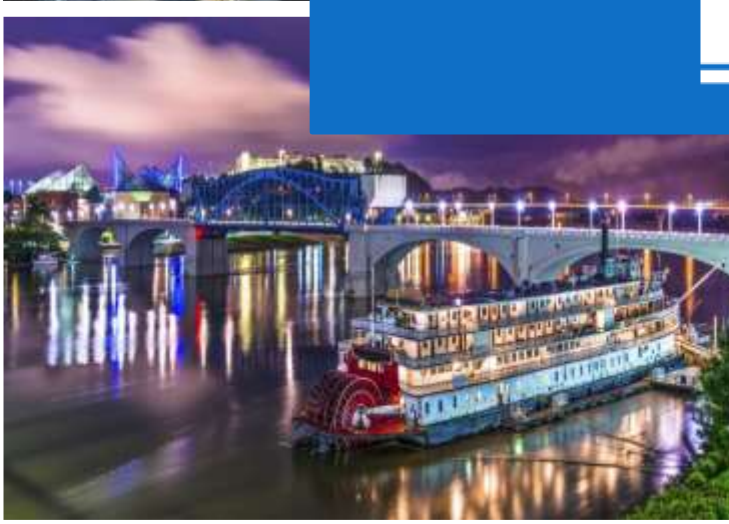
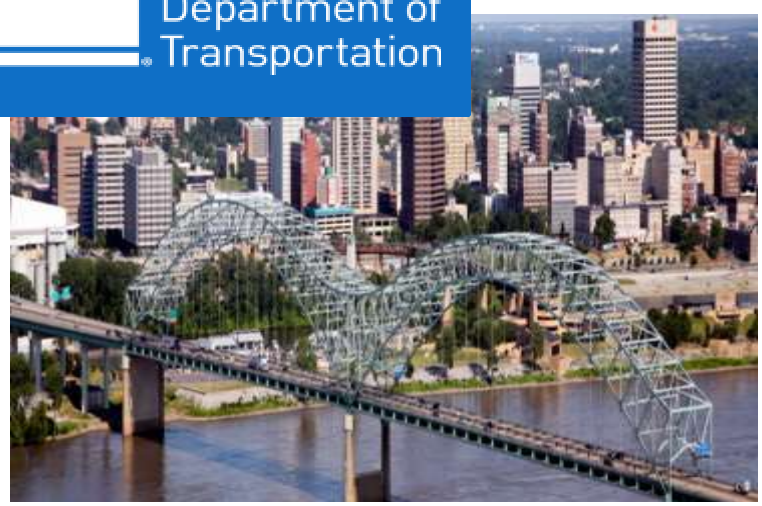
Tennessee Interstate Freight Bottleneck Analysis

Long Range Planning Division

January 11, 2019

TN TDOT Department of Transportation





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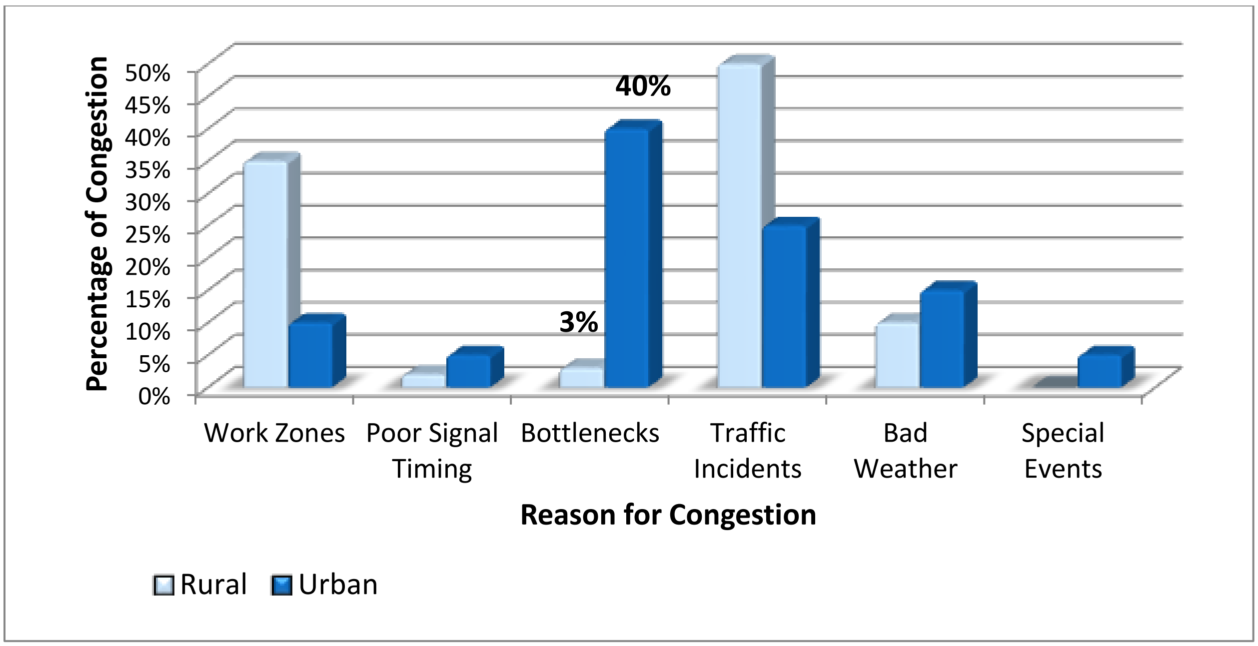
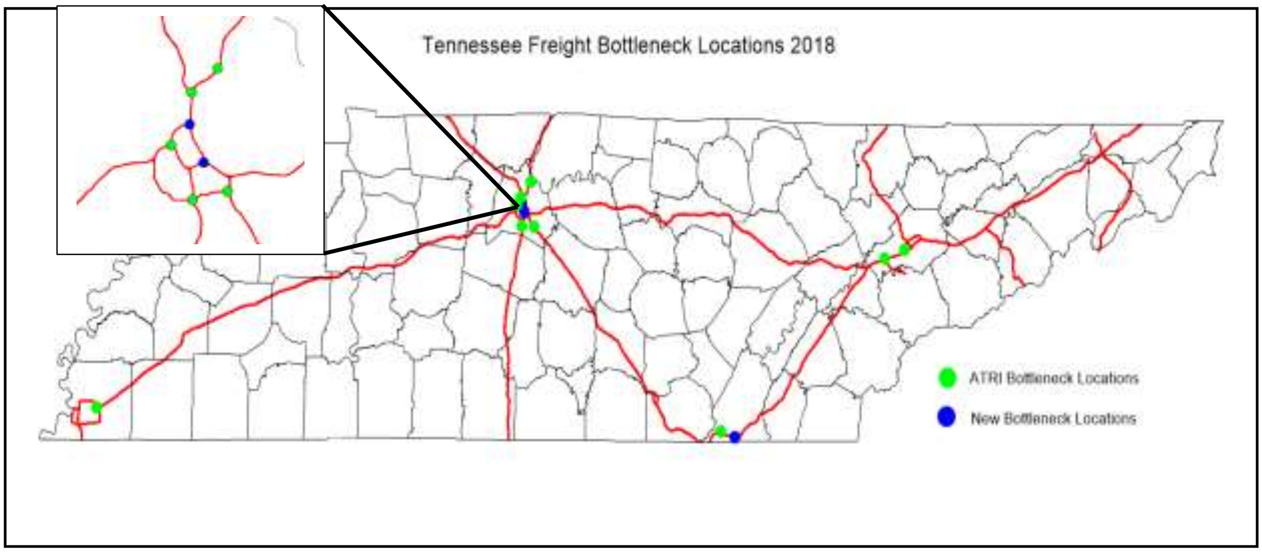
Executive Summary

The purpose of this report is to analyze Tennessee's interstates, in order to determine the types and locations of barriers and bottlenecks are that are causing freight inefficiencies in Tennessee. The freight bottleneck analysis can be used to inform freight project selection and prioritizing as well as future updates to the Tennessee Statewide Freight Plan. The analysis considers various bottleneck indicators such as: lane drops, interstate ramps, lane widths, changes in speed limits, and high frequency accident locations. Based upon these indicators, 29 potential bottlenecks were identified on Tennessee's interstate system. In order to narrow this list, travel speed data for peak and non-peak hours was also considered. Based on the travel speed data, 12 total bottlenecks were identified. Nine of these have also been identified by the American Transportation Research Institute.



Tennessee Bottleneck Locations:

We are currently developing an in-depth bottleneck analysis to study the issue at a deeper level. Throughout the interstates there were 29 locations that were identified as potential freight bottlenecks based on the number of indicators that fall within that area. However, this does not mean that each of these locations is a bottleneck just that they share the common characteristics that can lead to a freight bottleneck. Using the 29 identified locations and the NPMRDS data that displays the average peak hour and non-peak hour travel speed, the identification of the actual bottlenecks were identified. Using the NPMRDS data and the potential locations, there were 12 locations out of the 29 potential locations that were identified as an actual bottleneck due to the difference in travel speeds from peak hour and non-peak hour.



Freight Bottleneck Potential Outcome:

The next step for the bottleneck analysis in Tennessee is to develop a systematic ranking and prioritize the 12 freight bottleneck locations along the interstates. We will compare those locations to the current list of projects in the work plan. Once these high priority locations identified, we will work internally on addressing the flows through these bottlenecks using potentially technology advancements, construction, or other solutions to lessen the impact of the bottlenecks on the system in Tennessee

	Location	State	Average Speed	Peak Average Speed	Non-Peak Average Speed
1	Chattanooga: I-24 at Hwy 27	TN	49.4	42.2	52.8
2	Nashville: I-24 at I-440 (north)	TN	43.1	31.8	49.2
3	Memphis: I-40 at I-240 (east)	TN	37.7	30.8	40.7
4	Nashville: I-65 at I-440	TN	49.4	39.8	53.9
5	Nashville: I-40 at I-65 (east)	TN	43.5	33.3	48.3
6	Nashville: I-65 at RT 386	TN	52.7	47.2	55
7	Nashville: I-65 at I-24	TN	49.2	41	52.7
8	Knoxville: I-40/I-75 at I-140	TN	53.4	49.5	55
9	Knoxville: I-40 at I-640 (west)	TN	53.5	50.2	54.9
10	Nashville: I-24 at I-65	TN	51.1	44.2	53.6
11	Nashville: I-40 at I-24	TN	49.3	41.2	53
12	Chattanooga: I-75 at I-24	TN	53.7	46	56.4

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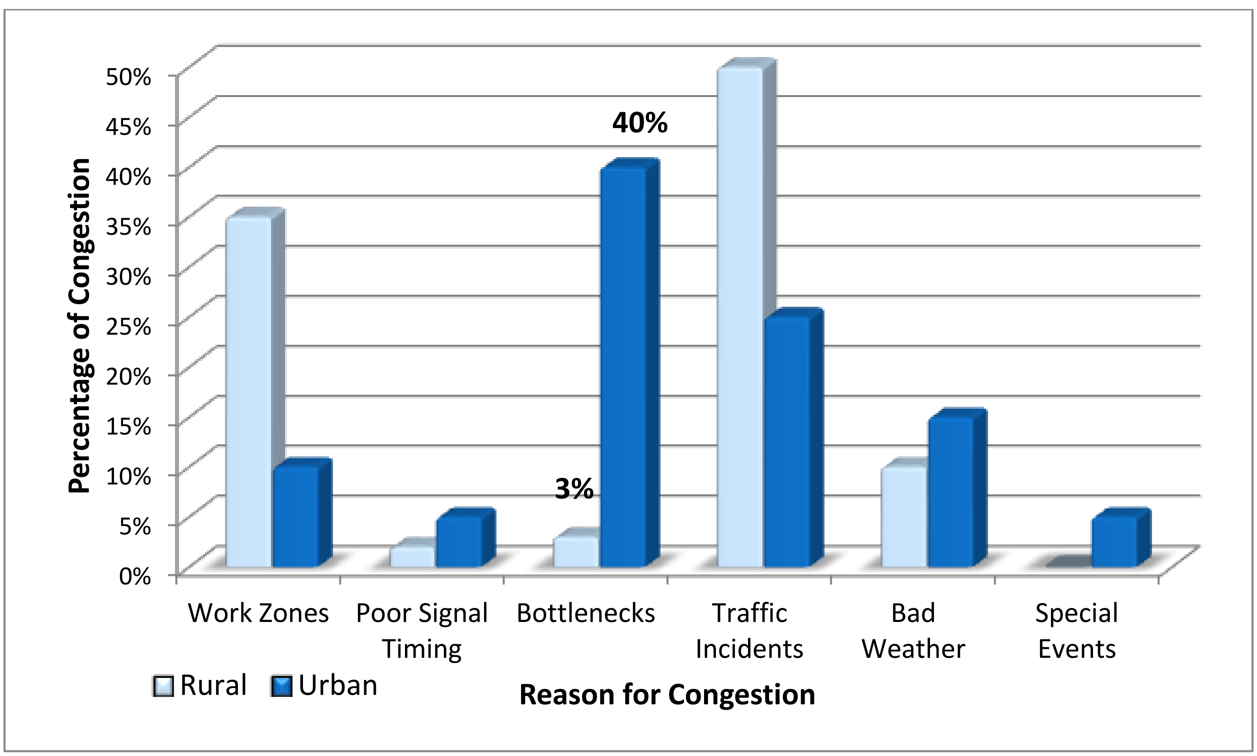
Chapter 1. Tennessee Freight Bottleneck Analysis

1.0 Introduction

The purpose of this report is to provide an analysis of the potential freight bottleneck locations within Tennessee that are causing freight to not move as effectively through Tennessee. A bottleneck is a localized disruption of vehicular traffic on a street, road, or highway. As opposed to a traffic jam, a bottleneck is a result of a specific physical condition, often the design of the road, badly timed traffic lights, or sharp curves. They can also be caused by temporary situations, such as vehicular accidents. Bottlenecks can also occur in other methods of transportation. Interstate bottlenecks affecting freight movement are a major problem today, because they delay a large number of truck freight shipments. They will become increasingly problematic in the future as the U.S. economy grows and generates more demand for truck freight shipments. If the U.S. economy grows at a conservative annual rate of 2.5 to 3 percent over the next 20 years, domestic freight tonnage will almost double and the volume of freight moving through the largest international gateways may triple or quadruple. **Figure 1.0** illustrates the national estimates of different variables that contribute to the total congestion based on the estimates made by the Federal Highway Administration (FHWA).

Figure 1.0. Congestion Contributors and Their Percentage. *Federal Highway Administration*



The main focus point for the freight bottleneck analysis was on the interstates. **Figure 1.1** illustrates the interstates in Tennessee that were used as the focus point for the freight bottleneck analysis. The reasoning for selecting the interstates for this analysis is because of the large amount of freight movement on the interstates compared to the rest of the roads in Tennessee. As represented in **figure 1.2** there is a large amount of freight movement on the interstates where the movement of freight off the interstates is relatively low.

The goal behind conducting a freight bottleneck analysis is to identify where the location are at in Tennessee along the interstates that are causing delays in the movement of freight. The reasoning for identifying these locations is because currently Tennessee has 169 freight projects that are eligible for funding. Knowing the locations of the freight bottlenecks and the current freight projects TDOT can prioritize the freight projects so that projects that fall near the freight bottleneck locations are handled first as well as future updates to the Tennessee statewide Freight Plan.

Figure 1.1. Map Visual of the Main Freight Road System

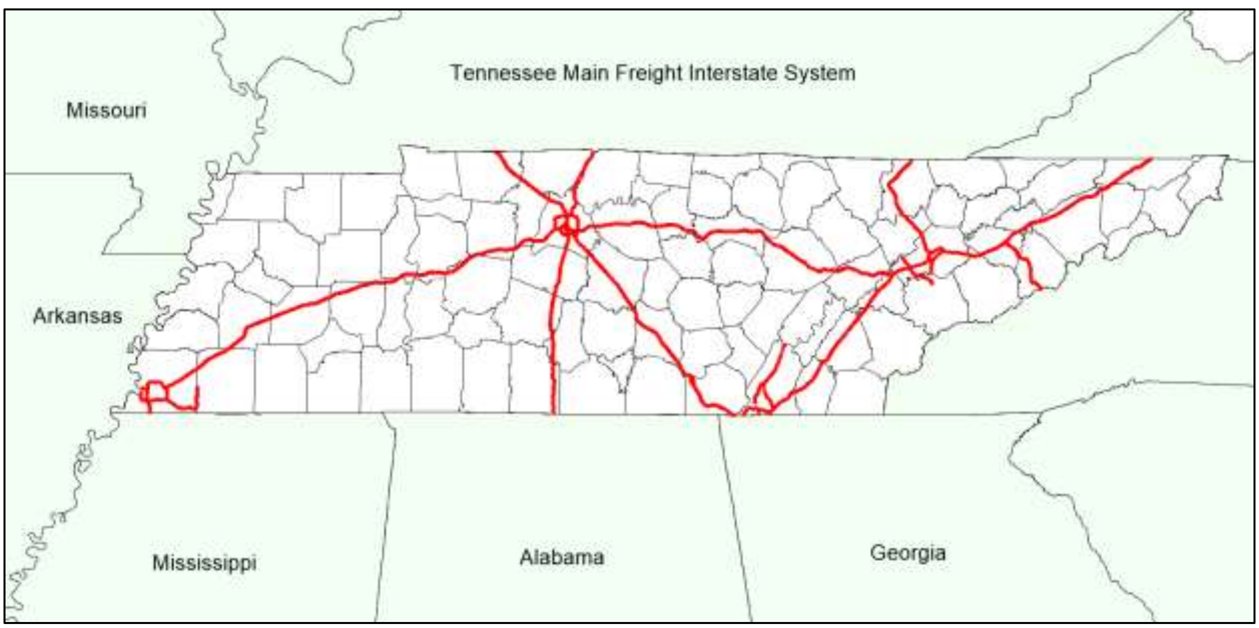
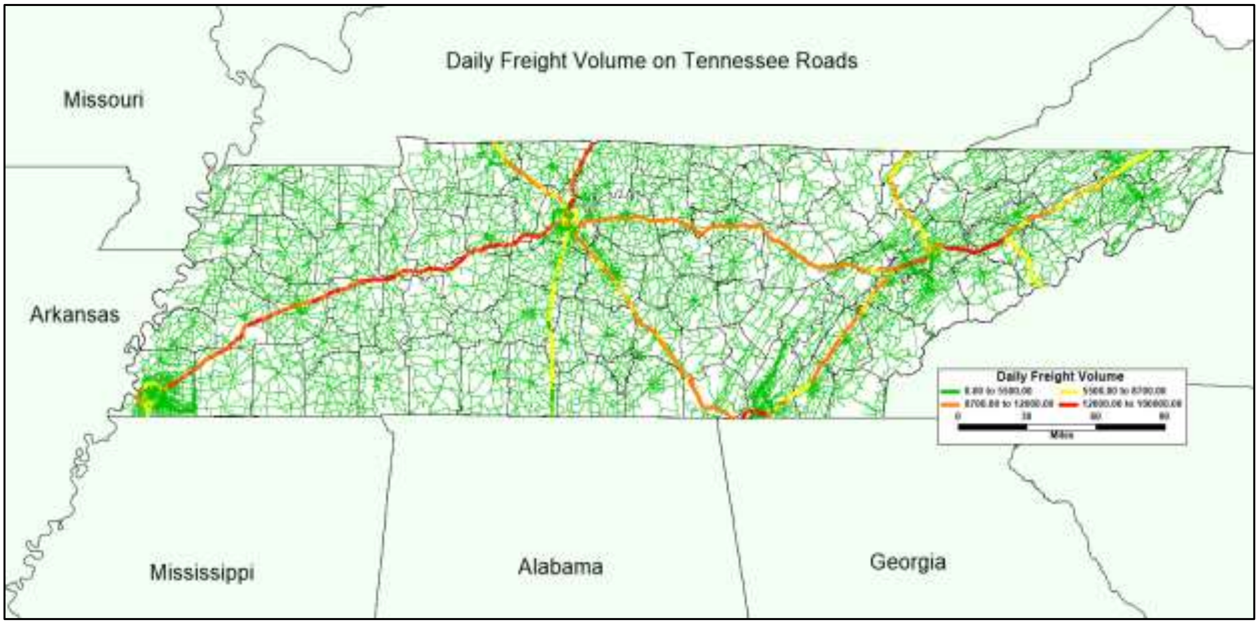


