and after the restrictions. The statistical test results in table 7-04 show that truck speeds significantly changed up in the morning time on eastbound direction and all time periods on westbound direction ($\alpha = 0.05$). And truck speeds significantly changed down during evening time on eastbound direction ($\alpha = 0.05$).

Table 7-03. Change of 85th percentile speed of trucks at McMillan road location

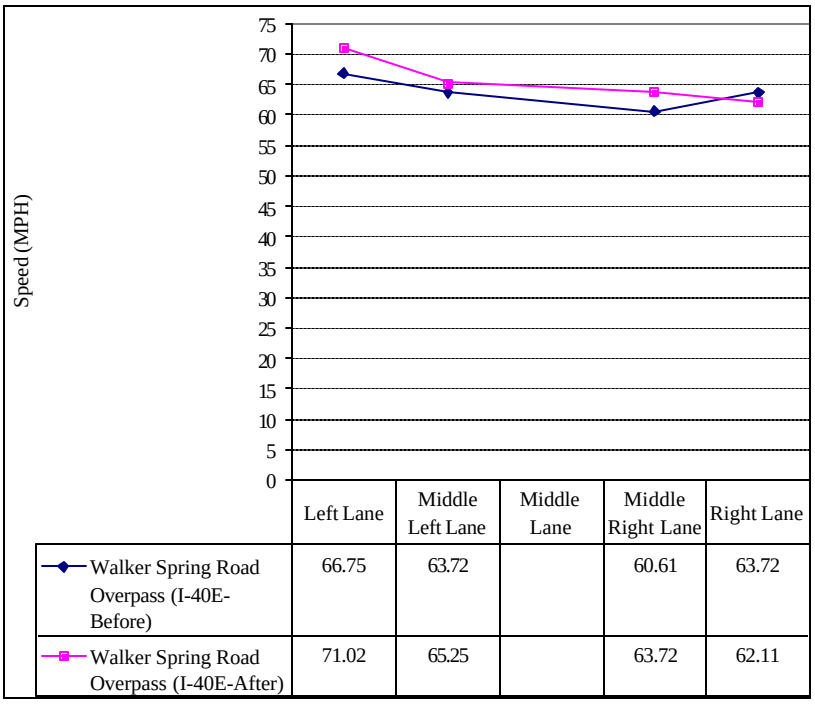
McMillan Road						
Time	Eastbound			Westbound		
	Speed (Before)	Speed (After)	Percent change	Speed (Before)	Speed (After)	Percent change
AM	68.87	68.91	+0.06	75.34	77.48	+2.84
Noon	68.87	68.87	0.00	73.31	80.21	+9.41
PM	67.17	67.17	0.00	74.88	77.27	+3.19

Table 7-04. A statistical test for truck speeds at McMillan road location

McMillan Road								
Time	Eastbound				Westbound			
	Average Speed (Before)	Average Speed (After)	Percent change	Signifi cantly change	Average Speed (Before)	Average Speed (After)	Percent change	Signifi cantly change
AM	62.30	62.90	+0.96	Yes	67.70	70.16	+3.63	Yes
Noon	62.77	62.39	-0.61	No	66.42	72.00	+8.40	Yes
PM	61.63	60.94	-1.12	Yes	67.11	69.36	+3.35	Yes

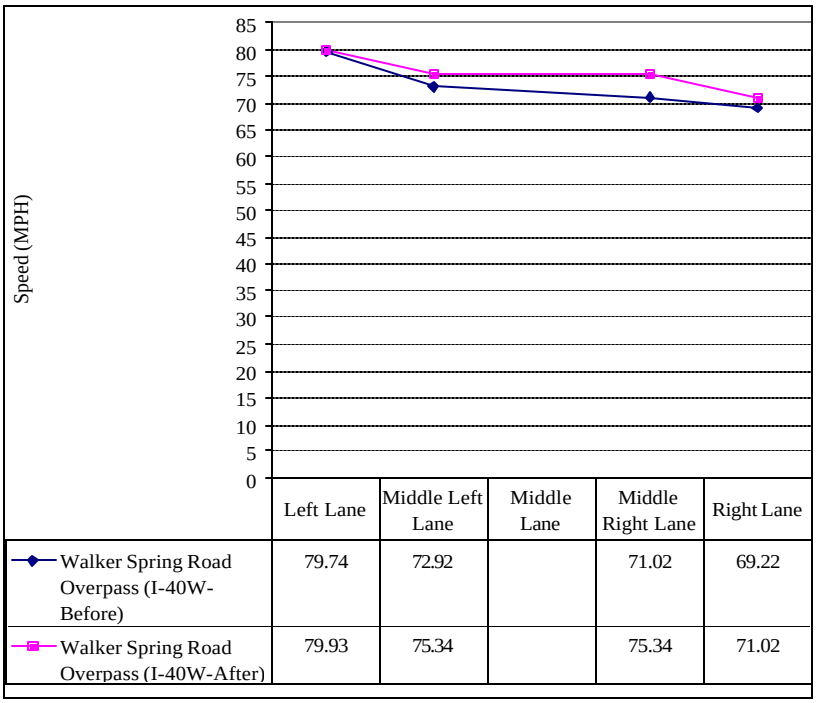
Comparison of Truck Speeds on Westside of Knoxville

Figure 7-13 through figure 7-18 show the comparison of 85th percentile speed of trucks 'before' and 'after' the lane restrictions in detail for each lane at Walker Spring road overpass location. Those truck speeds are compared separately according to the time period; morning, midday, and evening for each direction. Figure 7-13 and 7-14 show the comparison of truck speeds in the morning time for eastbound and westbound direction respectively. Figure 7-15 and 7-16 show the comparison of truck speeds in the midday time period. Figure 7-17 and 7-18 represent the comparison of truck speeds in the evening time period. After the restrictions, the 85th percentile speed of trucks slightly increased in all lanes for both directions except for the evening time period in westbound direction.