Figure 1.2. Daily Freight Volume on Tennessee Interstates

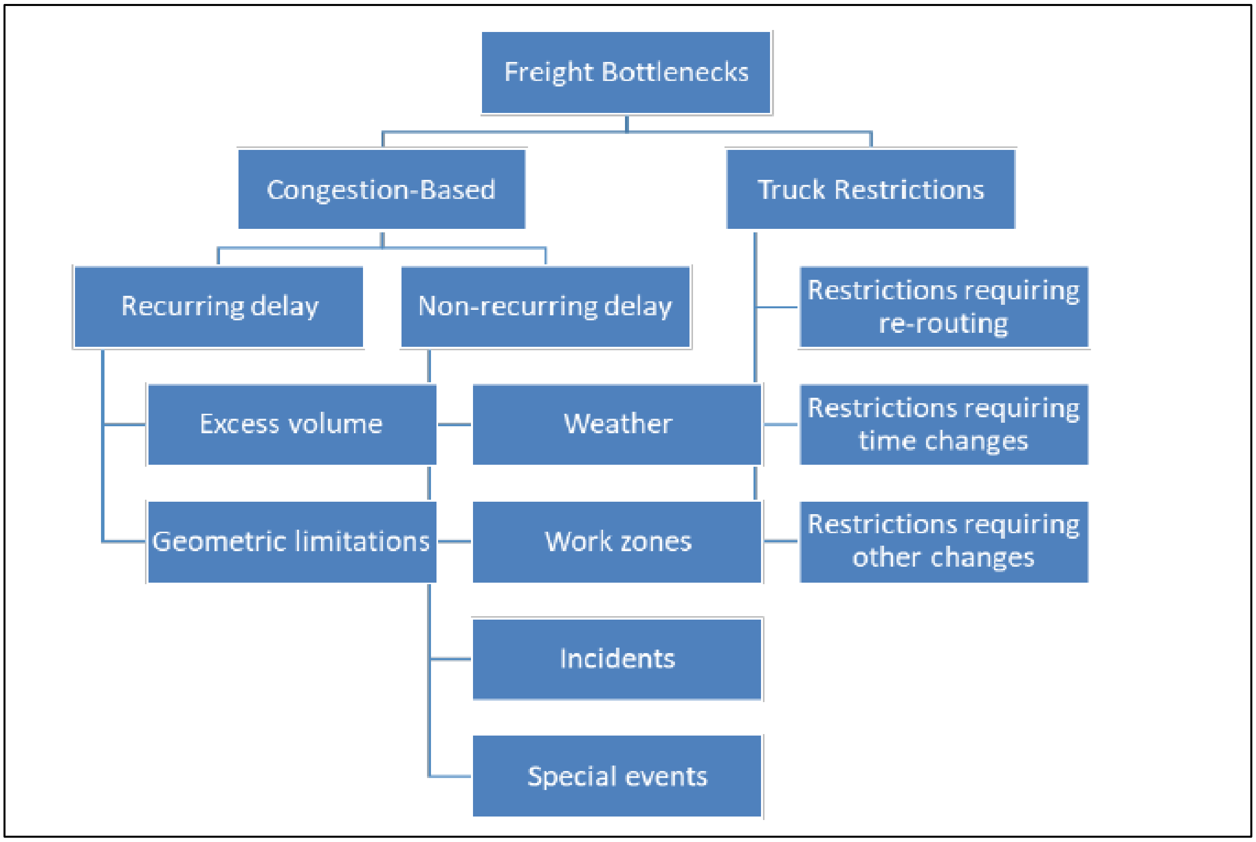


With the identification of the locations in which this analysis will be done, the next step is to identify the different factors that will be considered when determine how much of a risk a certain location is with response to delaying the movement of freight in Tennessee.

1.1 Indicators of Bottlenecks for Freight

The following section is used to describe the different indicators that will be used in this freight bottleneck analysis. The Federal Highway Administration identifies there are two main types of bottlenecks for freight; congestion bottlenecks and truck restriction bottlenecks. A *congestion bottleneck* is characterized by a significant reduction in average truck speeds, which can either be recurrent or non-recurrent. Their severity is a function of how many trucks are impacted, how significant truck speeds are reduced, and how long the significant reduction in truck speeds occur does. On the other side there is the *truck restriction bottleneck* which can be attributed to physical infrastructure condition which restricts truck movement or zoning requirements that prohibit trucks from operating on a specific route permanently or during a certain time period. Both uniquely impact truck operations and may require commercial vehicle operators to take an alternate route (typically longer), or travel at different times of day. **Figure 1.3** show the taxonomy of freight bottleneck by type, which was designed by the Federal Highway Administration.

Figure 1.3. FHWA's Taxonomy of Freight Bottleneck Types. *Federal Highway Administration*



With the understanding of the two main types of freight bottlenecks, that were classified by the Federal Highway Administration, the next step is to identify the bottleneck indicators that will be used in this report to get an understanding of the location within Tennessee. The indicators are going to be described which contribute to a bottleneck and provide a detail description of each indicator. Not only will there be a description of what each indicator is, but an understanding of how it contributes to the freight bottleneck. Traffic bottlenecks are caused by a wide variety of things such as:

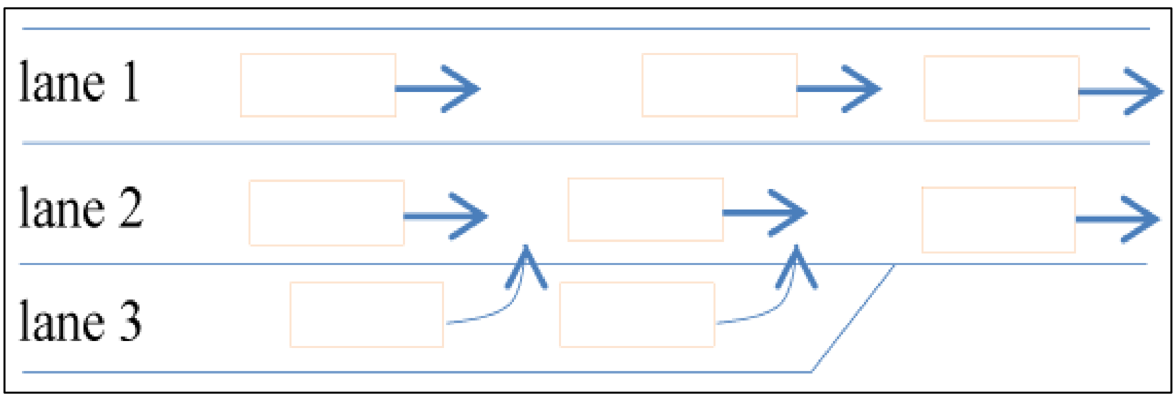
- ⇒ Lane drop, or the reduction in the number of lanes
- ⇒ Freeway ramps, both entering and exiting
- ⇒ Width of interstate lanes
- ⇒ Change in the speed limit
- ⇒ High frequency of accidents

Each of the bottleneck indicators is compared to the freight movement map to gain insight into the potential bottlenecks on Tennessee's interstates. Using the results of this comparative analysis, major and minor bottlenecks are then identified and classified.

Lane Drop of Reduction in the Number of Lanes

A reduction in the number of lanes is defined as a location on a highway where the number of lanes provided for traffic has decreased. A decrease in the number of lanes can lead to a potential bottleneck because as the lanes drop, vehicles will be forced to merge into the available lanes, which could result in vehicles needing to slow down or even, come to a complete stop in order to merge safely into the available lanes. This is compounded with freight trucks as their physical size needs more of a gap to safely merge within existing traffic. Additionally, the acceleration and deceleration concerns of a heavy truck vehicle operator impede the constant and consistent speeds of other traffic. Additionally, truck 'blind spots' and consideration of the passenger vehicles to give adequate merge room; reduce the flow of traffic (especially in high volume areas). **Figure 1.4** illustrates what a lane drop looks line on a road.

Figure 1.4 Illustration of a Lane Drop



Freeway Ramps Entering and Exiting

A freeway ramp is a short segment of a road that allows for vehicles to enter or exit off of a highway. Freeway ramps are a major indicator of a potential bottleneck because they have vehicles moving as a slower speed trying to enter onto the roads which have higher speeds. Some freeways can be larger threats to potential bottlenecks, because they will have a shorter merge lane which will cause vehicles to reduce speed to safely merge with the highway traffic into one highway lane. In some cases when there is a large volume of traffic trying to merge onto a road that also has a large traffic flow, the reduction of speed in both lanes is necessary to safely to safely navigate onto the highway. This will result in all traffic speeds being reduced or even come to a stop until the vehicles trying to merge have successfully made it onto the highway creating a potential bottleneck. **Figure 1.5** illustrates what a congested freeway ramp looks like, when there is a large number of a vehicle trying to merge onto a highway. There is a greater chance of being a bottleneck location with higher than normal volumes.

Figure 1.5. Freeway Ramp with Heavy Traffic

Width of Interstate Lanes

The width of a lane can also play an important role in the speed in which vehicles travel. When there are lanes that are wide, there is more potential for vehicles to travel faster because they have more room in their designated lane to operate. However, if there are lanes that are narrow, the speed of traffic could be restricted. Lane width will be important for freight bottlenecking because if traffic is traveling in lanes that are wider, they typically operate at higher speeds. When the road width is reduced, traffic typically reduces speed which could cause a bottleneck and result in slower or stop the flow of traffic.

Change in the Speed Limit

The change of speed limits works the same as the width of the road lanes. As travel speeds decrease and vehicles have to slow down, the number of vehicles will start to become congested because not every vehicle is going to reduce their speed and eventually there could be a cluster of faster vehicles trying to pass the slower vehicles. This will occur more in situations where the speed limit decreases, rather than where it increases.

High Frequency of Accidents

An accident hotspot can be defined as clusters which are the areas of dense accident occurrence and is also a bottleneck indicator. Due to the fact that accidents can happen at any location for a variety of reasons, it is extremely hard to predict accident hot spots the idea with accident hot spots is to analyze the accidents that happen on the interstates and systematically determine which locations are a higher risk for accidents based on a higher proportion of accidents occurring in a specific area over time.

Over-Capacity on Roads during Peak Hours

Roads that have over capacity volumes during peak periods are a major indicator of bottleneck, as having a road that has more vehicles than the road was originally designed. This can lead to an extreme reduction of free flowing movement of vehicles impacting, delaying and congesting the network. These larger than capacity volumes are typically found in urban areas during the peak morning and afternoon ‘rush hours’ Even though these roads are typically only congested during a few t peak hours of the day, it will have an extreme impact on freight movement as they will be delayed up to several hours because of the delay in bringing traffic back to normal flows.

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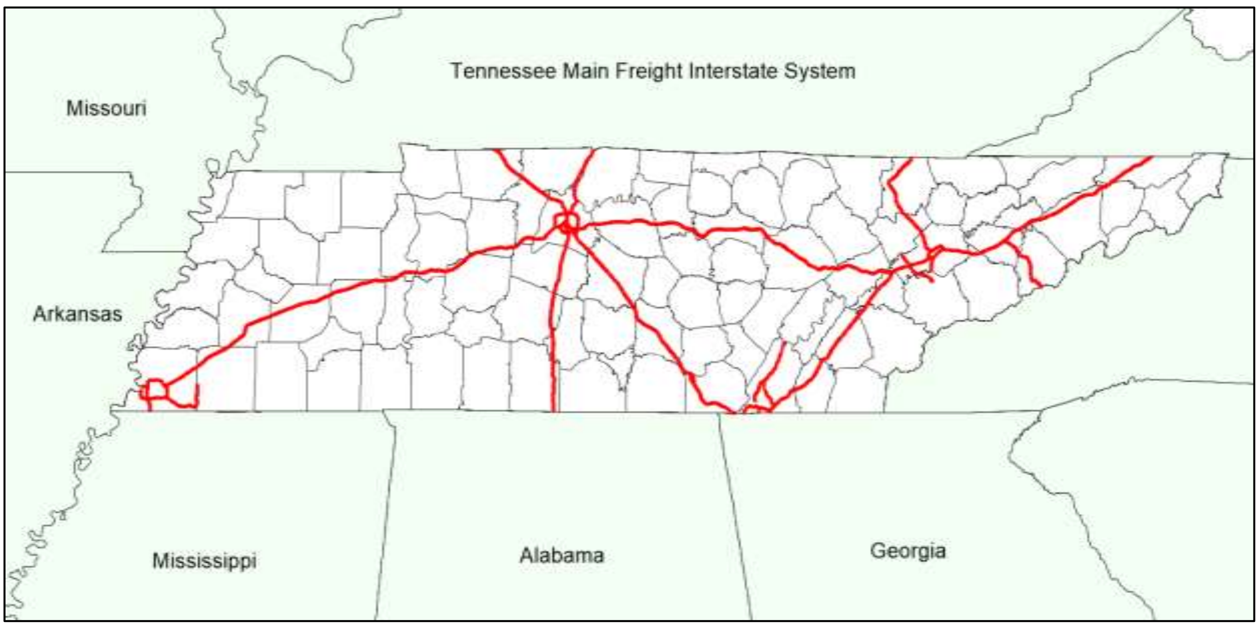
Chapter 2. Location of Bottleneck Indicators

The potential bottleneck locations on the Tennessee interstates are designed to identify the freight bottleneck indicators in Tennessee. The indicators that will be identified in this section are: lane drop or reduction in the number of lanes, freeway ramps entering and exiting, width of road lanes, change in the speed limit, accident hot spots, over capacity on roads during peak hours. This analysis will provide map images and statistical tables to summarize the data that is collected from each indicator. In addition, maps will break down the entire state of Tennessee, the four regions within the Department of Transportation, and a further detailed map of the major cities in Tennessee where most of these bottlenecks occur. **Figure 2.0** displays the interstates in Tennessee, to provide a visual representation of their location within Tennessee.

Figure 2.0. Map of Tennessee Interstate System



2.0 Number of Freight on the Interstates

Typical freight movement takes advantage and prioritizes movement on the Interstate Highway System. Higher speeds, multiple lanes, fuel stations, rest areas, truck parking are a few of the reasons why it is the preferred route over arterials or smaller roads. It is of critical importance that we measure the amount of freight on these bottlenecks as the indicators mentioned in the previous section impact freight movement delays proportionately than passenger vehicle delays. However, any bottleneck affects any user of the highway system (and alternate routes) to bypass the bottleneck location. **Figure 2.1** shows the freight movement throughout Tennessee on the interstates with **figure 2.2** through **Figure 2.5** showing close-up views of the major cities in Tennessee for 2010 and **figure 2.6** through **figure 2.10** showing the future 2040 freight movement on the interstates. The maps are displayed showing the number of freight units that are moved throughout the interstates based on daily counts. The maps will show that the areas in green have the lowest daily freight movement on the interstates.