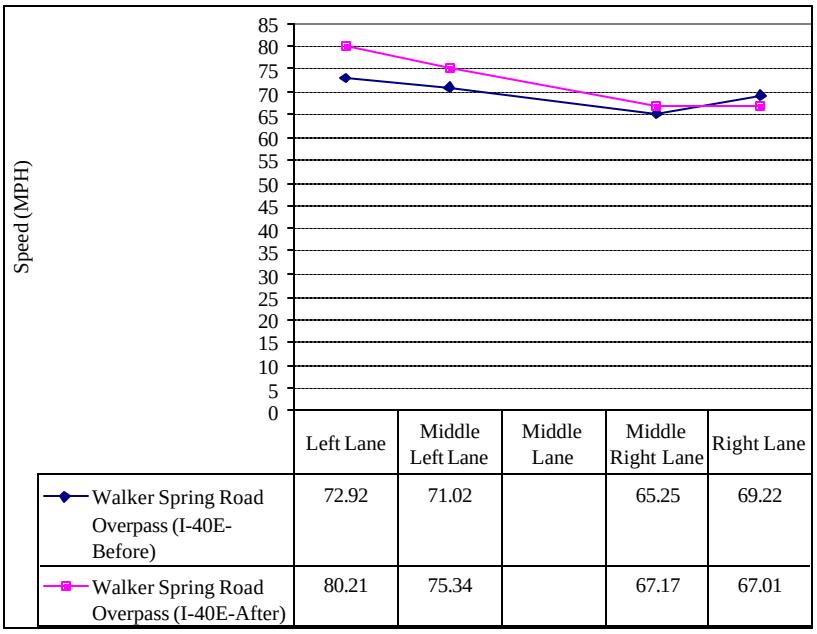
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass (I-40E-Before)	66.75	63.72		60.61	63.72
Walker Spring Road Overpass (I-40E-After)	71.02	65.25		63.72	62.11

Figure 7-13. Truck speeds in eastbound direction at Walker Spring road overpass in the morning time period



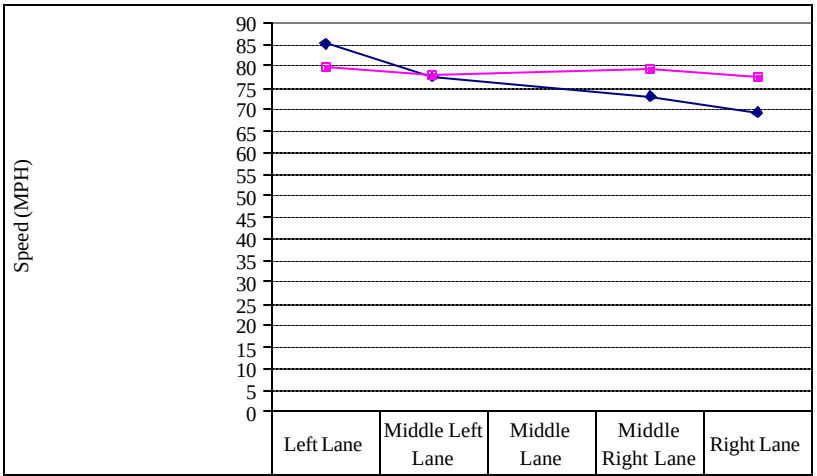
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass (I-40W-Before)	79.74	72.92		71.02	69.22
Walker Spring Road Overpass (I-40W-After)	79.93	75.34		75.34	71.02

Figure 7-14. Truck speeds in westbound direction at Walker Spring road overpass in the morning time period



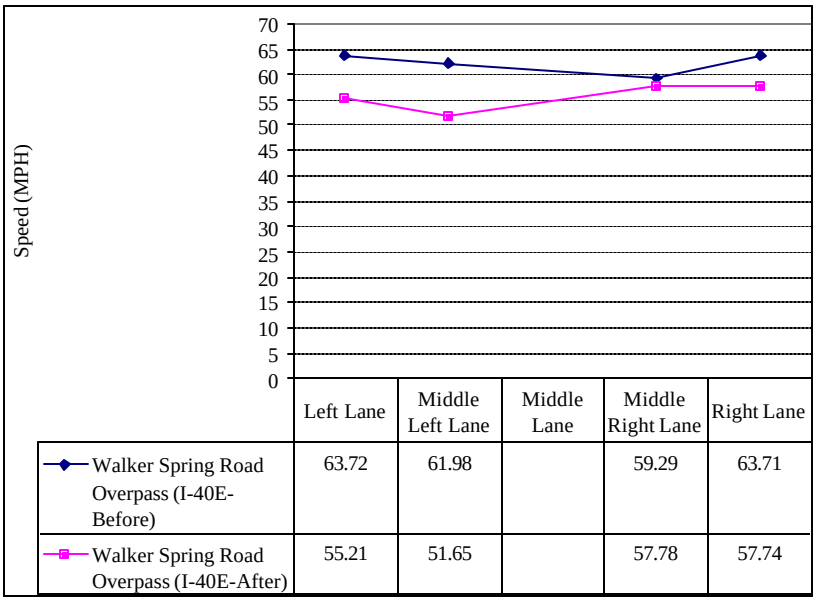
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass (I-40E-Before)	72.92	71.02		65.25	69.22
Walker Spring Road Overpass (I-40E-After)	80.21	75.34		67.17	67.01

Figure 7-15. Truck speeds in eastbound direction at Walker Spring road overpass in the midday time period



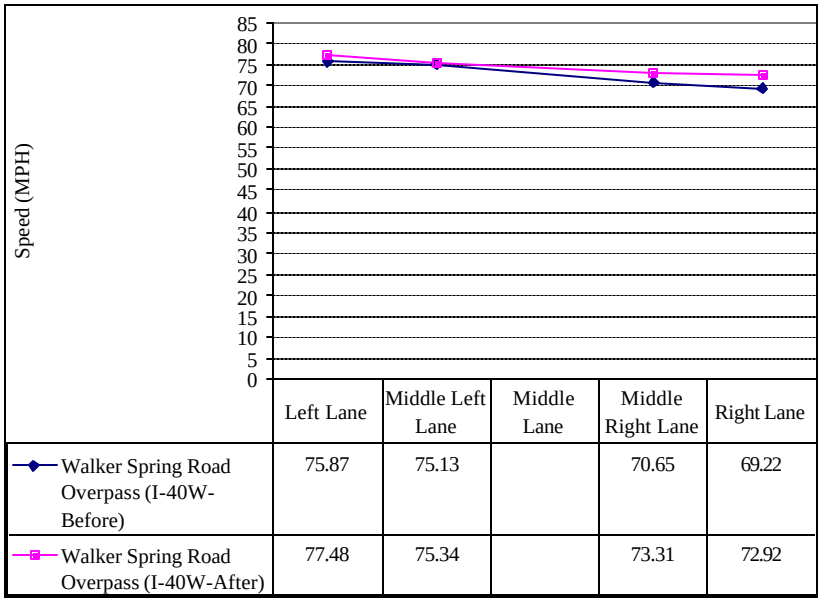
	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass (I-40W-Before)	85.23	77.48		72.92	69.44
Walker Spring Road Overpass (I-40W-After)	79.77	77.92		79.20	77.48

Figure 7-16. Truck speeds in westbound direction at Walker Spring road overpass in the midday time period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass (I-40E-Before)	63.72	61.98		59.29	63.71
Walker Spring Road Overpass (I-40E-After)	55.21	51.65		57.78	57.74

Figure 7-17. Truck speeds in eastbound direction at Walker Spring road overpass in the evening time period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Walker Spring Road Overpass (I-40W-Before)	75.87	75.13		70.65	69.22
Walker Spring Road Overpass (I-40W-After)	77.48	75.34		73.31	72.92

Figure 7-18. Truck speeds in westbound direction at Walker Spring road overpass in the evening time period

Table 7-05 shows the comparison of 85th percentile speed of trucks and Table 7-06 shows the statistical test results for speed of trucks between 'before' and 'after' the lane restriction in directional basis at Walker Spring road location. Based on 85th percentile speed, the speed of trucks in each lane increased for both directions except during evening time period of eastbound direction that the truck speed decreased by 10.92%. The results from the statistical test in table 7-06 show that trucks speeds significantly changed up during midday time on eastbound direction and all time periods on westbound direction ($\alpha = 0.05$). And the truck speeds significantly changed down during morning time and evening time on eastbound direction ($\alpha = 0.05$).

Figure 7-19 through figure 7-24 show the comparison of speed of trucks 'before' and 'after' the lane restrictions for each lane at Watt road overpass location. The values in y-axis represent the 85th percentile speed of trucks. The results are separately compared according to the time period; morning, midday, and evening. After the restrictions, the 85th percentile speed of trucks slightly decreased in all lanes for both directions except for the midday time period of westbound direction. However, the 85th percentile truck speeds for the 'after' situation of this location maintained about the same patterns across the lanes of both directions as those for the 'before' situation.

Table 7-07 shows the comparison of 85th percentile speed of trucks and table 7-08 shows the statistical test results for speed of trucks between 'before' and 'after' the lane restriction in directional basis at Watt road location. The overall speed of trucks decreased for both directions except during midday time period of westbound direction that the truck speed slightly increased. The results show that truck speeds significantly changed down during all time periods on eastbound direction ($\alpha = 0.05$). And the truck speeds significantly changed down during morning time and evening time, but increased during the midday time on westbound direction ($\alpha = 0.05$).

Table 7-05. Change of 85th percentile speed of trucks at Walker Spring road location

Walker Spring Road						
Time	Eastbound			Westbound		
	Speed (Before)	Speed (After)	Percent change	Speed (Before)	Speed (After)	Percent change
AM	63.42	63.80	+0.60	72.92	75.34	+3.32
Noon	68.87	71.02	+3.12	75.34	77.92	+3.42
PM	61.98	55.21	-10.92	72.92	75.34	+3.32

Table 7-06. A statistical test for truck speeds at Walker Spring road location

Walker Spring Road								
Time	Eastbound				Westbound			
	Average Speed (Before)	Average Speed (After)	Percent change	Signifi cantly change	Average Speed (Before)	Average Speed (After)	Percent change	Signifi cantly change
AM	52.25	49.14	-5.95	Yes	66.34	68.28	+2.92	Yes
Noon	56.49	64.17	+13.60	Yes	67.97	71.79	+5.62	Yes
PM	44.78	34.01	-24.05	Yes	65.46	68.51	+4.66	Yes

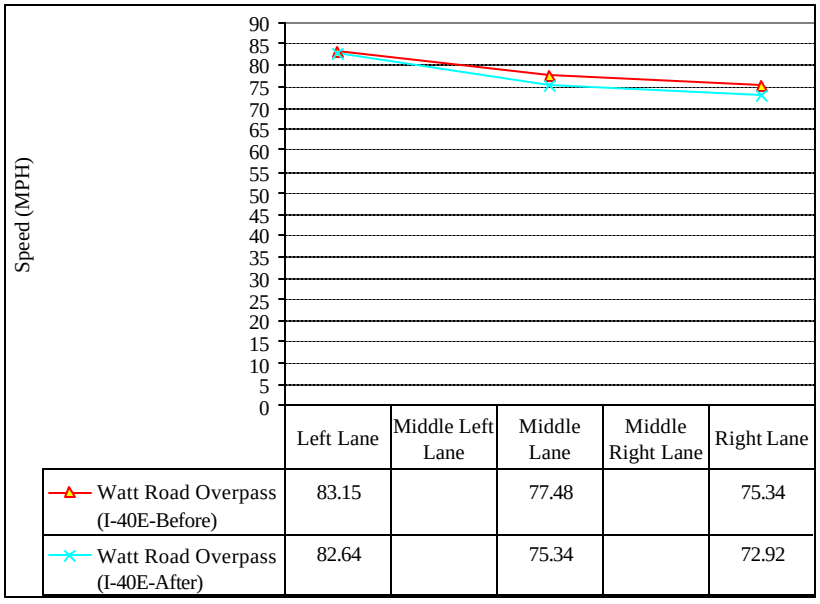


Figure 7-19. Truck speeds in eastbound direction at Watt road overpass in the morning time period

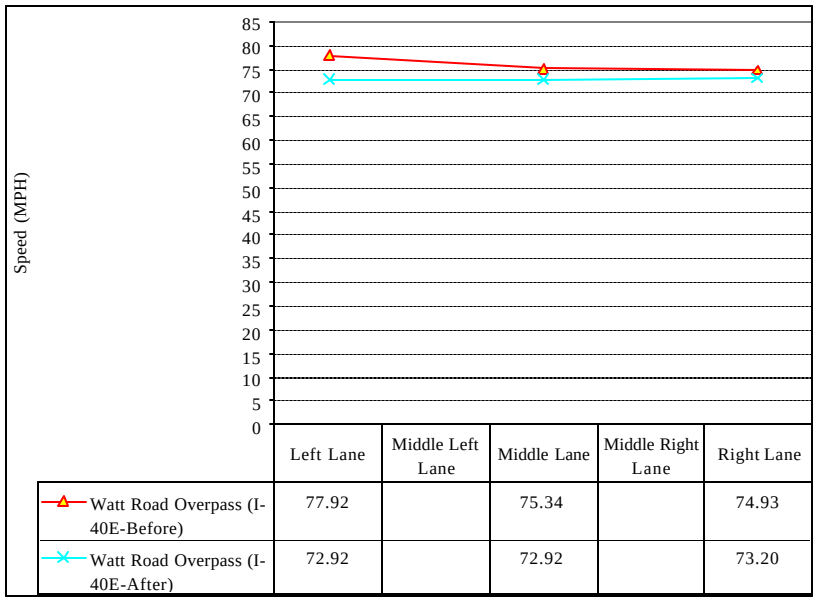


Figure 7-20. Truck speeds in westbound direction at Watt road overpass in the morning time period