Figure 2.1. Freight Volumes on the Interstates for 2010

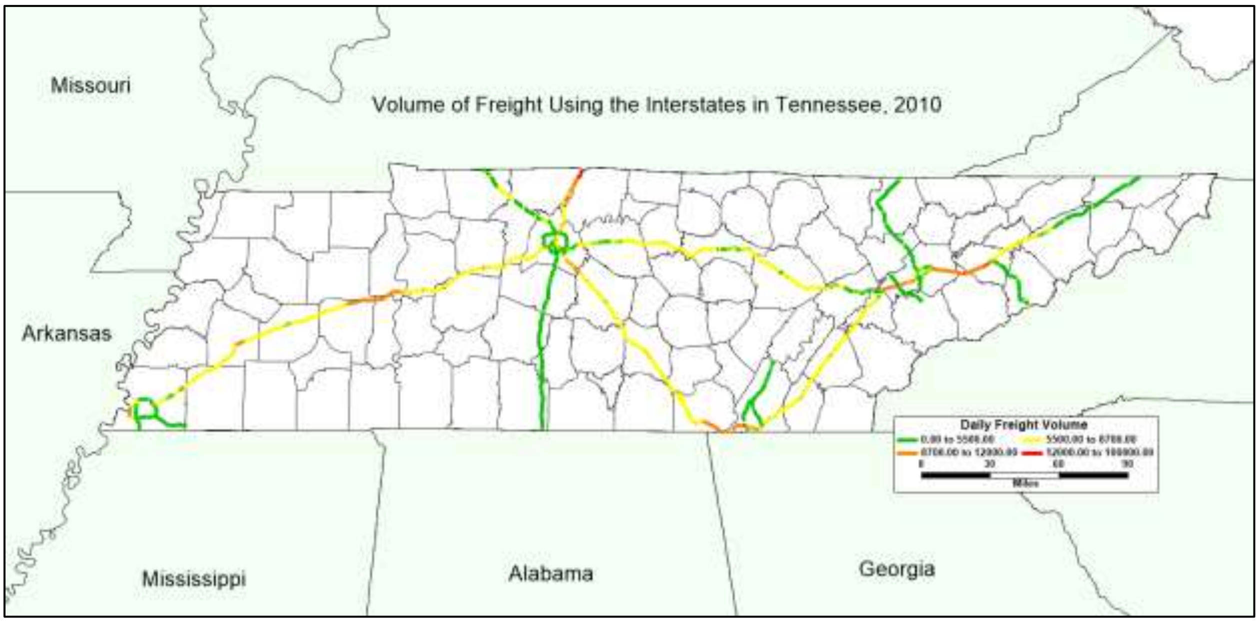


Figure 2.2. Freight Volumes on the Interstates for 2010 near Memphis

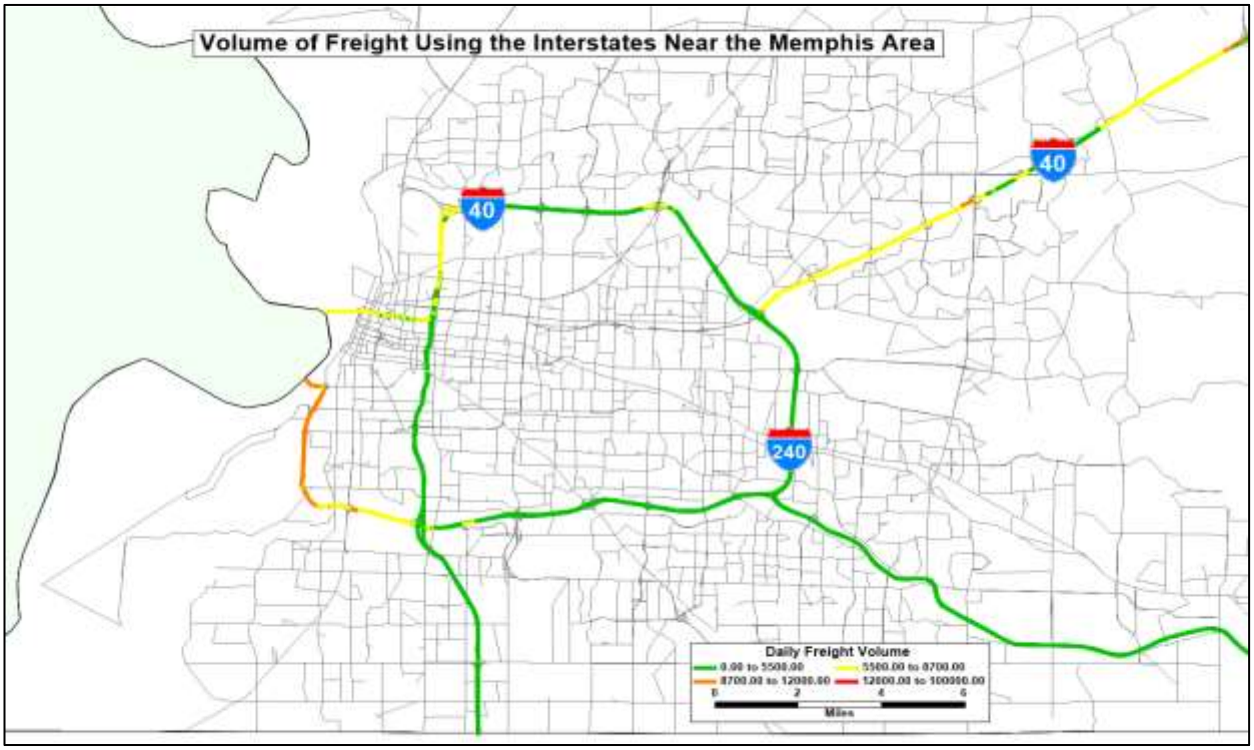


Figure 2.3. Freight Volumes on the Interstates for 2010 near Nashville

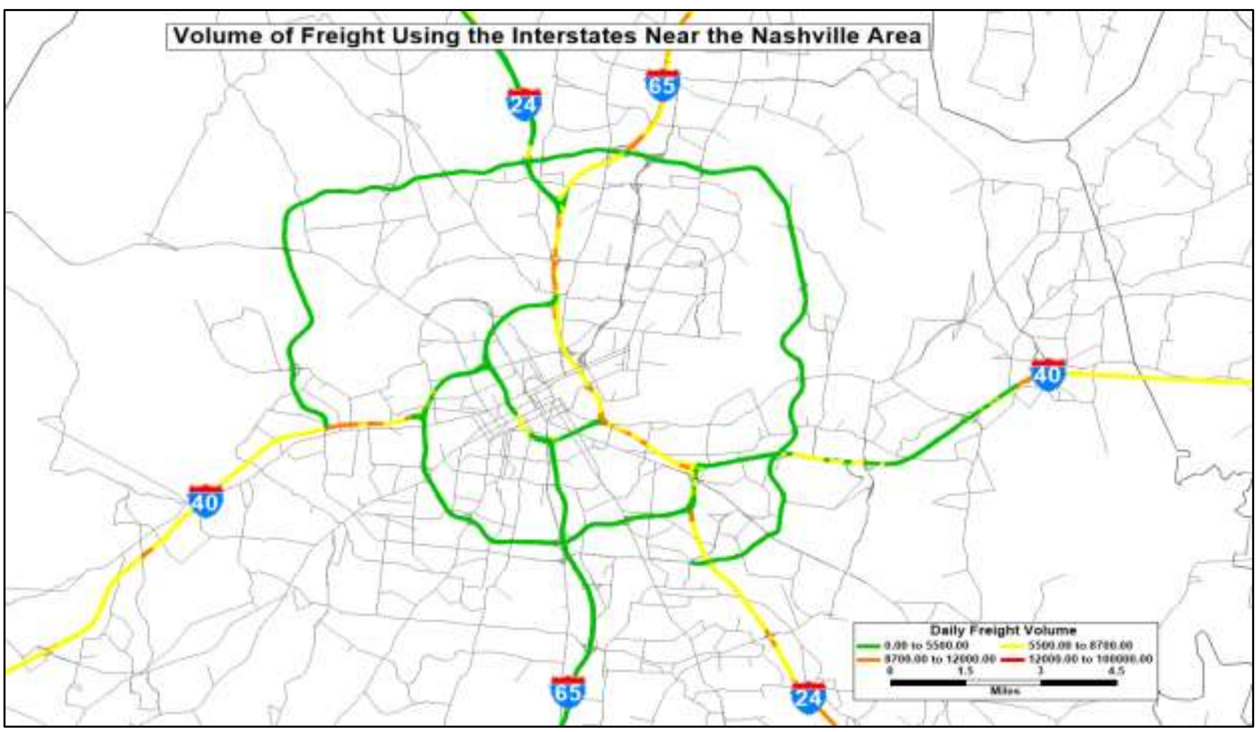


Figure 2.4. Chattanooga Freight Volumes on the Interstates for 2010 near Chattanooga