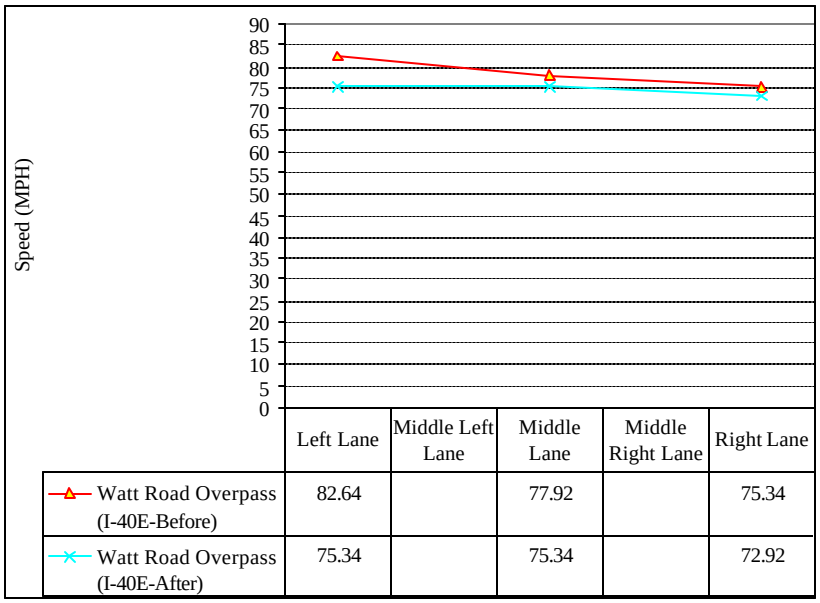
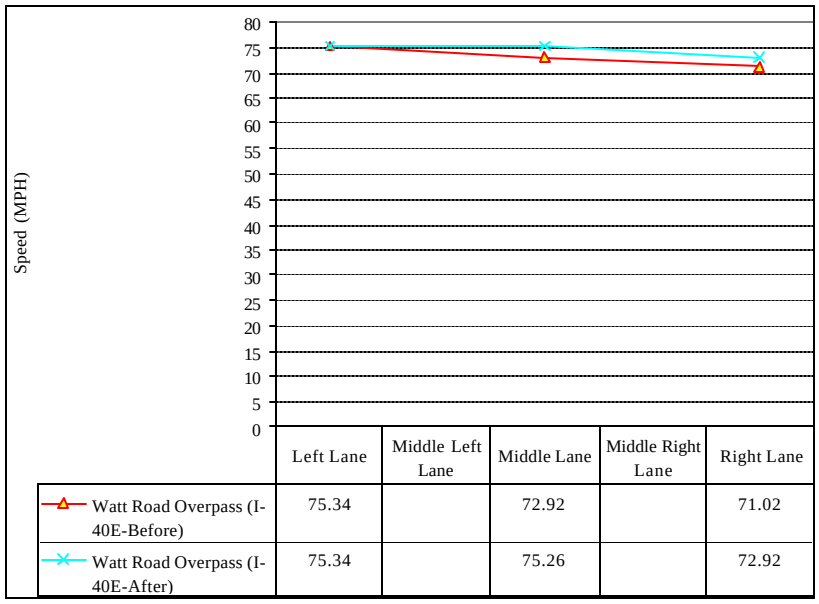
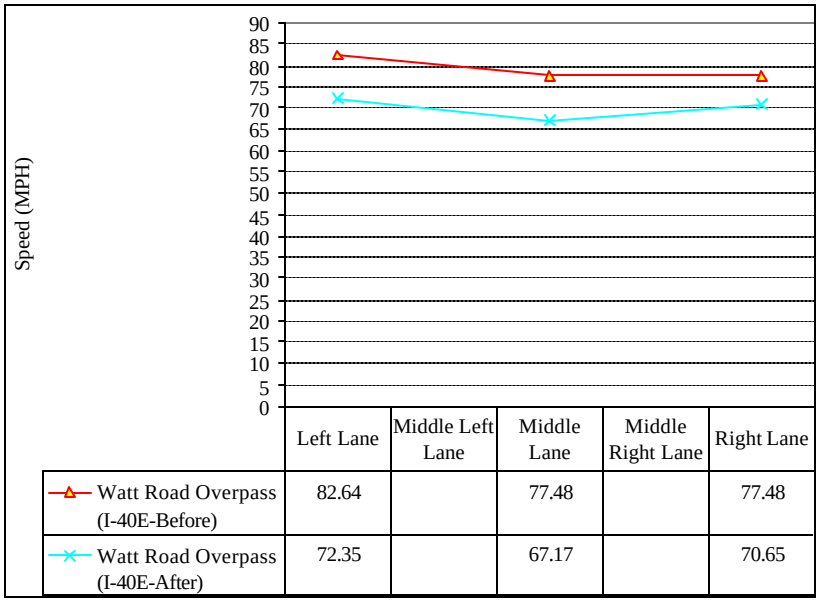


Figure 7-21. Truck speeds in eastbound direction at Watt road overpass in the midday time period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Watt Road Overpass (I-40E-Before)	75.34		72.92		71.02
Watt Road Overpass (I-40E-After)	75.34		75.26		72.92

Figure 7-22. Truck speeds in westbound direction at Watt road overpass in the midday time period



	Left Lane	Middle Left Lane	Middle Lane	Middle Right Lane	Right Lane
Watt Road Overpass (I-40E-Before)	82.64		77.48		77.48
Watt Road Overpass (I-40E-After)	72.35		67.17		70.65

Figure 7-23. Truck speeds in eastbound direction at Watt road overpass in the evening time period

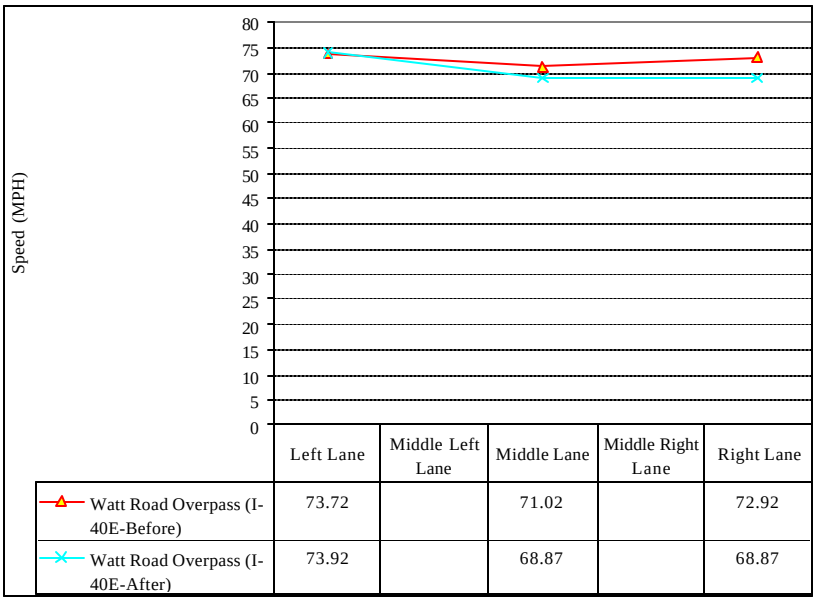


Figure 7-24. Truck speeds in westbound direction at Watt road overpass in the evening time period

Table 7-07. Change of 85th percentile speed of trucks at Watt road location

Watt Road						
Time	Eastbound			Westbound		
	Speed (Before)	Speed (After)	Percent change	Speed (Before)	Speed (After)	Percent change
AM	77.48	74.93	-3.29	75.34	72.92	-3.21
Noon	77.48	73.31	-5.38	72.92	73.31	+0.53
PM	77.48	68.87	-11.11	72.92	68.87	-5.55

Table 7-08. Statistical test for truck speeds at Watt road location (average truck speed)

Watt Road								
Time	Eastbound				Westbound			
	Average Speed (Before)	Average Speed (After)	Percent change	Significantly change	Average Speed (Before)	Average Speed (After)	Percent change	Significantly change
AM	69.51	67.26	-3.24	Yes	67.56	66.10	-2.16	Yes
Noon	69.31	62.36	-10.03	Yes	65.93	67.18	+1.90	Yes
PM	69.98	63.20	-9.69	Yes	66.31	63.92	-3.60	Yes

The following tables summarize the statistical test results for differences of percentage of trucks and differences of speed of trucks in each lane to identify the relation between their changes between the ‘before’ and ‘after’ situation.

Table 7-09 through 7-12 show that there were no relations between the changes in percentage of trucks in each lane and the changes in truck speeds in each lane. It is observed that there were no uniform patterns of apparent changes for the truck speeds due to the implementation of truck lane use restriction. Most of the time, the changes of truck speeds between ‘before’ and ‘after’ situation were significantly different in a fluctuate pattern in all lanes while the changes in percentage of trucks at valid locations were only significantly decreased in the left lane.

It should be reminded that the effectiveness of the lane use restriction signs cannot be assessed from the data and results obtained at Watt road site. And there were no significant differences of percentage of trucks in any lanes any time except in a left lane during midday time in westbound direction.

Table 7-09. Summaries of statistical tests for the differences in number of trucks and truck speeds in each lane at Deep Springs road location

Direction	Lane	Time	No. of trucks (Before)	No. of Trucks (After)	Change in percentage of trucks (%)	Different in number of trucks	Change in truck speeds (%)	Significantly Change in truck speeds
East	Right Lane	AM	1127	561	+15.29	Not significant	-1.26	Significant
		Noon	722	1043	+19.00	Not significant	+4.66	Significant
		PM	864	1148	+28.50	Not significant	-0.14	Not significant
	Middle Lane	AM	1059	393	-6.77	Not significant	-2.79	Significant
		Noon	855	748	+0.50	Not significant	+3.30	Significant
		PM	961	966	-4.36	Not significant	+3.34	Significant
	Left Lane	AM	163	13	-72.76	Not significant	-7.27	Significant
		Noon	163	23	-86.33	Significant	+1.39	Not significant
		PM	229	31	-87.16	Significant	+2.25	Not significant
West	Right Lane	AM	683	1469	+14.18	Not significant	-1.43	Significant
		Noon	780	1413	+18.94	Not significant	+0.58	Not significant
		PM	1132	1409	+25.97	Not significant	+0.20	Not significant
	Middle Lane	AM	577	1086	-2.37	Not significant	-0.35	Not significant
		Noon	764	1092	-4.51	Not significant	+2.59	Significant
		PM	1108	1052	-3.91	Not significant	-0.14	Not significant
	Left Lane	AM	116	34	-86.12	Significant	+3.18	Not significant
		Noon	103	27	-87.92	Significant	-6.75	Significant
		PM	277	26	-90.46	Significant	-0.93	Not significant

Table 7-10. Summaries of statistical tests for the differences in number of trucks and truck speeds in each lane at McMillan road location

Direction	Lane	Time	No. of trucks (Before)	No. of Trucks (After)	Change in percentage of trucks (%)	Different in number of trucks	Change in truck speeds (%)	Significantly Change in truck speeds
East	Right Lane	AM	737	561	+10.85	Not significant	+2.35	Significant
		Noon	892	896	+32.73	Not significant	+3.64	Significant
		PM	735	926	+22.21	Not significant	-0.27	Not significant
	Middle Lane	AM	703	502	+3.99	Not significant	+1.07	Not significant
		Noon	1072	941	+16.01	Not significant	-0.54	Not significant
		PM	898	994	+7.35	Not significant	+0.04	Not significant
	Left Lane	AM	143	24	-75.55	Significant	+1.32	Not significant
		Noon	523	45	-88.63	Significant	-1.36	Not significant
		PM	268	40	-85.53	Significant	-8.06	Significant
West	Right Lane	AM	1047	949	+6.03	Not significant	+3.21	Significant
		Noon	1025	823	+37.14	Significant	+5.88	Significant
		PM	1275	1149	+20.11	Not significant	+3.85	Significant
	Middle Lane	AM	778	685	+2.99	Not significant	+5.23	Significant
		Noon	1242	663	-8.83	Not significant	+11.85	Significant
		PM	1249	885	-5.78	Not significant	+4.19	Significant
	Left Lane	AM	111	21	-77.84	Not significant	+1.17	Not significant
		Noon	304	18	-89.80	Significant	+8.80	Significant
		PM	211	21	-86.82	Significant	-2.08	Not significant