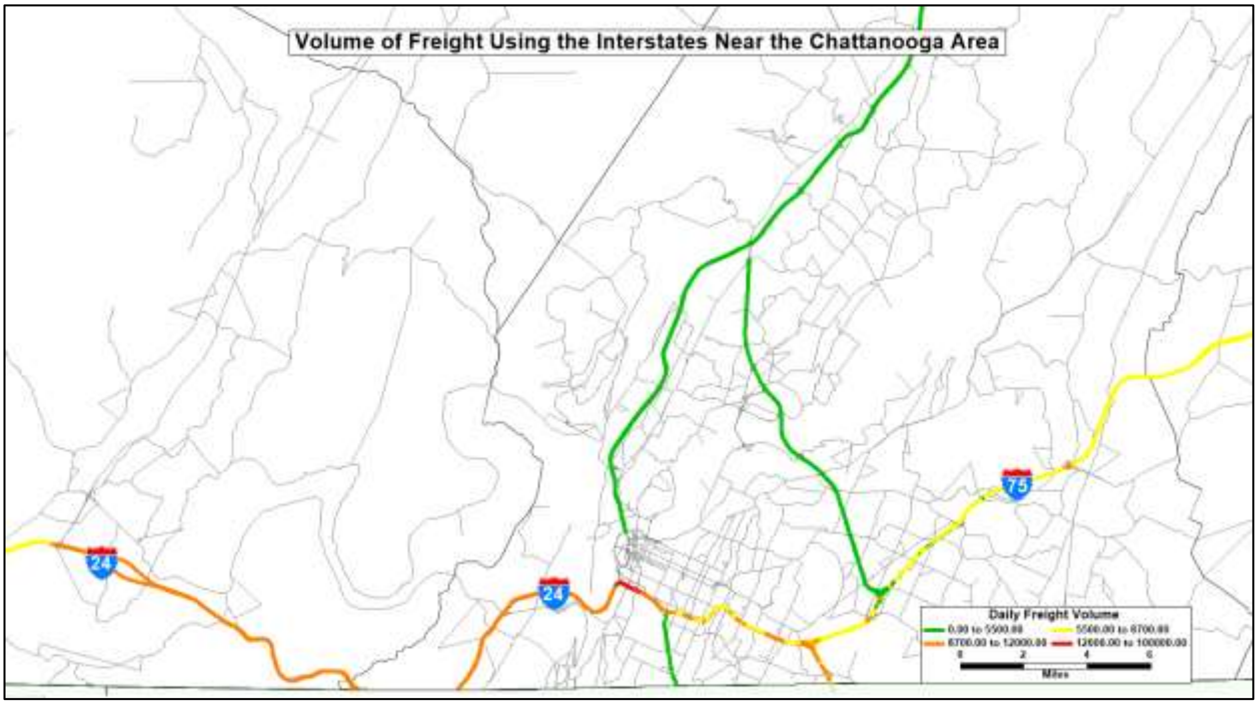


Figure 2.5. Knoxville Freight Volumes on the Interstates for 2010 near Knoxville

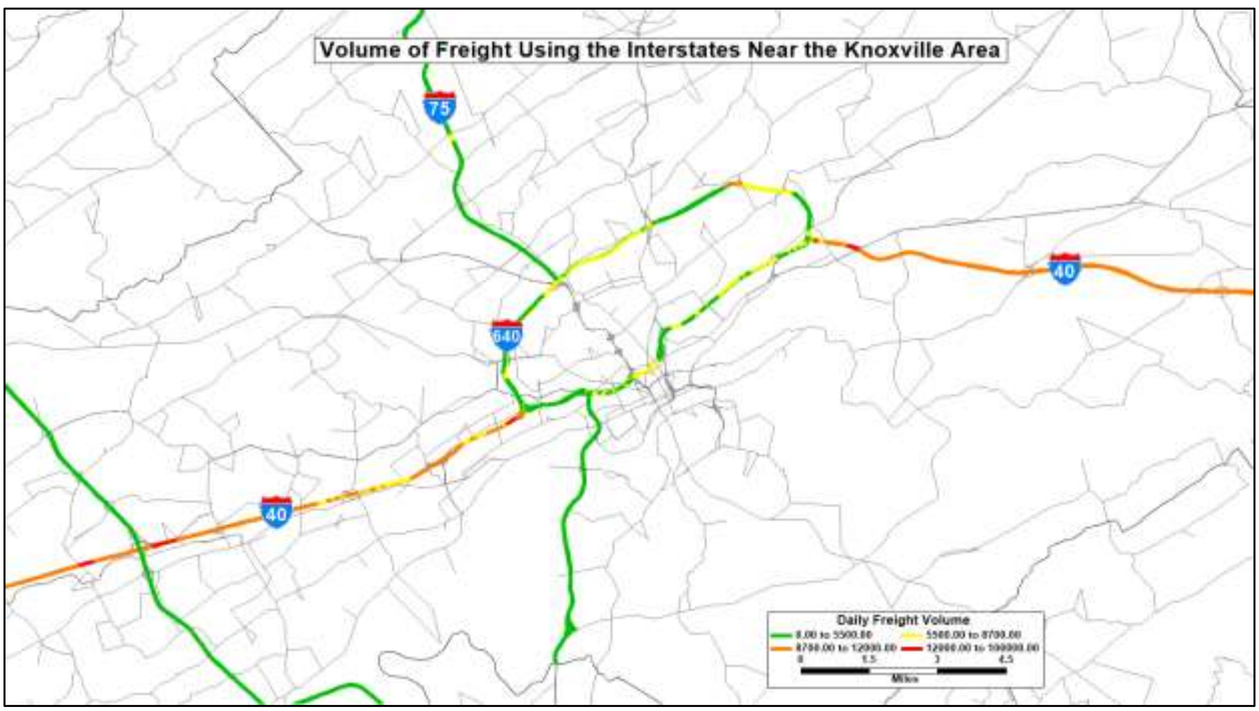


Figure 2.6. Freight Volumes on the Interstates for 2040

Figure 2.7. Freight Volumes on the Interstates for 2040 near Memphis

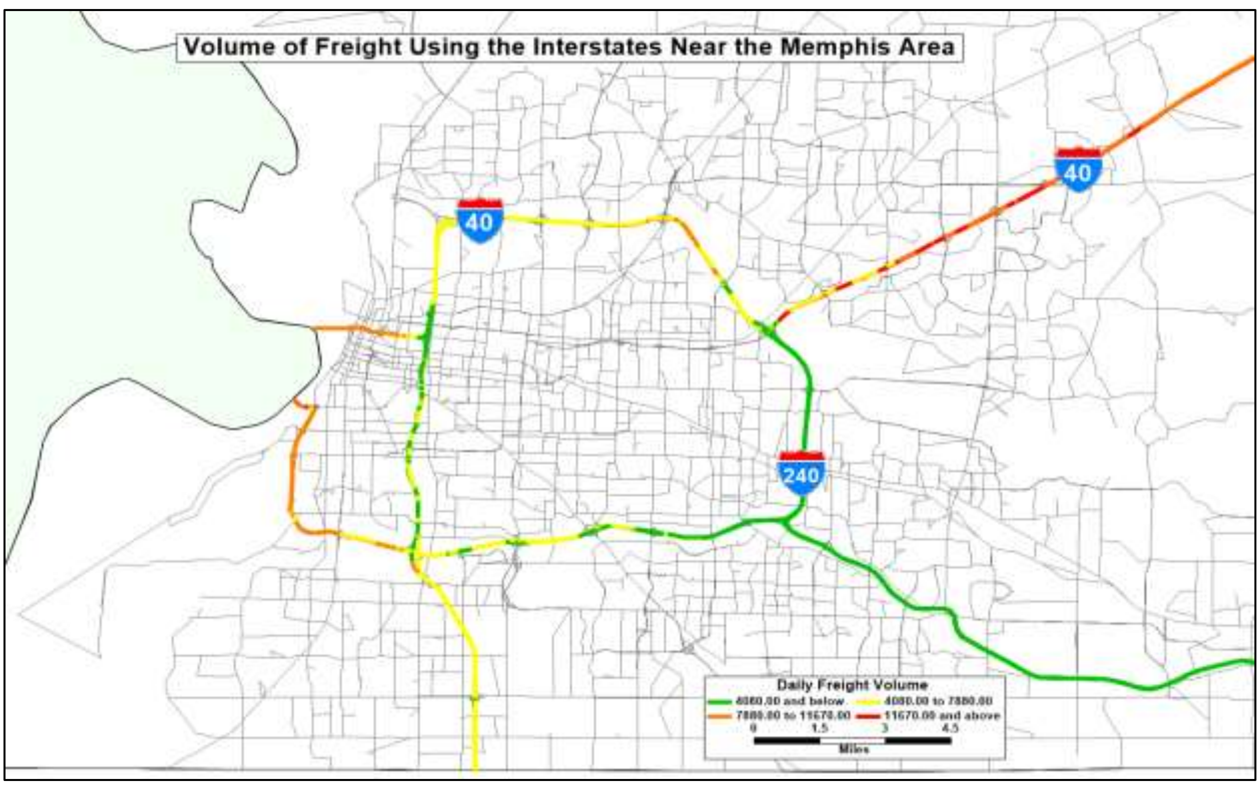


Figure 2.8. Freight Volumes on the Interstates for 2040 near Nashville

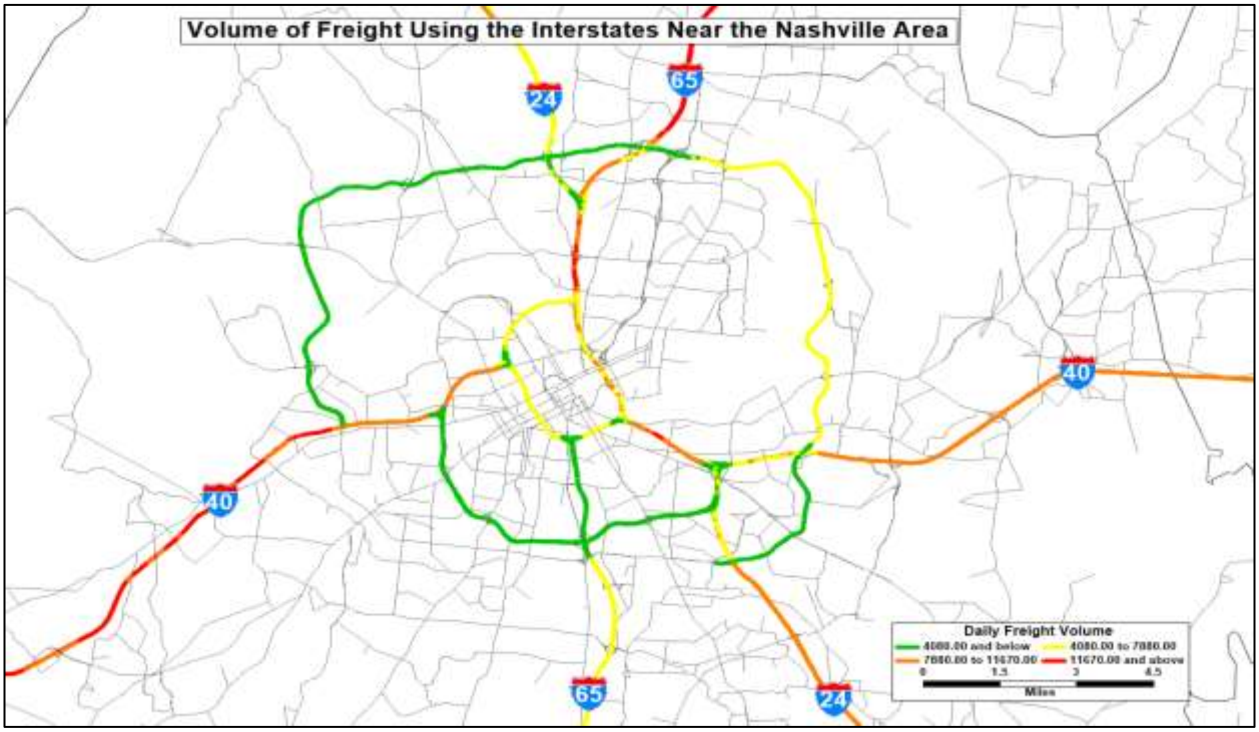


Figure 2.9. Freight Volumes on the Interstates for 2040 near Chattanooga

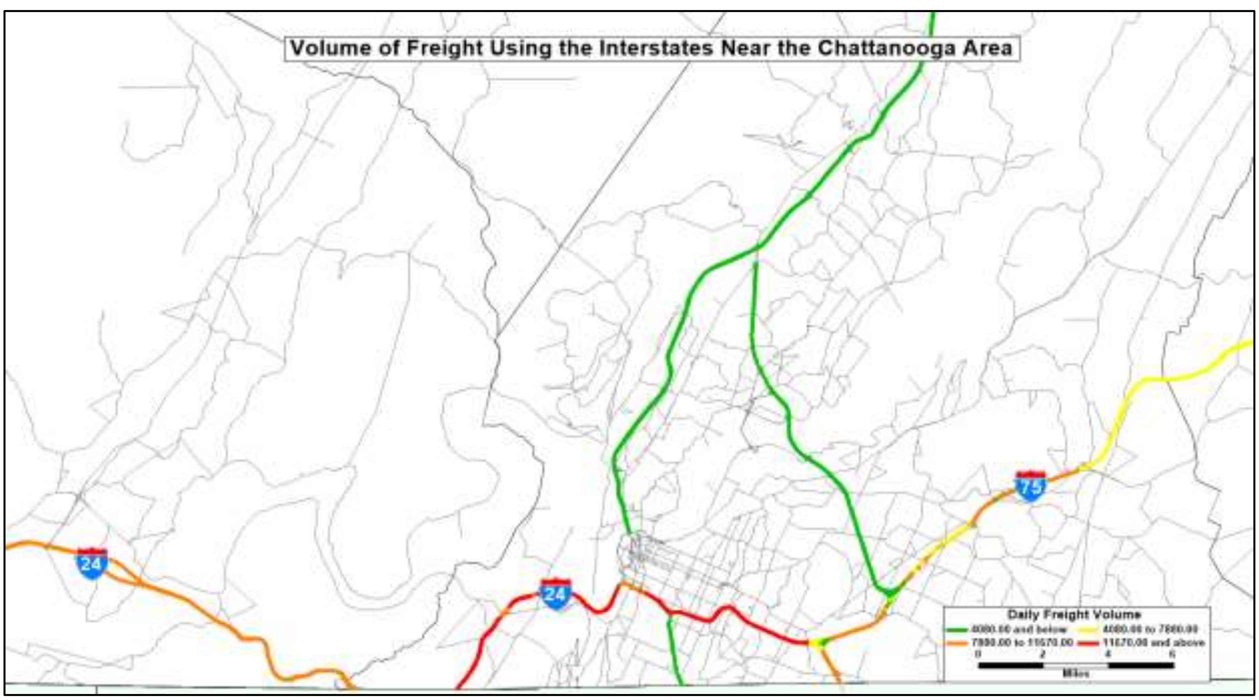
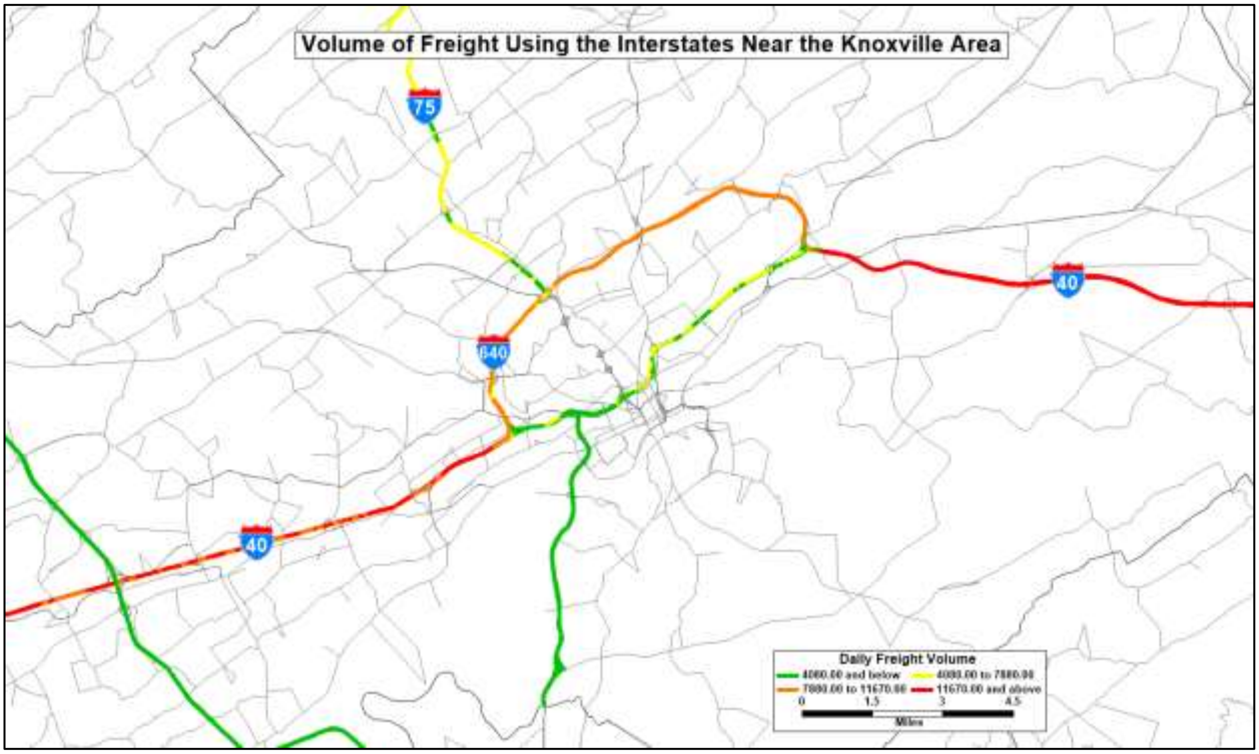


Figure 2.10. Freight Volumes on the Interstates for 2040 near Knoxville



As explained in the previous section on the preference of commercial motor vehicles utilizing the interstate highway system; it is even more critical when projecting out the growth that is predicted in 2040 and beyond. Tennessee Department of Transportation in the past recent years have constructed and opened by-passes around the major cities to potentially divert freight on these alterior routes to create less of a bottleneck, in addition to adding lanes on the current network. Two examples of these by-passes are I-840 which by-passes Nashville and I-269 which by-passes Memphis from a freight run through perspective through the state.

2.1 Ramps

The second indicator that will be analyzed as a bottleneck is the use of ramps on the interstates. **Figure 2.11** displays the major interstates in Tennessee and the ramps that are within the state, showing that a large number of the ramps are on these major interstates. Throughout Tennessee the Statewide Model identified 4,382 ramps on both the interstates and non-interstates roads, with over 70% of the ramps being location on a major interstate. On the ramps the speed limit is typically between 35 mph and 45 mph, while the speeds that vehicles are either entering or exiting the interstates are between 55 mph to 70 mph. To safely merge on and off the interstate system, vehicles would have to rapidly accelerate or decelerate with traffic potentially creating a bottleneck.

Figure 2.11. Location of Ramps in Tennessee

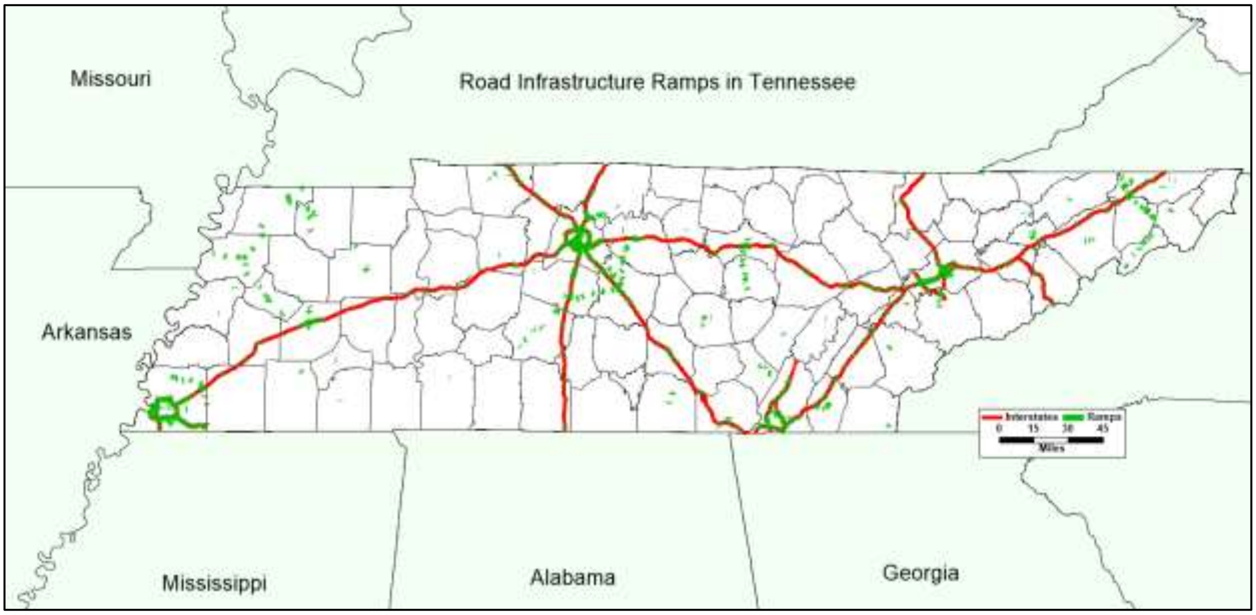


Figure 2.12. Location of Ramps near Memphis

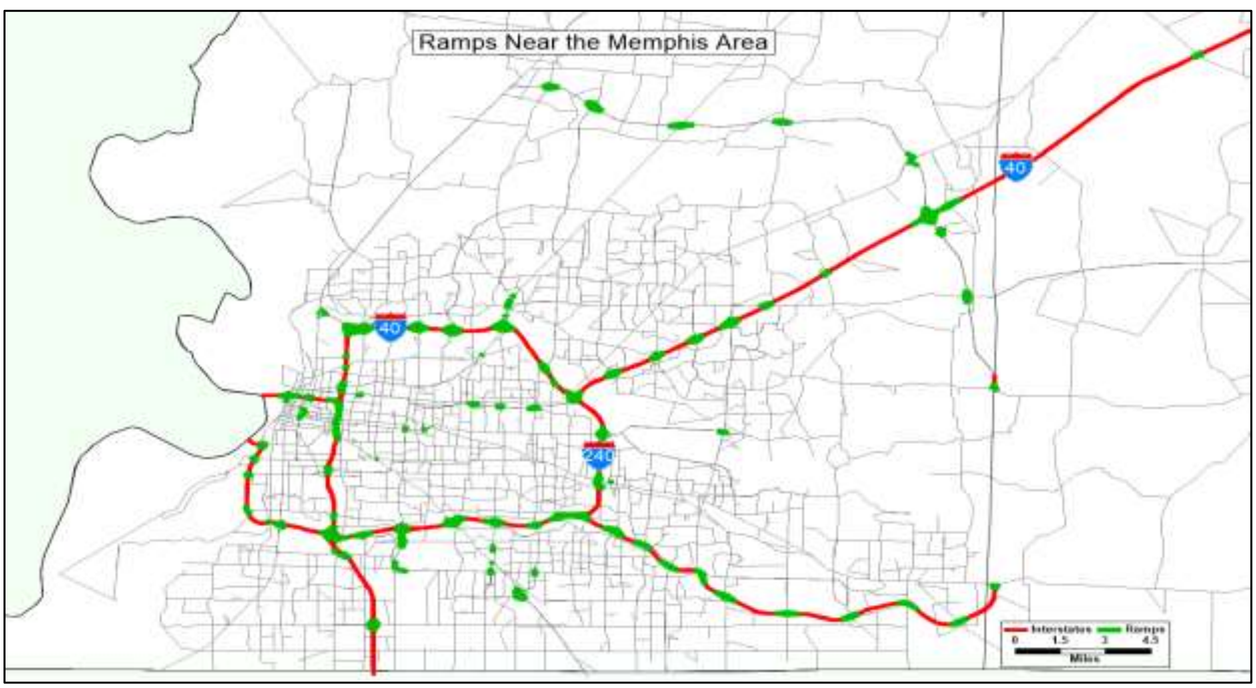


Figure 2.13. Location of Ramps near Nashville

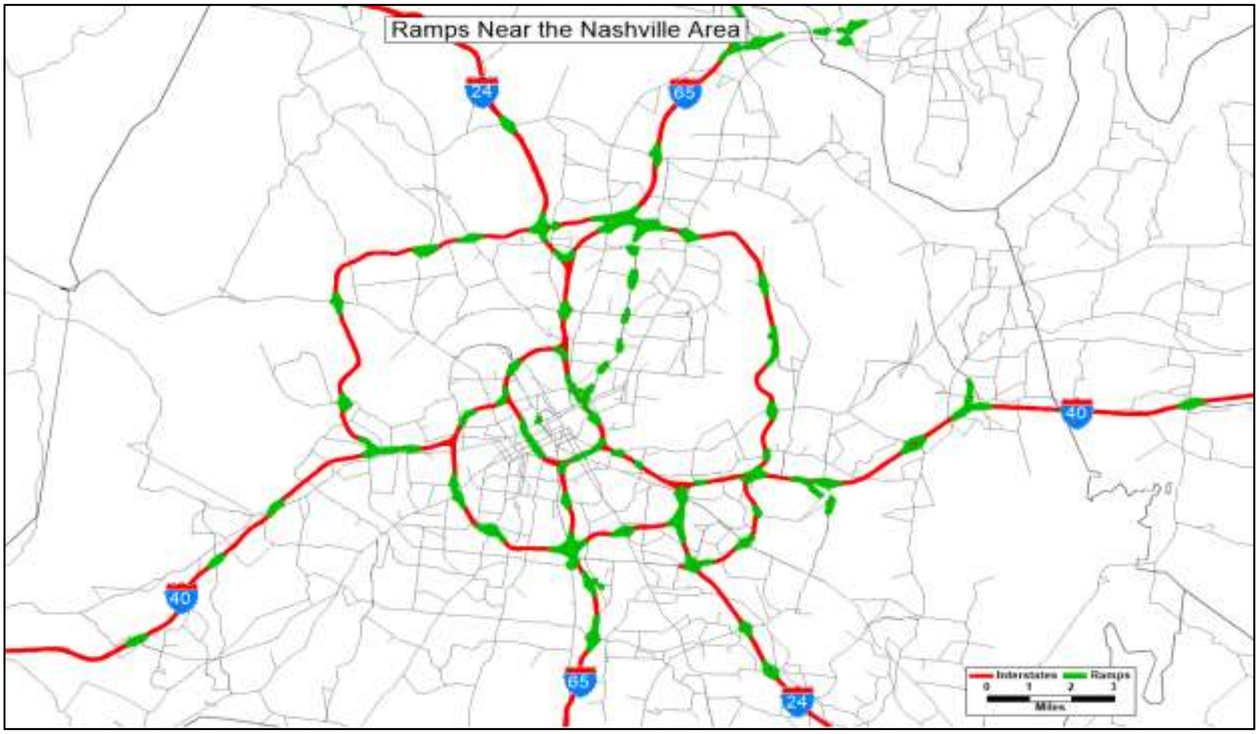


Figure 2.14. Location of Ramps near Chattanooga

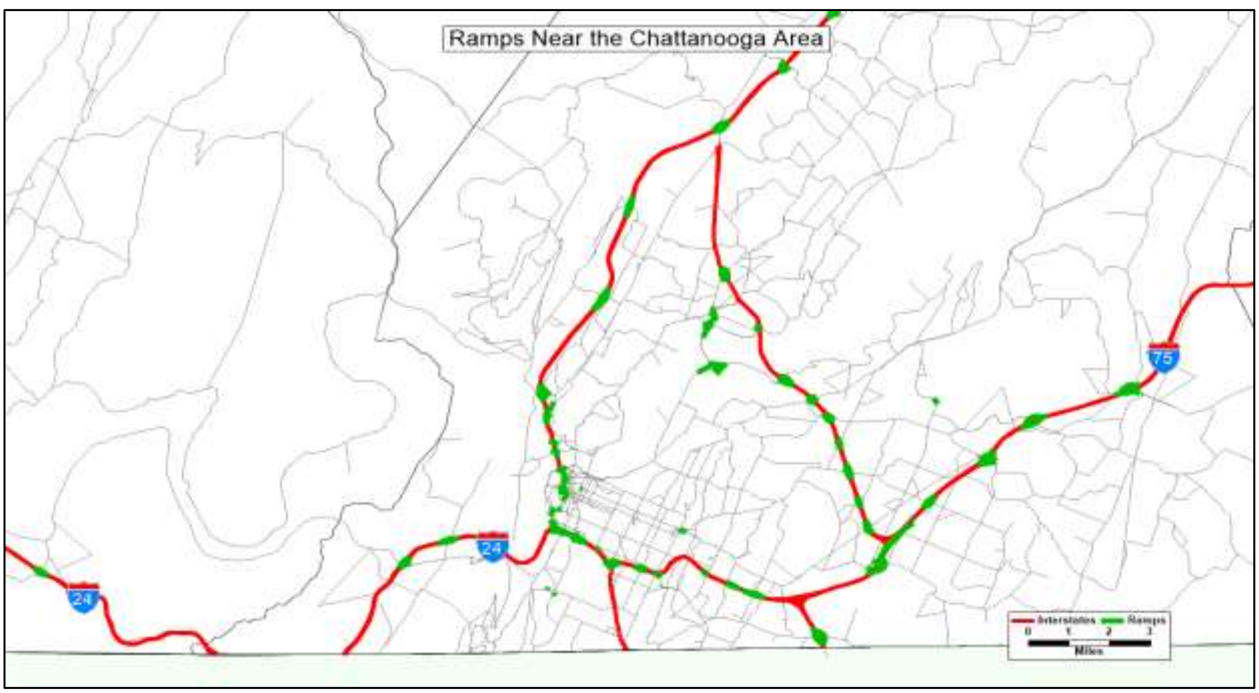
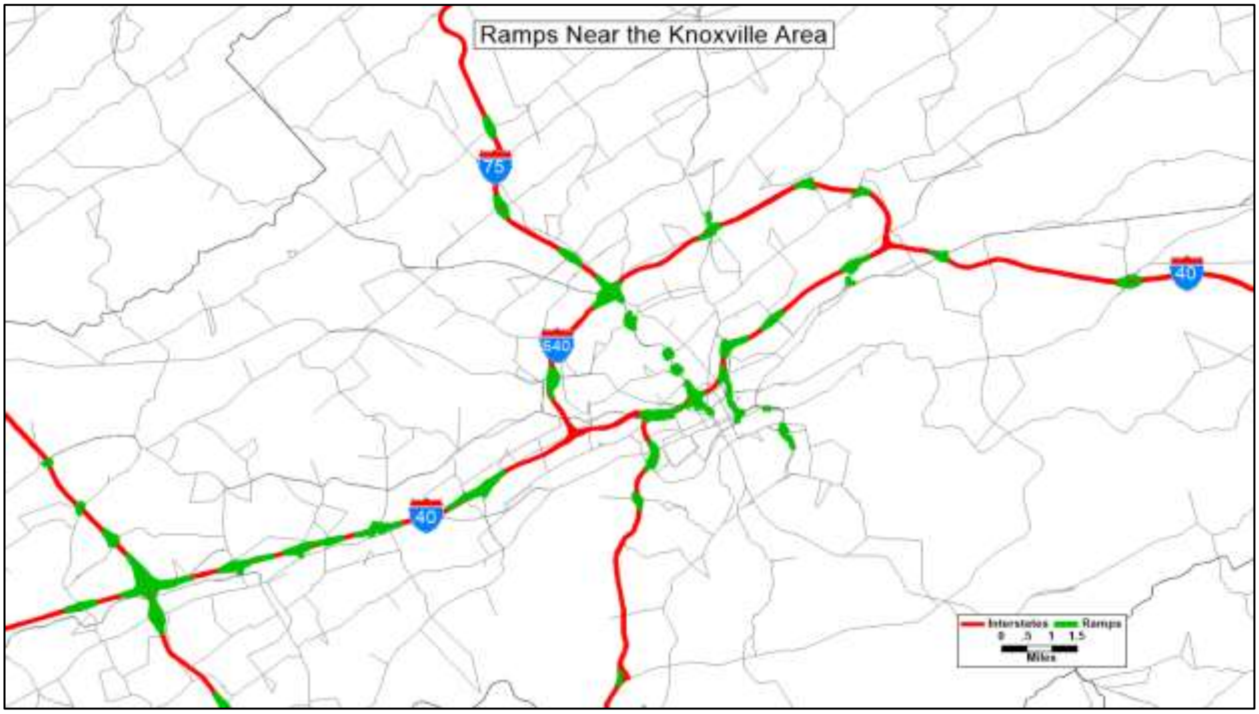


Figure 2.15. Location of Ramps near Knoxville



After a close examination of the ramps in Tennessee, it is clear that a majority of the ramps in Tennessee are closer to the areas that contain a larger city, such as the five displayed above. In Tennessee there are 4,382 ramps, however, 2,478 of those ramps or 56% of them are located within these four major cities. **Table 2.0** displays the number of ramps that are located within each of these cities.