Table 7-11. Summaries of statistical tests for the differences in number of trucks and truck speeds in each lane at Walker Spring road location

Direction	Lane	Time	No. of trucks (Before)	No. of Trucks (After)	Change in percentage of trucks (%)	Different in number of trucks	Change in truck speeds (%)	Significantly Change in truck speeds
East	Right Lane	AM	100	78	+19.83	Not significant	-16.27	Significant
		Noon	172	75	+45.85	Not significant	+7.58	Significant
		PM	128	122	+49.75	Not significant	-22.88	Significant
	Middle Right Lane	AM	626	455	+16.12	Not significant	-9.68	Significant
		Noon	1202	419	+33.4	Not significant	+13.77	Significant
		PM	791	593	+17	Not significant	-14.68	Significant
	Middle Left Lane	AM	823	372	-11.14	Not significant	+0.54	Not significant
		Noon	1297	331	-13.94	Not significant	+16.23	Significant
		PM	981	609	-3.11	Not significant	-33.41	Significant
	Left Lane	AM	115	29	-50.48	Not significant	+11.10	Significant
		Noon	285	10	-88.17	Significant	+23.26	Significant
		PM	252	53	-66.61	Significant	-22.53	Significant
West	Right Lane	AM	285	105	+12.94	Not significant	+1.33	Not significant
		Noon	260	116	+33.08	Not significant	+10.82	Significant
		PM	153	79	+20.51	Not significant	+5.82	Significant
	Middle Right Lane	AM	887	390	+44.47	Significant	+6.26	Significant
		Noon	715	383	+33.13	Not significant	+9.61	Significant
		PM	843	460	+27.47	Not significant	+6.96	Significant
	Middle Left Lane	AM	1256	304	-21.11	Not significant	+2.40	Significant
		Noon	940	332	-12.22	Not significant	+3.68	Significant
		PM	1171	440	-12.23	Not significant	+3.84	Significant
	Left Lane	AM	270	25	-67.07	Not significant	+1.36	Not significant
		Noon	155	34	-100.00	Significant	-5.99	Significant
		PM	286	71	-42.02	Not significant	+5.61	Significant

Table 7-12. Summaries of statistical tests for the differences in number of trucks and truck speeds in each lane at Watt road location

Direction	Lane	Time	No. of trucks (Before)	No. of Trucks (After)	Change in percentage of trucks (%)	Different in number of trucks	Change in truck speeds (%)	Significantly Change in truck speeds
East	Right Lane	AM	946	501	-1.86	Not significant	-4.54	Significant
		Noon	1200	605	-6.52	Not significant	-7.75	Significant
		PM	1256	291	-20.87	Not significant	-7.03	Significant
	Middle Lane	AM	586	332	+4.97	Not significant	-1.22	Not significant
		Noon	944	576	+13.21	Not significant	-12.07	Significant
		PM	892	333	+34.49	Not significant	-11.54	Significant
	Left Lane	AM	43	17	-26.74	Not significant	-2.81	Not significant
		Noon	139	50	-33.33	Not significant	-14.11	Significant
		PM	114	23	-27.40	Not significant	-12.83	Significant
West	Right Lane	AM	509	363	+18.5	Not significant	-2.12	Significant
		Noon	686	176	+30.56	Not significant	+0.81	Not significant
		PM	634	128	+10.31	Not significant	-4.50	Significant
	Middle Lane	AM	982	609	+3.03	Not significant	-1.53	Significant
		Noon	1172	329	-1.02	Not significant	+2.81	Significant
		PM	963	182	+3.25	Not significant	-3.99	Significant
	Left Lane	AM	240	70	-51.52	Not significant	-3.81	Significant
		Noon	314	33	-62.93	Significant	+2.50	Not significant
		PM	266	31	-36.34	Not significant	+3.21	Not significant

Chapter 8 Conclusions and Observations

Conclusions

The 'before' and 'after' data were collected by digital video cameras at four locations and there were two directions of traffic at each location. Thus there were eight sets of data, and for each set there are three different time periods during each day of data collection. The data collected at all these locations for the 'before' period are perfectly valid for what they were gathered for -- truck traffic's lane distribution and travel speed. The 'after' data are also valid for the information that was extracted, truck traffic lane distribution and travel speed. However, the 'after' data have another expectation associated with them, as they are expected to reflect the impact of the truck lane use restriction. For this latter purpose, the location of the sites where data were collected should be downstream from the beginning of the lane use restriction so that the trucks moving along the left lane have enough time to make the necessary lane change. Further, there should not be any other special reasons and restrictions that may impact lane use characteristics. Based on these considerations, a few of the data collection sites appear to be not fully suitable for the purpose of 'before' and 'after' comparisons, and these include the Watt Road sites in both eastbound and westbound directions. The same is true for the westbound direction at Walker Spring exit. Thus for the westside of Knoxville, only one location, Walker Spring eastbound, meets all requirements for reflecting the impact of truck lane restriction. It should be pointed out that Lovell Road exit would have been appropriate for the westside of this project, but it could not be used because of ongoing construction of the overpass at this interchange.

Although some of the data collection locations on the west side of Knoxville were not ideally suitable for this study, almost all data collection sites on the east side were well suited. Even though there are a few small truck stops near the Strawberry Plains Pike exit, which is near the McMillan Road site, those truck stops do not generate as much truck traffic as those near the Watt Road exit on the west side.

The 'before'/'after' comparisons at the appropriate locations show that the percentage of trucks using the left lane decreased significantly since the truck lane use restrictions went into effect. Further, the lane use restriction did not add significantly more number of trucks on the right lane, which accommodates merging vehicles from an entrance ramp. The impact on the travel speed of trucks has been mixed. Truck speeds increased at certain locations significantly and they also decreased significantly at a few other applicable locations. Although there were significant changes in truck speeds between the 'before' and 'after' situations, there was no consistent pattern, and the changes cannot be contributed to the lane use restriction of trucks. It should be added that the enforcement of the truck lane use restriction during the study period appeared to be minimal. The 'signing' for the restriction also was at a minimum level. The success of this strategy is significant considering the low level of effort required and expended.

General Observations and Suggestions

It is suggested as a general idea that if a truck lane use restriction is to be used, it should be applied continuously for a long stretch of a highway. In the case of the experimental application in Knoxville, the restriction was applied in a discontinuous manner because of construction projects in the central area of Knoxville. If however, the restriction is adopted permanently, it should be continued through the central area wherever three lanes or more are available in one direction. The 'signing' plan can be improved. There should be advance-warning signs ahead of the beginning of the restriction areas to provide necessary time for trucks to make adjustments to fully comply when entering the restricted areas. The same policy should be used for other cities such as Nashville and Memphis if lane restriction is to be used in those areas.

The visibility of the lane use restriction signs is important for adequate response from truck drivers. Since the signs are especially applicable to trucks traveling on the outside left lane, it will be a good idea to add signs about the restriction on the median side of the roadway in each direction in addition to the right side. In the case of the Knoxville experiment, the first signs at the beginning of the restricted zones were

equipped with two orange color flags to draw the attention of truck drivers. This practice is recommended in future applications.

A study of the impact of truck lane use restriction on the safety of passenger cars will be interesting. However, for such a study data have to be collected over a long period of time covering several years. Although the finding shows no impact of truck lane use restriction on patterns of speed changes of trucks, it is observed that truck speeds in both ‘before’ and ‘after’ the restriction periods were quite high. This speeding issue of trucks should be studied in more depth, and appropriate strategies should be implemented to lower speed.

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APPENDIX

Appendix

Table A-01. Statistical test results from SAS for the truck speed at Deep Springs road location

Location	Direction	Lane	Time	No. of trucks (Before)	Normal distribution (Before)	No. of trucks (After)	Normal distribution (After)	Equality of variances	p-value from equality of variance	p-value from t-test for speed	Significantly Change in speed
Deep Springs Road	East	Right Lane	7.30-8.30	1127	Nonnormal	561	Nonnormal	Unequal	0.0411	0.0272	Significant
			12.30-1.30	722	Nonnormal	1043	Nonnormal	Equal	0.0980	0.0001	Significant
			4.30-5.30	864	Nonnormal	1148	Nonnormal	Unequal	0.0001	0.7229	Notsignificant
		Middle Lane	7.30-8.30	1059	Nonnormal	393	Nonnormal	Equal	0.3266	0.0001	Significant
			12.30-1.30	855	Nonnormal	748	Nonnormal	Unequal	0.0393	0.0001	Significant
			4.30-5.30	961	Nonnormal	966	Nonnormal	Unequal	0.0001	0.0001	Significant
		Left Lane	7.30-8.30	163	Nonnormal	13	Normal	Equal	0.4464	0.0368	Significant
			12.30-1.30	163	Nonnormal	23	Normal	Equal	0.4758	0.5643	Notsignificant
			4.30-5.30	229	Normal	31	Normal	Unequal	0.0034	0.3291	Notsignificant
	West	Right Lane	7.30-8.30	683	Nonnormal	1469	Nonnormal	Unequal	0.0002	0.0009	Significant
			12.30-1.30	780	Nonnormal	1413	Nonnormal	Equal	0.7465	0.1786	Notsignificant
			4.30-5.30	1132	Nonnormal	1409	Nonnormal	Equal	0.5644	0.6024	Notsignificant
		Middle Lane	7.30-8.30	577	Nonnormal	1086	Nonnormal	Unequal	0.0001	0.4979	Notsignificant
			12.30-1.30	764	Nonnormal	1092	Nonnormal	Unequal	0.0001	0.0001	Significant
			4.30-5.30	1108	Nonnormal	1052	Nonnormal	Unequal	0.0001	0.7564	Notsignificant
		Left Lane	7.30-8.30	116	Normal	34	Normal	Equal	0.8224	0.1384	Notsignificant
			12.30-1.30	103	Nonnormal	27	Normal	Equal	0.0724	0.0018	Significant
			4.30-5.30	277	Nonnormal	26	Normal	Equal	0.2780	0.6692	Notsignificant

Table A-02. Statistical test results from SAS for the truck speed at McMillan road location

Location	Direction	Lane	Time	No. of trucks (Before)	Normal distribution (Before)	No. of trucks (After)	Normal distribution (After)	Equality of variances	p-value from equality of variance	p-value from t-test for speed	Significantly Change in speed
McMillan Road	East	Right Lane	7.30-8.30	737	Nonnormal	561	Nonnormal	Equal	0.1080	0.0001	Significant
			12.30-1.30	892	Nonnormal	896	Nonnormal	Equal	0.3107	0.0015	Significant
			4.30-5.30	735	Nonnormal	926	Nonnormal	Unequal	0.0192	0.5454	Notsignificant
		Middle Lane	7.30-8.30	703	Nonnormal	502	Nonnormal	Unequal	0.0001	0.0667	Notsignificant
			12.30-1.30	1072	Nonnormal	941	Nonnormal	Equal	0.0641	0.2508	Notsignificant
			4.30-5.30	898	Nonnormal	994	Nonnormal	Unequal	0.0001	0.9353	Notsignificant
		Left Lane	7.30-8.30	143	Normal	24	Normal	Equal	0.5489	0.5166	Notsignificant
			12.30-1.30	523	Nonnormal	45	Normal	Equal	0.8608	0.4571	Notsignificant
			4.30-5.30	268	Nonnormal	40	Normal	Equal	0.1385	0.0001	Significant
	West	Right Lane	7.30-8.30	1047	Nonnormal	949	Nonnormal	Equal	0.9413	0.0001	Significant
			12.30-1.30	1025	Nonnormal	823	Nonnormal	Unequal	0.0246	0.0001	Significant
			4.30-5.30	1275	Nonnormal	1149	Nonnormal	Equal	0.4522	0.0001	Significant
		Middle Lane	7.30-8.30	778	Nonnormal	685	Nonnormal	Unequal	0.0024	0.0001	Significant
			12.30-1.30	1242	Nonnormal	663	Nonnormal	Equal	0.0545	0.0001	Significant
			4.30-5.30	1249	Nonnormal	885	Nonnormal	Equal	0.6819	0.0001	Significant
		Left Lane	7.30-8.30	111	Normal	21	Normal	Equal	0.5470	0.6083	Notsignificant
			12.30-1.30	304	Nonnormal	18	Normal	Equal	0.4726	0.0018	Significant
			4.30-5.30	211	Nonnormal	21	Normal	Equal	0.2098	0.2980	Notsignificant