Table 2.0. Number of Ramps Based off Location in Tennessee

Location	Number of Ramps	Percentage of Total Ramps
All of Tennessee	4,382	100%
Nashville	911	21%
Memphis	896	20%
Knoxville	544	12%
Chattanooga	74	2%
Rest of Tennessee	1957	44%

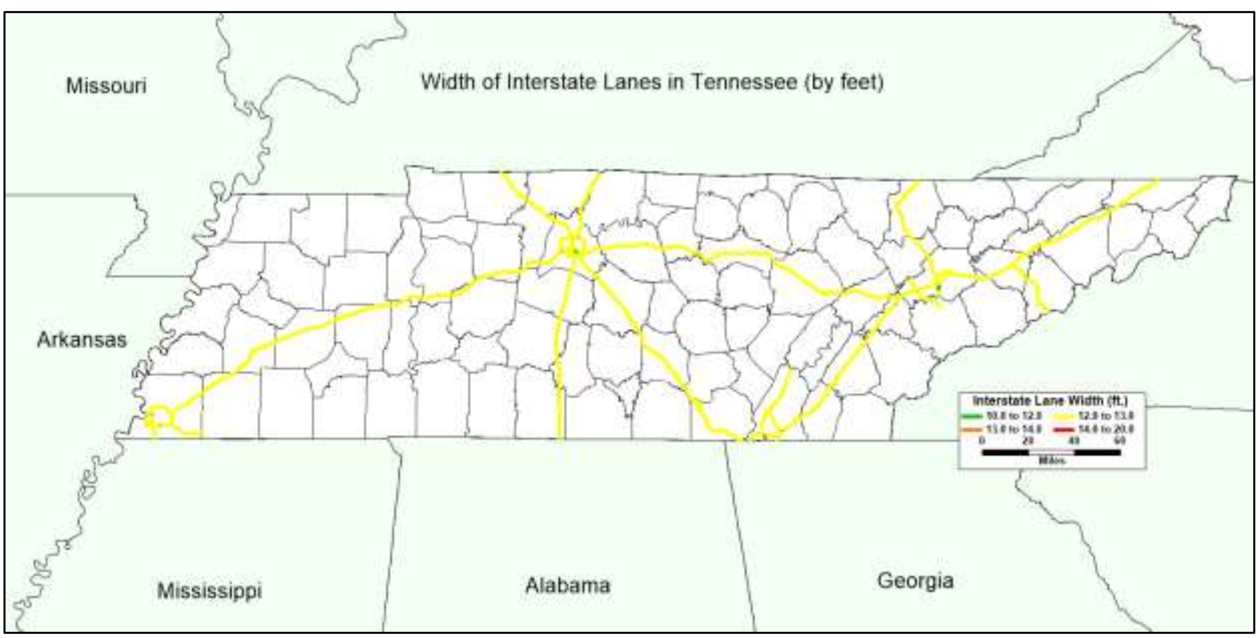
An analysis of the ramps shows that when it comes to a bottleneck being caused by a ramp, there is a greater chance of one happening near the downtown areas of communities that contain a large number of ramps, compared to the smaller locations. The reasoning for this is because in an area with only one ramp near, such as the rural areas of Tennessee, there is only going to be a small number of vehicles that will be trying to merge over. Where is a region such as Memphis where there are multiple ramps near each other, vehicles are going to be merging from different locations, trying to reach various destinations, which can cause a cluster of vehicles and delay traffic.

This becomes a major delay for freight because unlike a personal vehicle a freight truck is going to need a larger space to merge off of the ramp, which is not always a easy scenario especially during the peak hours of the day. With freight having to wait longer for a gap in traffic in order to successfully reach the interstate.

2.2 Width of Interstate Lanes

The second indicator that will be analyzed is the width of the lanes on the interstate. **Figure 2.16** provides an illustration of the interstates lane width from a statewide representation. **Figure 2.16** shows that a majority of the lane widths for the interstates in Tennessee is between 11 feet and 12 feet. Which overall would not be a threat to freight, however, when the lanes change widths there becomes an issue with the movement of vehicles.

Figure 2.16. Tennessee Interstate Lane Width



To provide a closer visual of the lane widths in Tennessee, the same five cities, Memphis, Nashville, Chattanooga, and Knoxville, will be closely analyzed to determine where the lane width locations are amongst those major cities as shown in **figure 2.17** through **figure 2.20**.

Figure 2.17. Memphis Interstate Lane Width

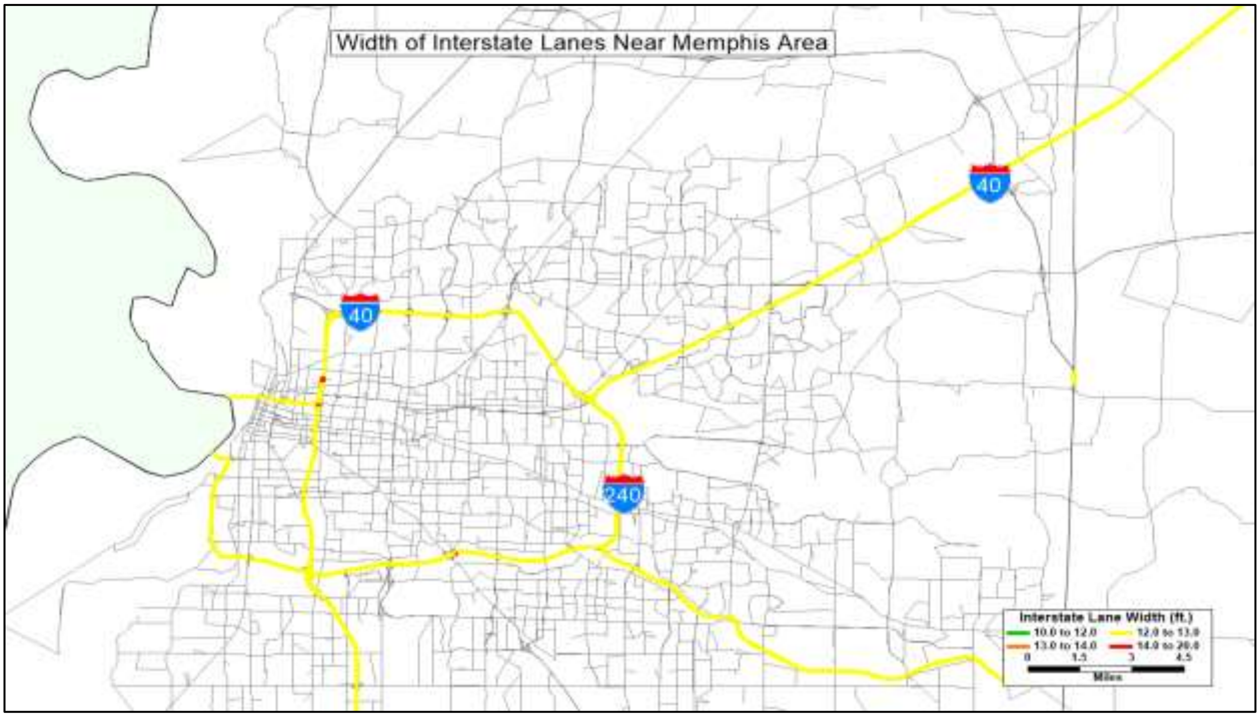


Figure 2.18. Nashville Interstate Lane Width

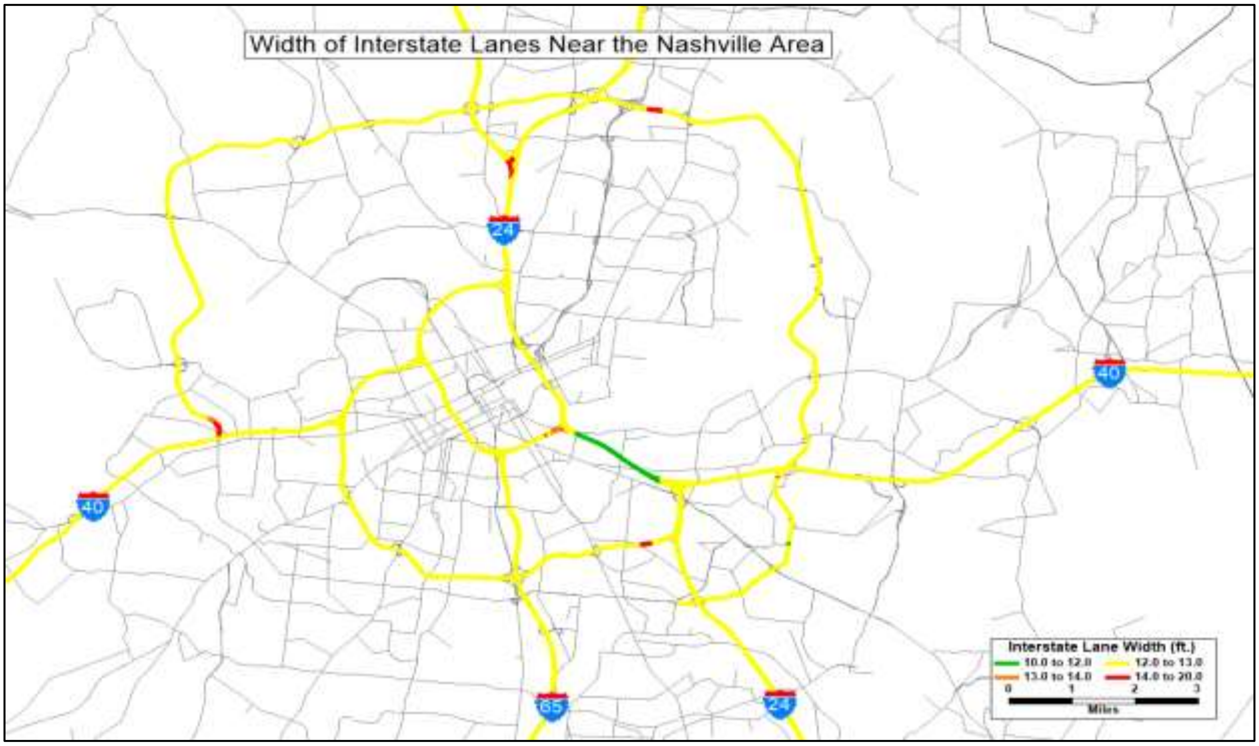


Figure 2.19. Chattanooga Interstate Lane Width

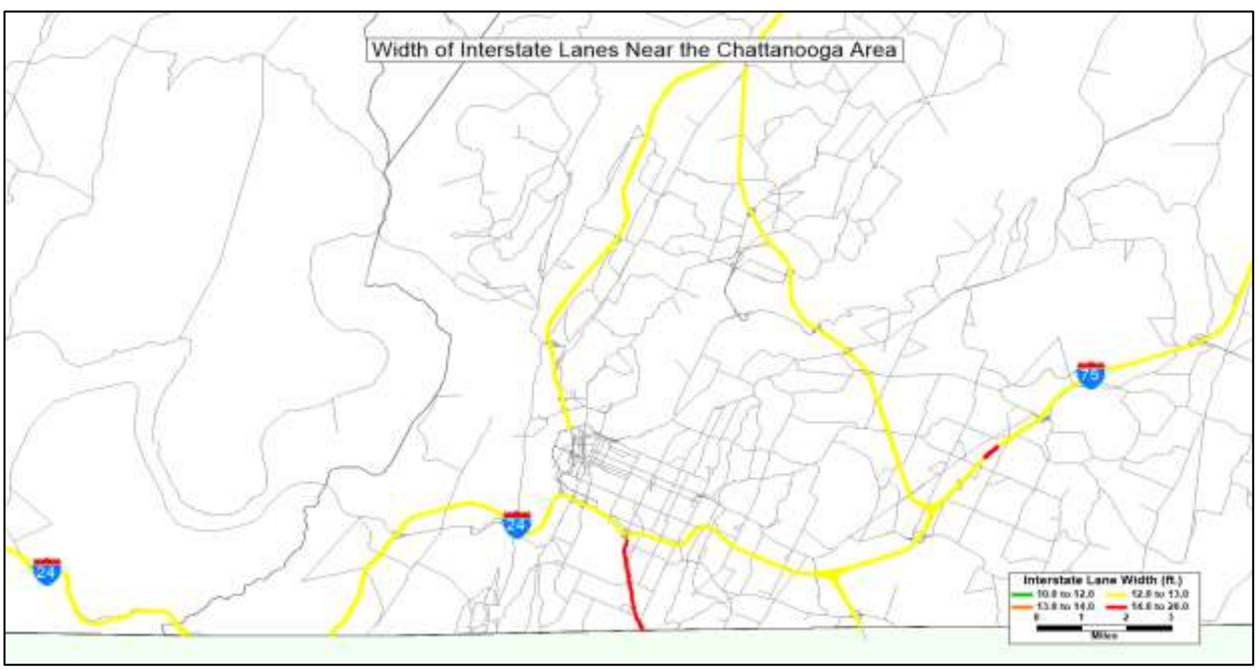
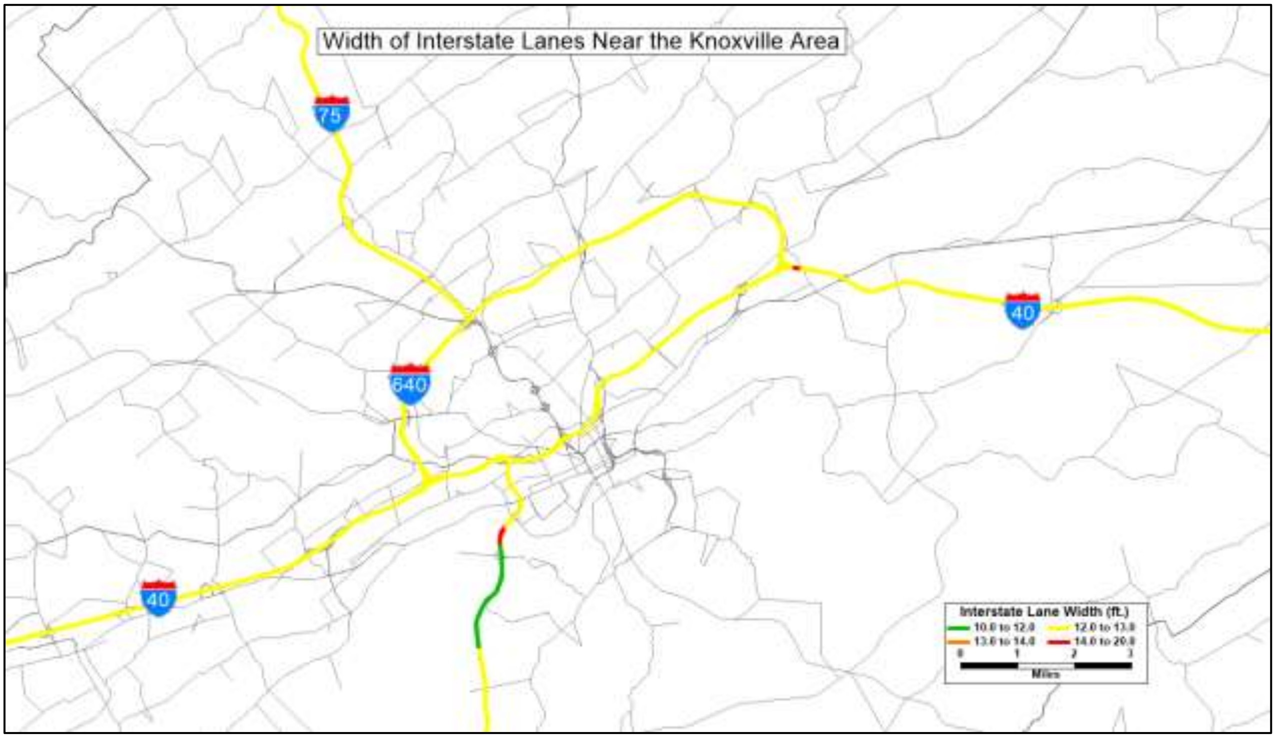


Figure 2.20. Knoxville Interstate Lane Width



With an evaluation of the lane widths for Tennessee, the majority of the lanes are between 11.1 feet and 12 feet, with the occasional location of a lane being 11 feet or over 13 feet. With the width of lanes being very similar throughout the state of Tennessee, it would seem as if they are not a large indicator of a bottleneck standing alone, but when there is another indicator within proximity to a narrow lane then there could possibly be a larger bottleneck. **Table 2.1** illustrates the number of miles the interstate is based on the width of the lanes.

Table 2.1. Number of Miles of Interstate base on Lane width

Lane Width Category	Number of Miles	Percentage of Interstate
11 miles	3.2	0.2%
11.1 to 12 miles	2222.4	99.6%
12.1 to 13 miles	0.79	0.03%
13.1 to 14 miles	4.3	0..2

A final analysis on the lane widths on the Tennessee interstates is that the four regions of Tennessee are very similar when it comes to the width of the interstates lanes, with the exception of the small gap in Nashville, where the lane drops to 11 feet. With this consistency throughout

Tennessee, there is a good chance that the width of lanes does not play a huge role in potential bottleneck location for freight.

2.3 Changes in Speed Limit

Another indicator of bottlenecking is the change of speed limit on the interstates or any other road that freight travels on. The change of speed limits becomes a bottleneck both when the speed limit is dropped and when the speed limit increase. However, it will be mainly where speed are decreasing as not everyone is going to decrease speeds at the same time and some vehicles are going to remain a faster speed which could cause congestion when faster traveling vehicles and slower traveling vehicles. **Figure 2.21** shows the Tennessee interstates speed limits.

Figure 2.21. Tennessee Interstate Speed Limit

Analyzing the statewide speed limits for the interstates, it is clear that their numerous locations where the speed limits is reduced or increased in Tennessee. The following figures, **figure 2.22** through **figure 2.25** will look at the following areas to get a closer look at the ways in which speed limits are reduced and increased in the different areas.

Figure 2.22. Memphis Interstate Speed Limit

Figure 2.23. Nashville Interstate Speed Limit

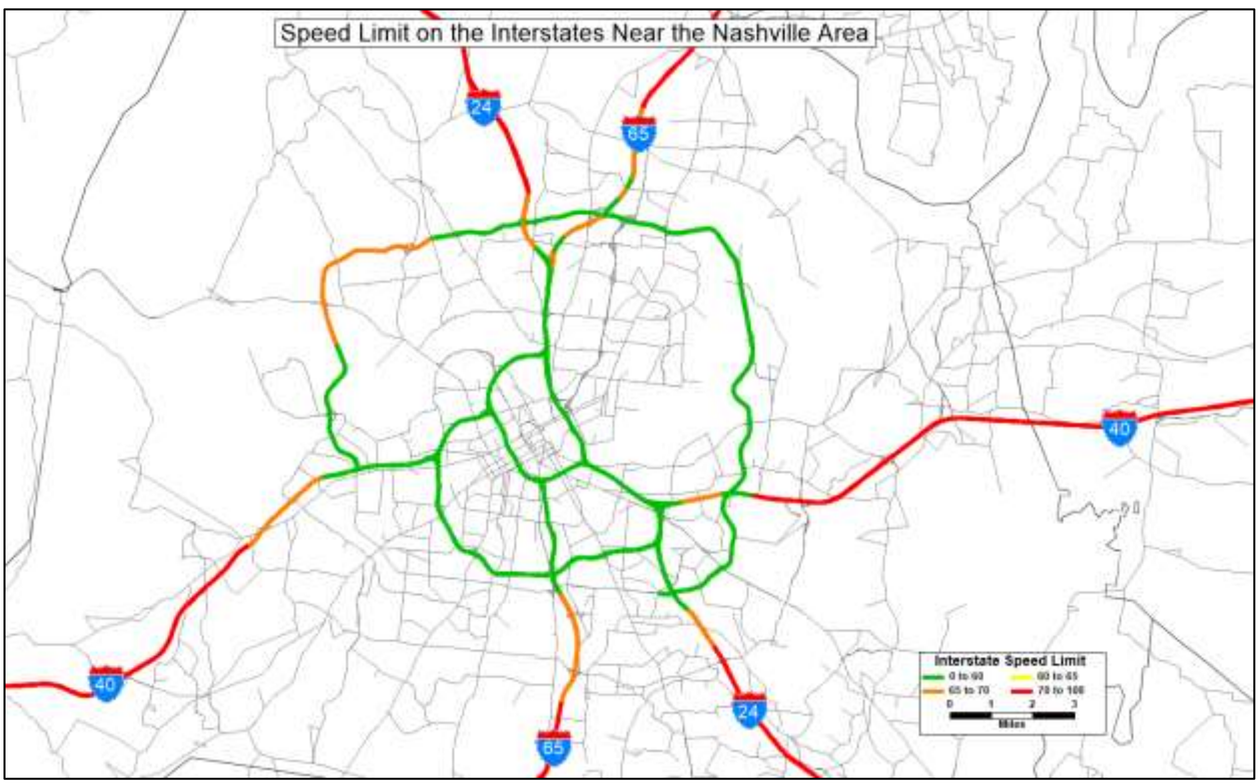


Figure 2.24. Chattanooga Interstate Speed Limit

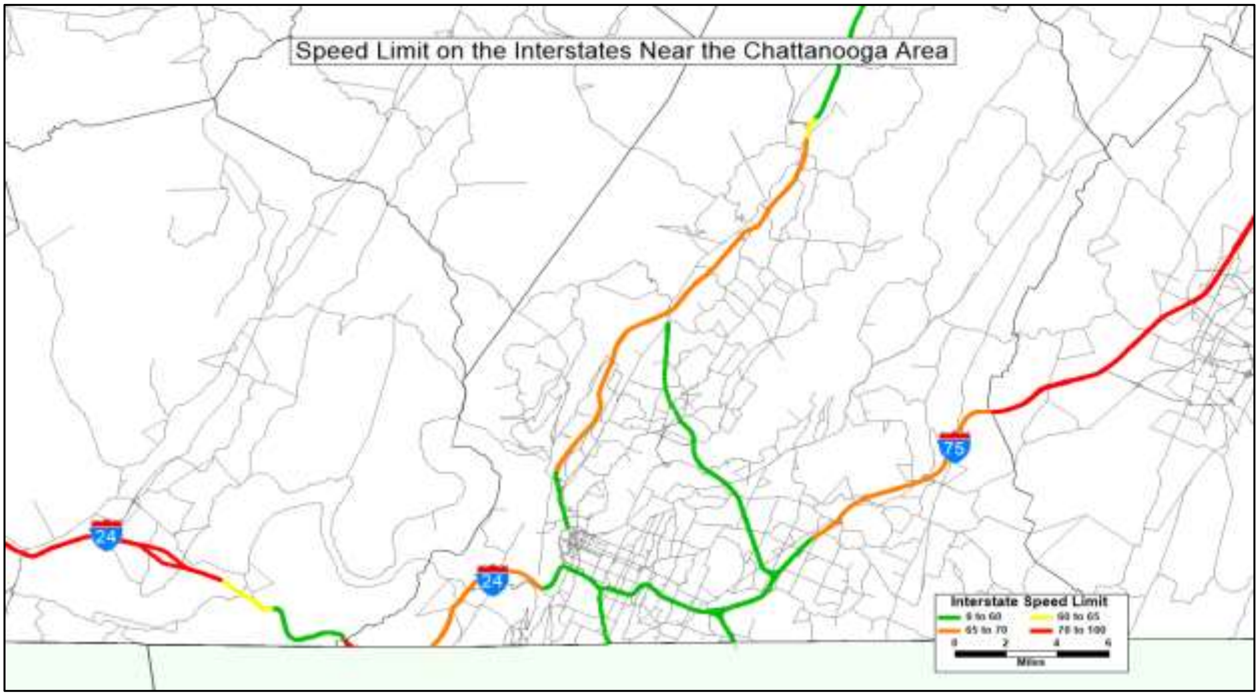
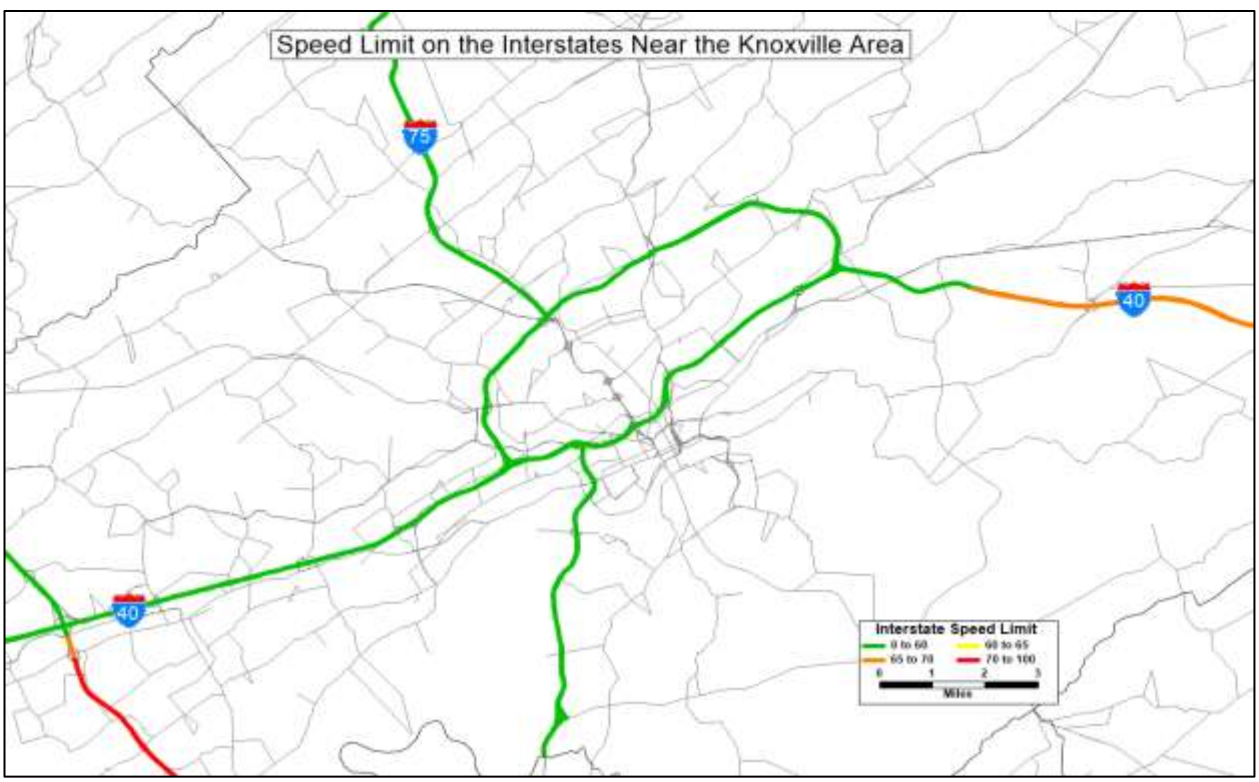


Figure 2.25. Knoxville Interstate Speed Limit



After analyzing the statewide interstate speed limits and the breakdown of the major cities in Tennessee, the speed limits have a similar design to the ramps. On the interstates the speed limits is 70 miles per hour when it is not around a large population of people, however, once it reaches a city, the speed limits start to decrease. In some location the speed limits decrease over a longer period of time, allowing drivers to steadily decrease to the slower speeds from the faster one. These locations would be assumed as having a lower chance of a bottleneck because it allows the driver to have time to adjust speeds. However, in some situation the speed change is fast and does not allow the driver time to adjust from the fast 70 mph to the slower 60 mph. In these locations it would be expected to see bottlenecks as vehicles are using their breaks harder and there is a larger chance of accidents in these areas of faster speed reduction**.**

As a final comment about the speed limits in Tennessee on the interstates is that when it comes to the four regions in Tennessee, each one has its own challenges when it comes to speed limit reduction on the interstate. Speed limits reduction at a faster pace is considered one of the major influences on a bottleneck, if the speed limits were decreased gradually then bottlenecks could be reduced, and freight would move more smoothly though these areas of slower speed.

2.4 Over Capacity Roads during Peak Hours

A major indicator to congestion on a road that happens as populations increase or new employment arises which causes people to travel on certain roads is the capacity of the roadways during the peak hours. Having a roadway that is over capacity will cause vehicles to move slowly thought the road because of the lack of room for vehicles to move. Some of the ways over capacity roadways have been solved is by increasing the number of lanes, however, this is only a temporary fix as eventually induced demand will set in and more people will start to drive. A second way is by influencing the use of alternative modes of transportation to reduce the number of vehicles on the road. Now switching alternative modes is not always a simple thing when it comes to freight movement because of the lack of resources and infrastructure to move other modes, but this can be done with person vehicles when roads get over crowded. Switching personal drivers to other modes can free up space on the road ways which will allow for freight to move faster through the previously congested areas. **Figure 2.26** through **Figure 2.30** illustrate the Tennessee interstate capacity for the base year 2010, where **figure 2.31** through **figure 2.35** will illustrate the future 2040 road capacity based on the predicted change in demand.