Table A-03. Statistical test results from SAS for the truck speed at Walker Spring road location

Location	Direction	Lane	Time	Sample (Before)	Normal distribution (Before)	Sample (After)	Normal distribution (After)	Equality of variances	p-value from equality of variance	p-value from t-test for speed	Significantly Change in speed
Walker Spring Road	East	Right Lane	7.30-8.30	100	Nonnormal	78	Nonnormal	Unequal	0.0001	0.0001	Significant
			12.30-1.30	172	Nonnormal	75	Normal	Unequal	0.0005	0.0029	Significant
			4.30-5.30	128	Nonnormal	122	Nonnormal	Equal	0.1496	0.0001	Significant
		Middle Right Lane	7.30-8.30	626	Nonnormal	455	Nonnormal	Unequal	0.0001	0.0001	Significant
			12.30-1.30	1202	Nonnormal	419	Nonnormal	Unequal	0.0001	0.0001	Significant
			4.30-5.30	791	Nonnormal	593	Nonnormal	Unequal	0.0067	0.0001	Significant
		Middle Left Lane	7.30-8.30	823	Nonnormal	372	Nonnormal	Equal	0.3346	0.7485	Notsignificant
			12.30-1.30	1297	Nonnormal	331	Nonnormal	Equal	0.2337	0.0001	Significant
			4.30-5.30	981	Nonnormal	609	Nonnormal	Unequal	0.0001	0.0001	Significant
		Left Lane	7.30-8.30	115	Nonnormal	29	Nonnormal	Equal	0.7802	0.0453	Significant
			12.30-1.30	285	Nonnormal	10	Normal	Equal	0.1238	0.0231	Significant
			4.30-5.30	252	Nonnormal	53	Nonnormal	Unequal	0.0054	0.0001	Significant
	West	Right Lane	7.30-8.30	285	Nonnormal	105	Normal	Equal	0.6879	0.2428	Notsignificant
			12.30-1.30	260	Nonnormal	116	Nonnormal	Equal	0.4505	0.0001	Significant
			4.30-5.30	153	Nonnormal	79	Normal	Equal	0.3498	0.0002	Significant
		Middle Right Lane	7.30-8.30	887	Nonnormal	390	Nonnormal	Equal	0.5468	0.0001	Significant
			12.30-1.30	715	Nonnormal	383	Nonnormal	Equal	0.8003	0.0001	Significant
			4.30-5.30	843	Nonnormal	460	Nonnormal	Equal	0.9773	0.0001	Significant
		Middle Left Lane	7.30-8.30	1256	Nonnormal	304	Nonnormal	Equal	0.5465	0.0001	Significant
			12.30-1.30	940	Nonnormal	332	Nonnormal	Unequal	0.0073	0.0001	Significant
			4.30-5.30	1171	Nonnormal	440	Nonnormal	Unequal	0.0001	0.0001	Significant
		Left Lane	7.30-8.30	270	Nonnormal	25	Nonnormal	Equal	0.2418	0.5395	Notsignificant
			12.30-1.30	155	Nonnormal	34	Normal	Equal	0.3938	0.0047	Significant
			4.30-5.30	286	Normal	71	Normal	Equal	0.2621	0.0001	Significant

Table A-04. Statistical test results from SAS for the truck speed at Watt road location

Location	Direction	Lane	Time	No. of trucks (Before)	Normal distribution (Before)	No. of trucks (After)	Normal distribution (After)	Equality of variances	p-value from equality of variance	p-value from t-test for speed	Significantly Change in speed
Watt Road	East	Right Lane	7.30-8.30	946	Nonnormal	501	Nonnormal	Equal	0.1643	0.0001	Significant
			12.30-1.30	1200	Nonnormal	605	Nonnormal	Unequal	0.0001	0.0001	Significant
			4.30-5.30	1256	Nonnormal	291	Nonnormal	Equal	0.0609	0.0001	Significant
		Middle Lane	7.30-8.30	586	Nonnormal	332	Normal	Equal	0.4675	0.0554	Notsignificant
			12.30-1.30	944	Nonnormal	576	Nonnormal	Unequal	0.0001	0.0001	Significant
			4.30-5.30	892	Nonnormal	333	Nonnormal	Unequal	0.0001	0.0001	Significant
		Left Lane	7.30-8.30	43	Normal	17	Nonnormal	Equal	0.9938	0.2794	Notsignificant
			12.30-1.30	139	Normal	50	Nonnormal	Unequal	0.0001	0.0005	Significant
			4.30-5.30	114	Normal	23	Normal	Equal	0.4102	0.0001	Significant
	West	Right Lane	7.30-8.30	509	Nonnormal	363	Nonnormal	Equal	0.5208	0.0033	Significant
			12.30-1.30	686	Nonnormal	176	Normal	Equal	0.4242	0.2883	Notsignificant
			4.30-5.30	634	Nonnormal	128	Normal	Unequal	0.0032	0.0001	Significant
		Middle Lane	7.30-8.30	982	Nonnormal	609	Nonnormal	Unequal	0.0092	0.0052	Significant
			12.30-1.30	1172	Nonnormal	329	Nonnormal	Equal	0.2843	0.0001	Significant
			4.30-5.30	963	Nonnormal	182	Normal	Unequal	0.0098	0.0001	Significant
		Left Lane	7.30-8.30	240	Normal	70	Normal	Unequal	0.0234	0.0047	Significant
			12.30-1.30	314	Normal	33	Normal	Equal	0.1135	0.2426	Notsignificant
			4.30-5.30	266	Normal	31	Normal	Equal	0.3199	0.0852	Notsignificant

Vita

Vasin Kiattikomol was born in Bangkok, Thailand, in 1978. He received a Bachelor's degree of Civil Engineering from Sirindhorn International Institute of Technology, Thammasat University in his hometown in 1999. He entered the University of Tennessee for pursuing a master's degree in Civil Engineering (Transportation) in 2000. During his graduate study, he worked with the department of Civil and Environmental Engineering as a teaching and research assistant. During his career in the Transportation field, he had opportunities to publish and present papers, attended several conferences within the United States, and helped in delivering a short course in Bangkok in collaboration with Engineering Institute of Thailand. He is a student member of two well-known engineering societies in the United States: National Society of Professional Engineers and Institute of Transportation Engineers.

In August 2002, he received the Master of Science Degree in Civil Engineering with a concentration in Transportation Engineering.