Figure 2.26. Tennessee Interstate Daily Capacity, 2010

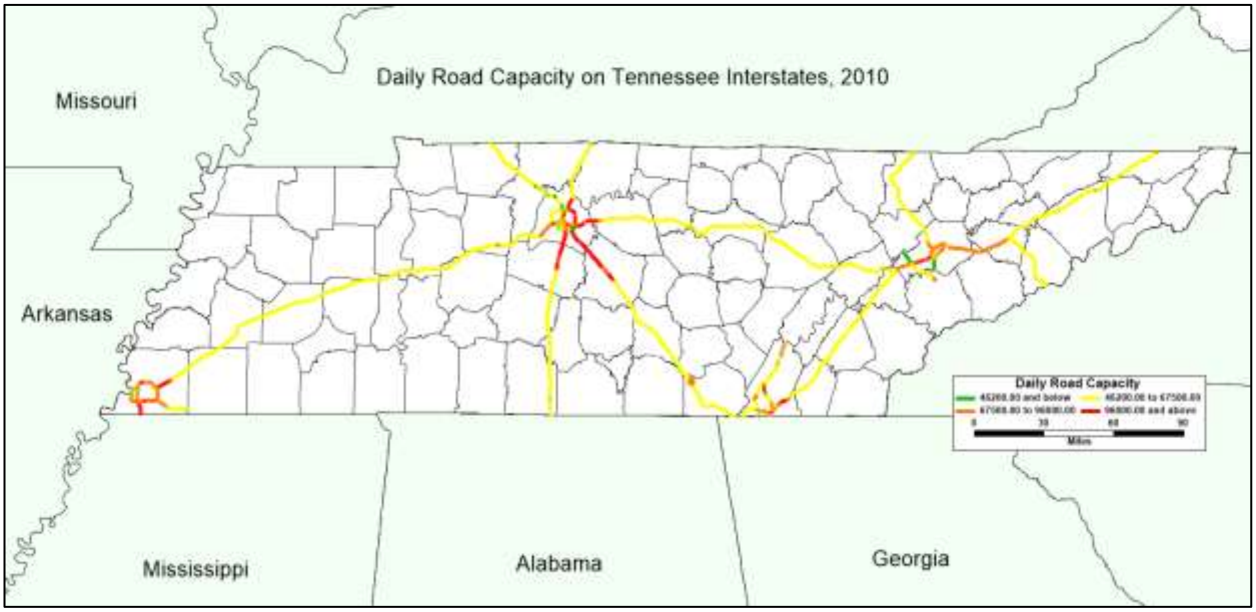


Figure 2.27. Memphis Interstate Daily Capacity, 2010

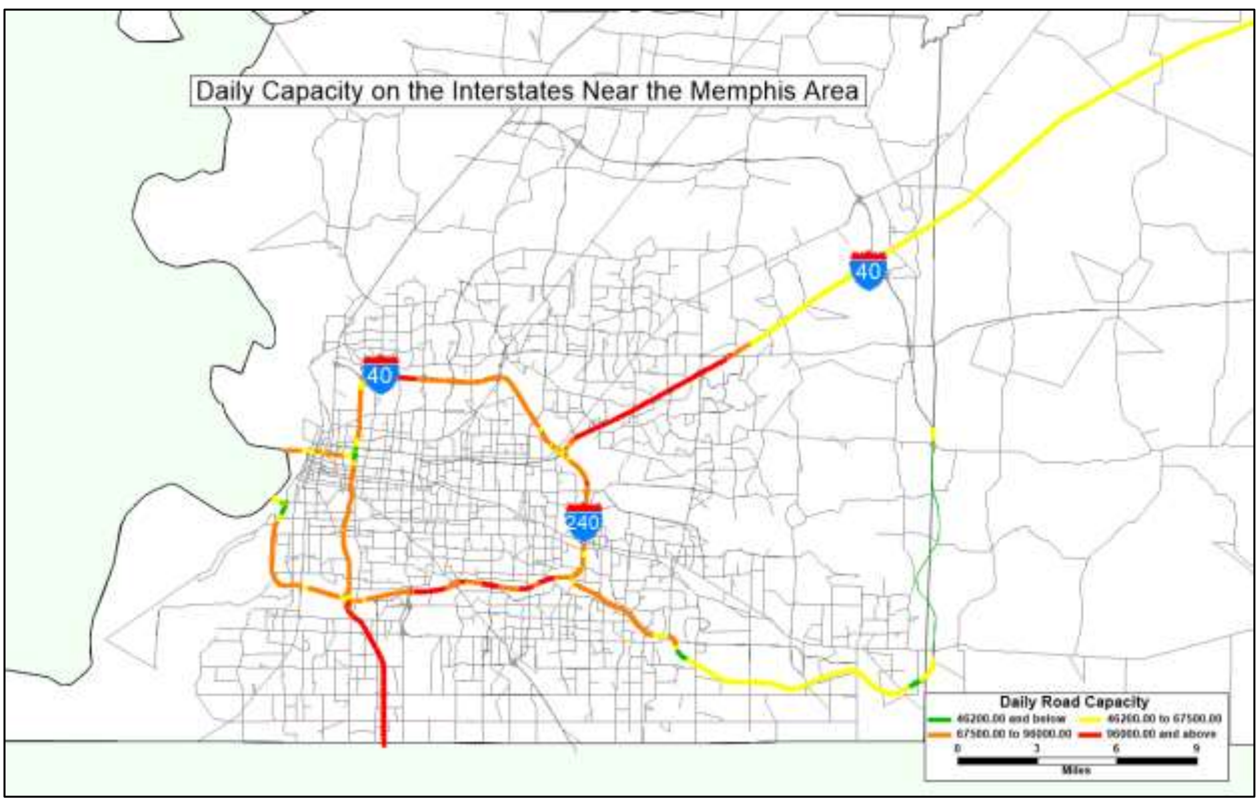


Figure 2.28. Nashville Interstate Daily Capacity, 2010

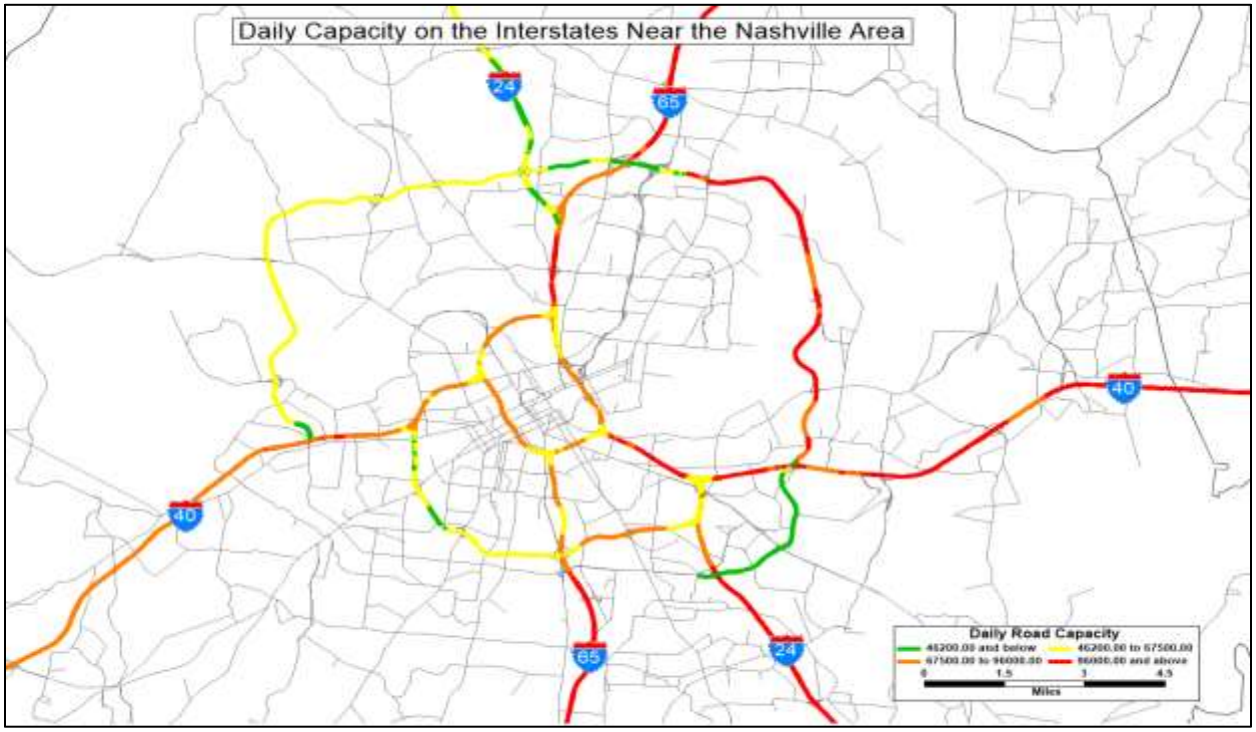


Figure 2.29. Chattanooga Interstate Daily Capacity, 2010

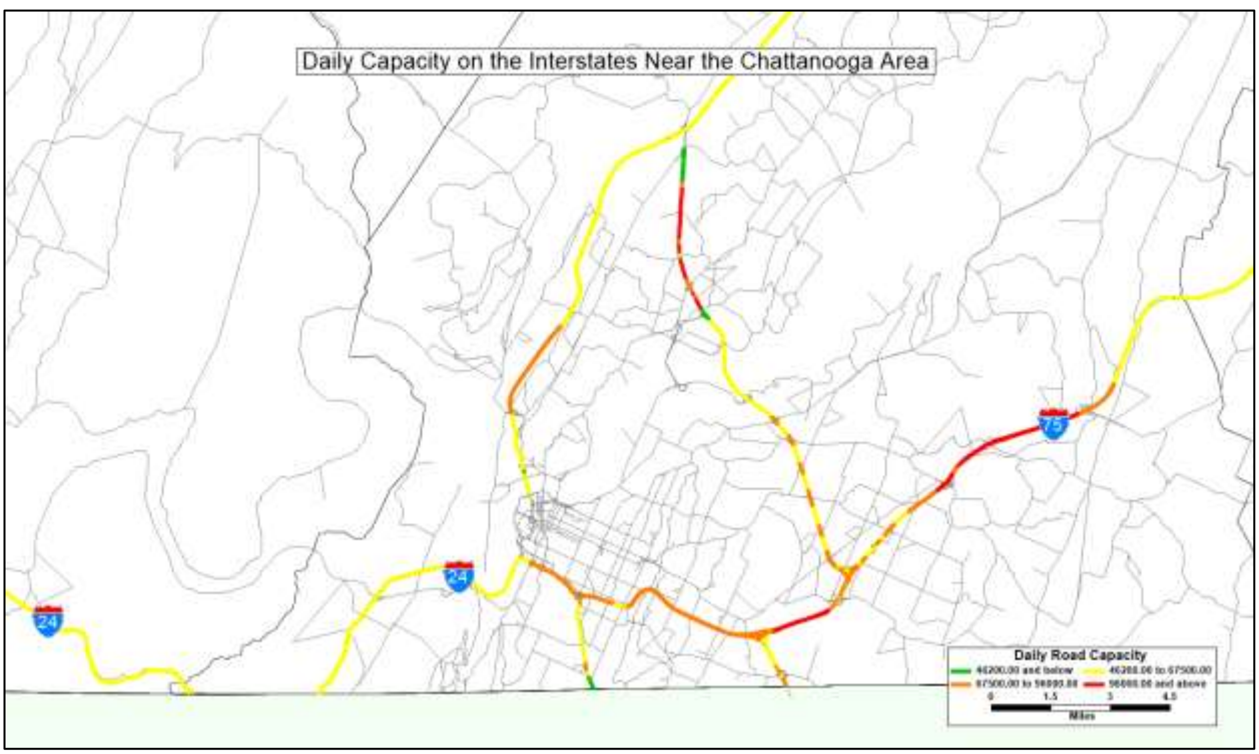


Figure 2.30. Knoxville Interstate Daily Capacity, 2010

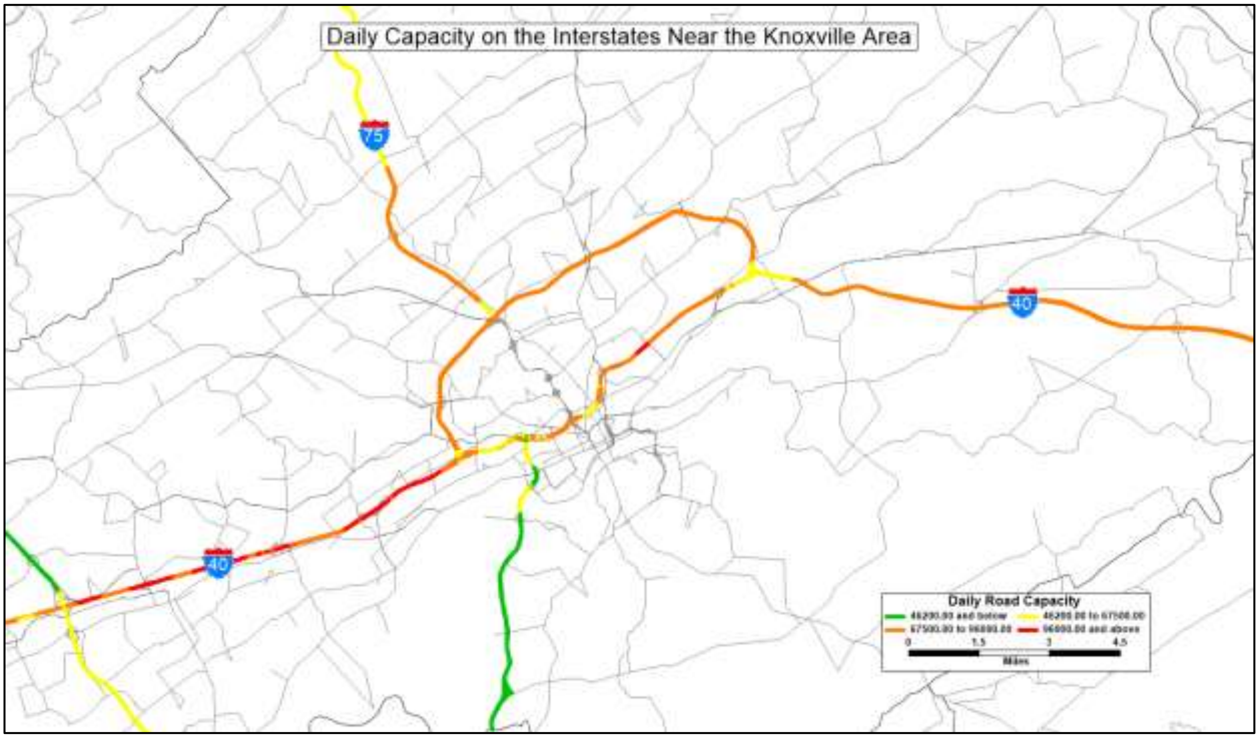


Figure 2.30. Knoxville Interstate Daily Capacity, 2010

Figure 2.31. Tennessee Interstate Daily Capacity, 2010

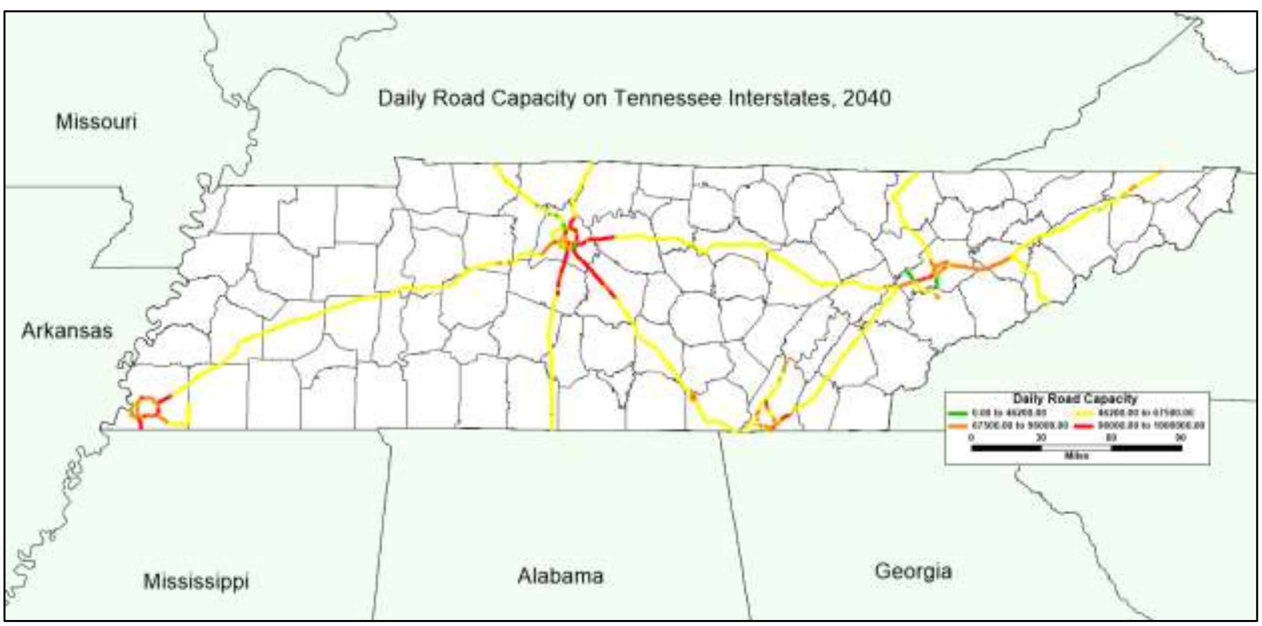


Figure 2.32. Memphis Interstate Daily Capacity, 2040

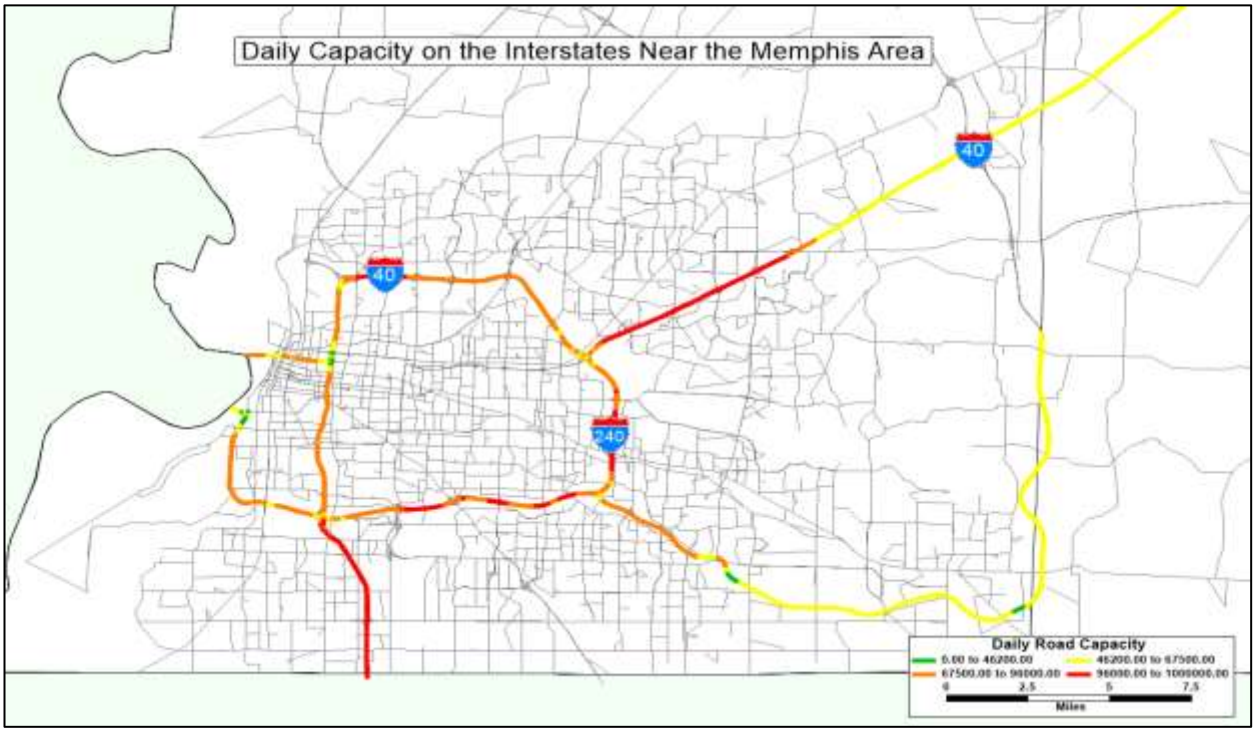


Figure 2.33. Nashville Interstate Daily Capacity, 2040

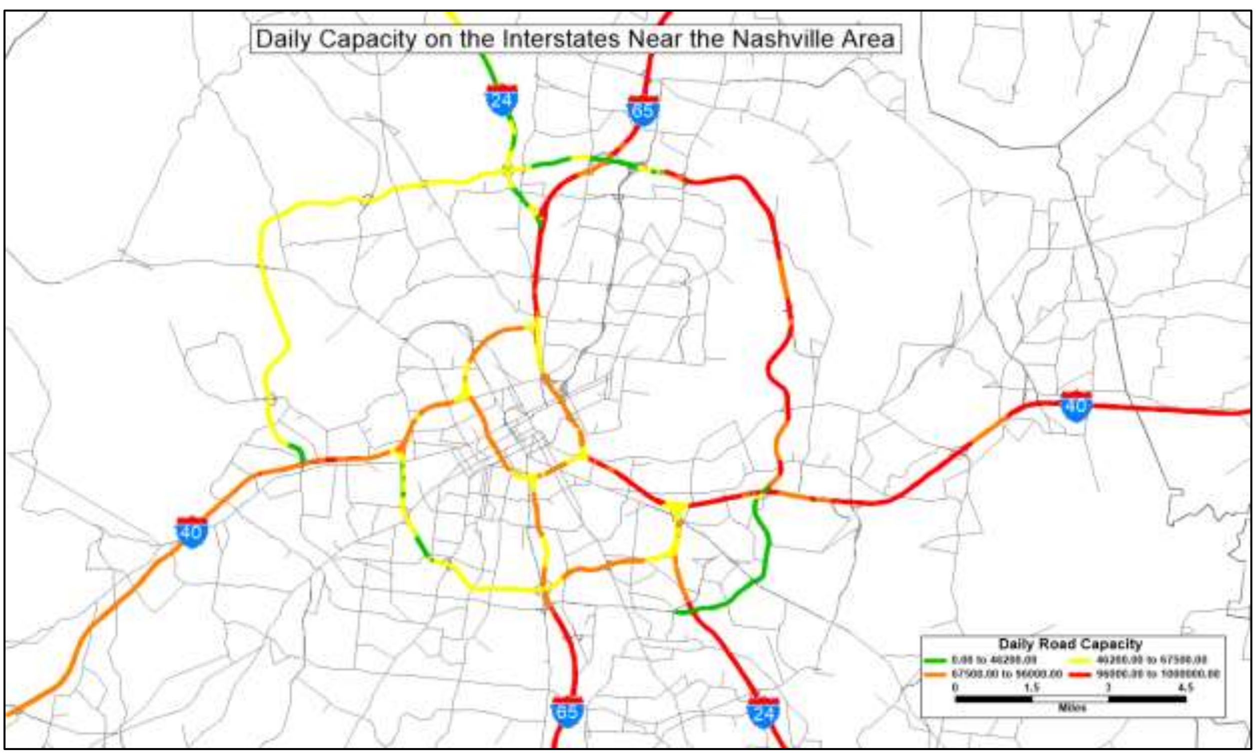


Figure 2.34. Chattanooga Interstate Daily Capacity, 2040

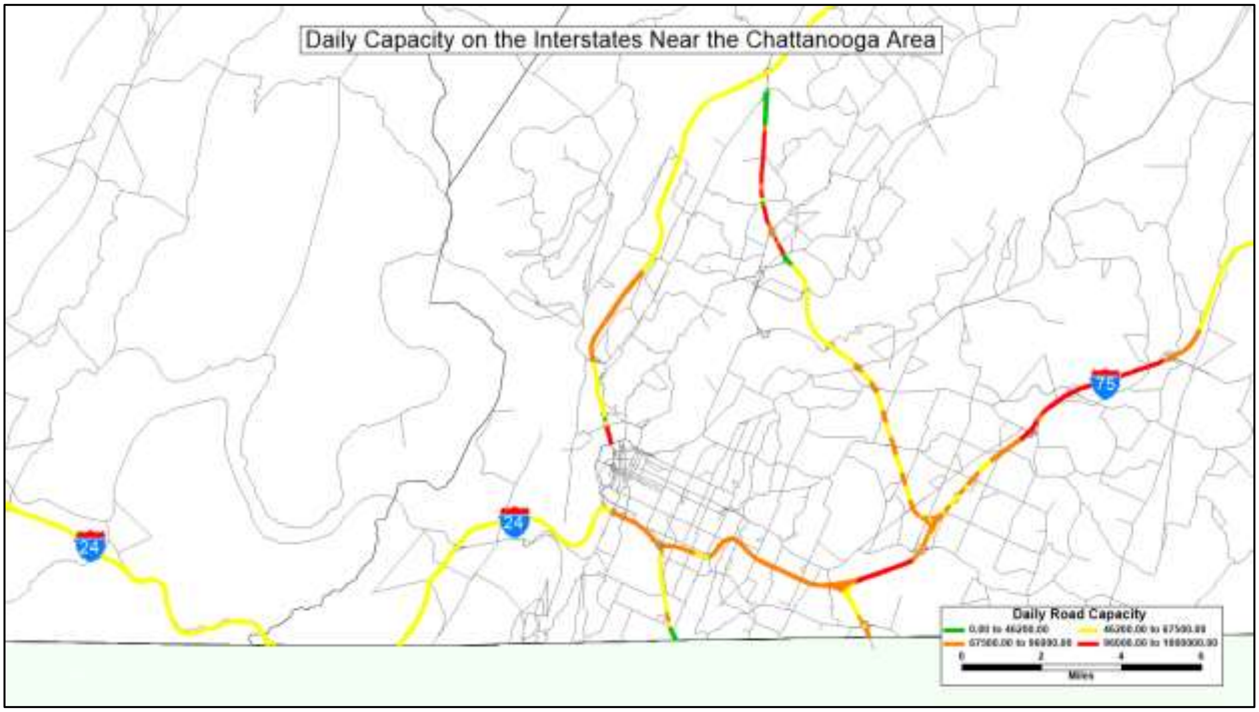
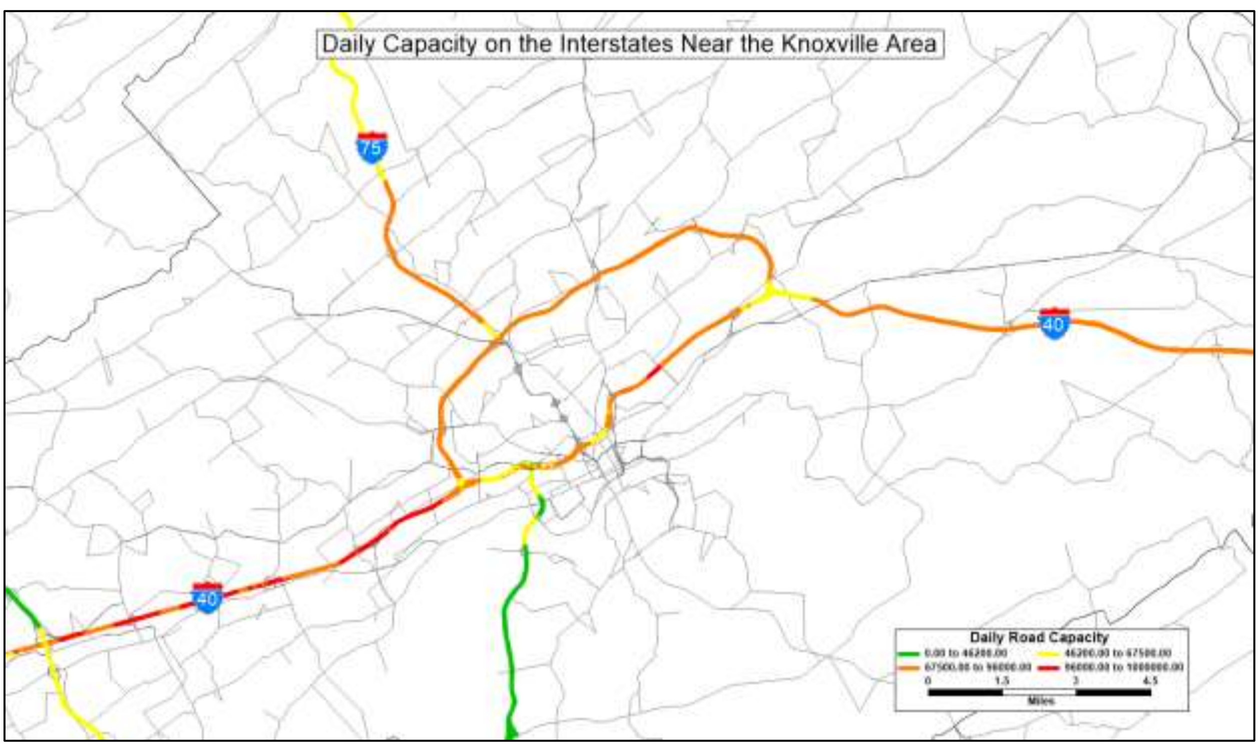


Figure 2.35. Knoxville Interstate Daily Capacity, 2040



The capacity of the interstates in Tennessee, have an opposite effect as the freight movement, which shows that the closer you got to the downtown area of a business district the less freight there is. In the daily capacity maps, it shows that the interstate sections with the lowest amount of capacity are in the rural areas, while the downtown areas have a higher capacity level. This comes in relation to the number of lanes that the interstate has. As there are more lanes there is going to be more capacity available for vehicles, the big question is how much traffic actually travels on these roads and how close is it to reaching its capacity limit. The daily freight movement can be compared to the daily capacity to determine what percentage of the capacity on the interstate is coming from freight movement. **Figure 2.36** through **Figure 2.40** represents the percentage of the interstate capacity that is freight movement on Tennessee interstates for 2010. Where **figure 2.41**through **figure 2.45** represent the freight movement on Tennessee interstates for the future 2040. The percentage of freight movement is calculated using the total number of freight trips that are being made by the total trips for all modes of transportation (bus, car, motorcycle, etc.).

Figure 2.36. Percentage of Freight on Interstate, 2010

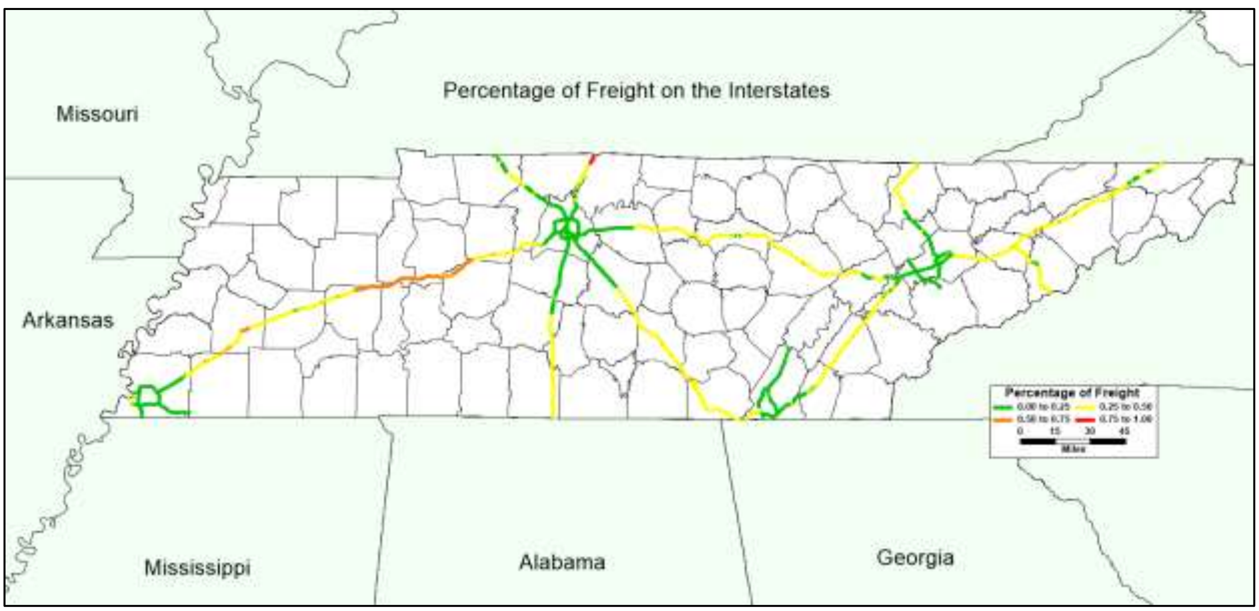


Figure 2.37. Memphis Percentage of Freight on Interstate, 2010

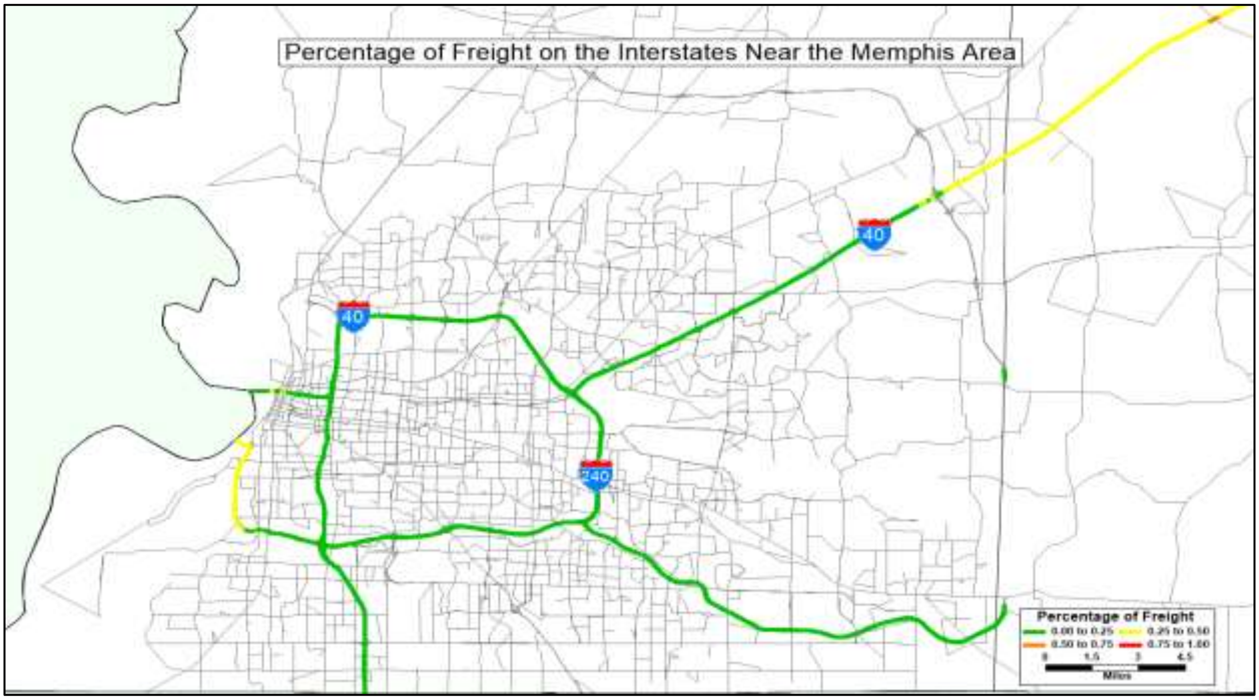


Figure 2.38. Nashville Percentage of Freight on Interstate, 2010

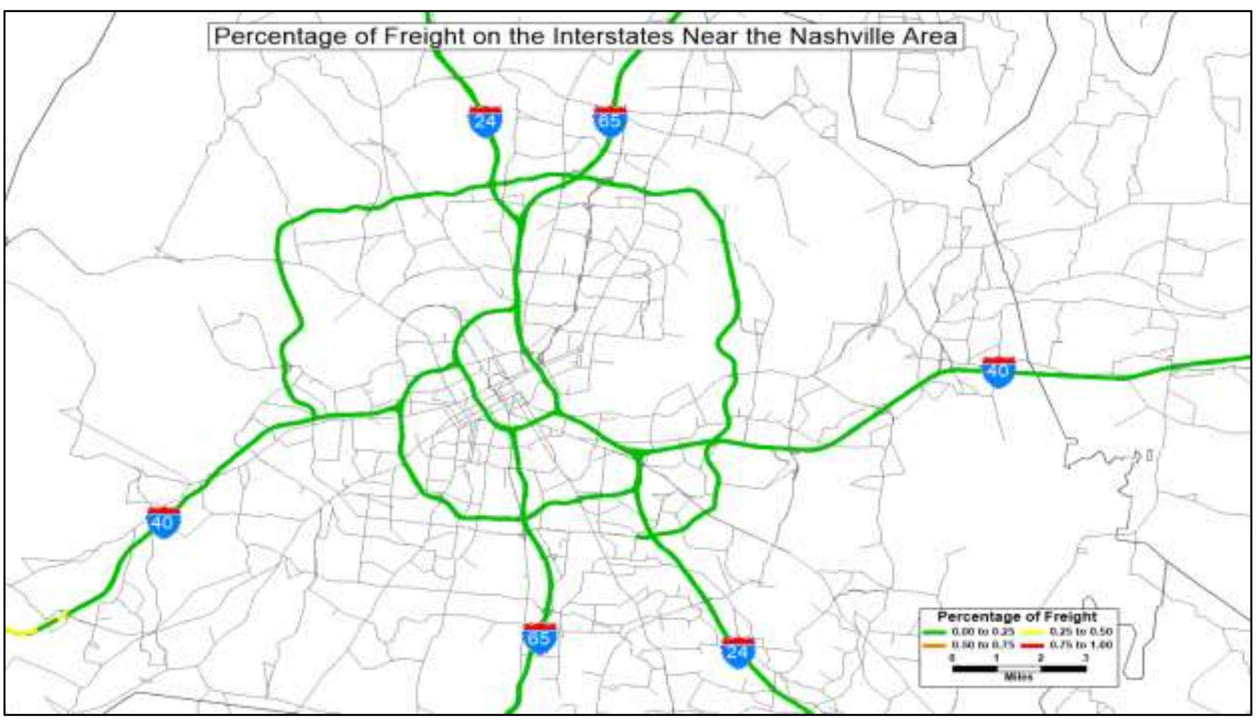


Figure 2.39. Chattanooga Percentage of Freight on Interstate, 2010

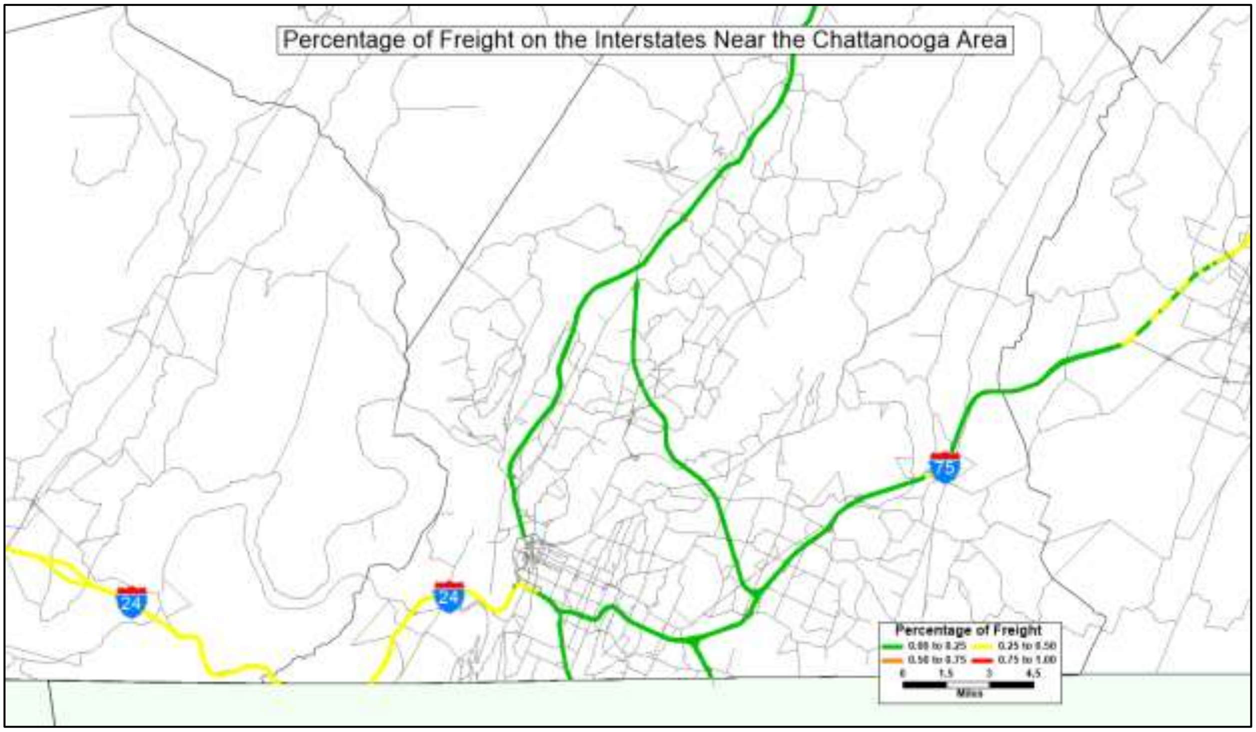


Figure 2.40. Knoxville Percentage of Freight on Interstate, 2010

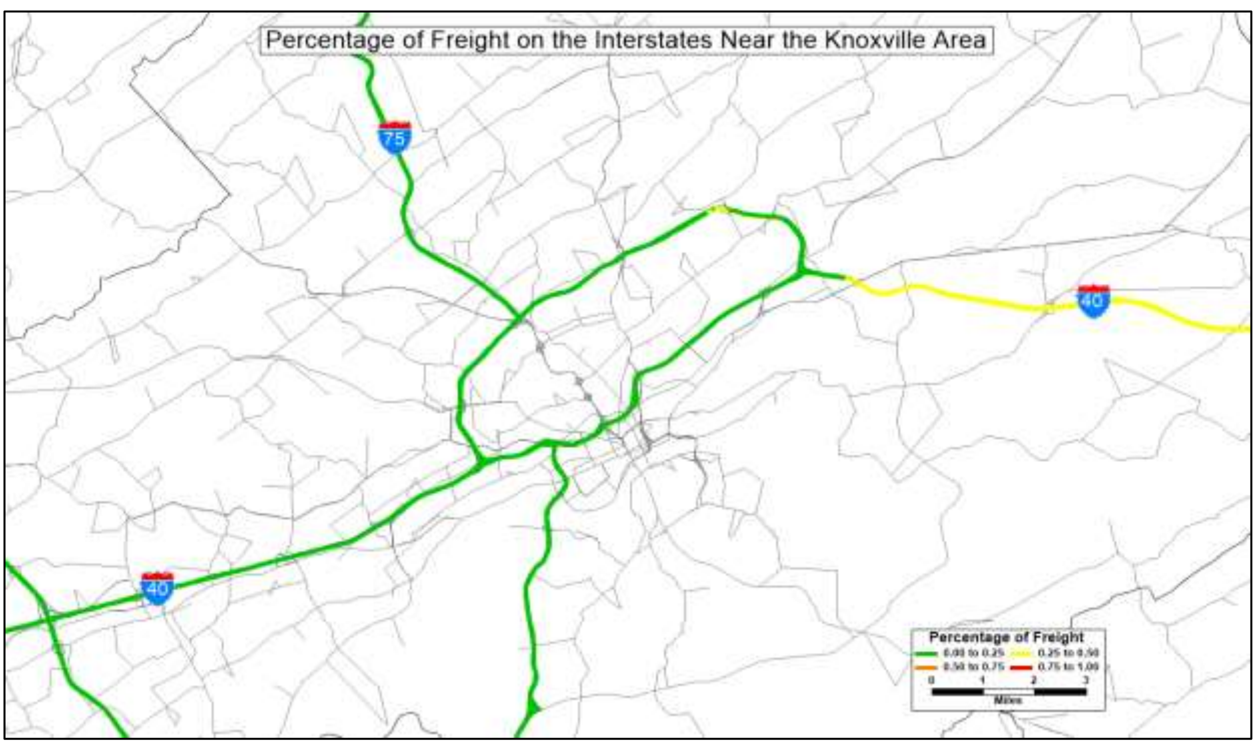


Figure 2.41. Percentage of Freight on Interstate, 2040

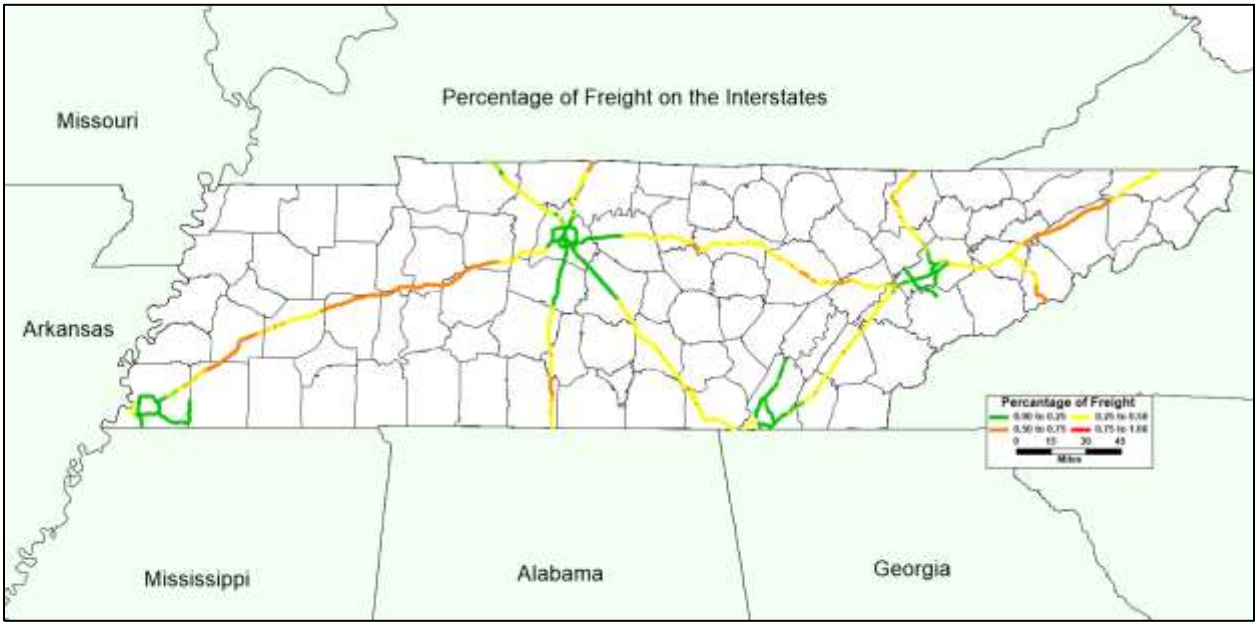


Figure 2.42. Memphis Percentage of Freight on Interstate, 2040

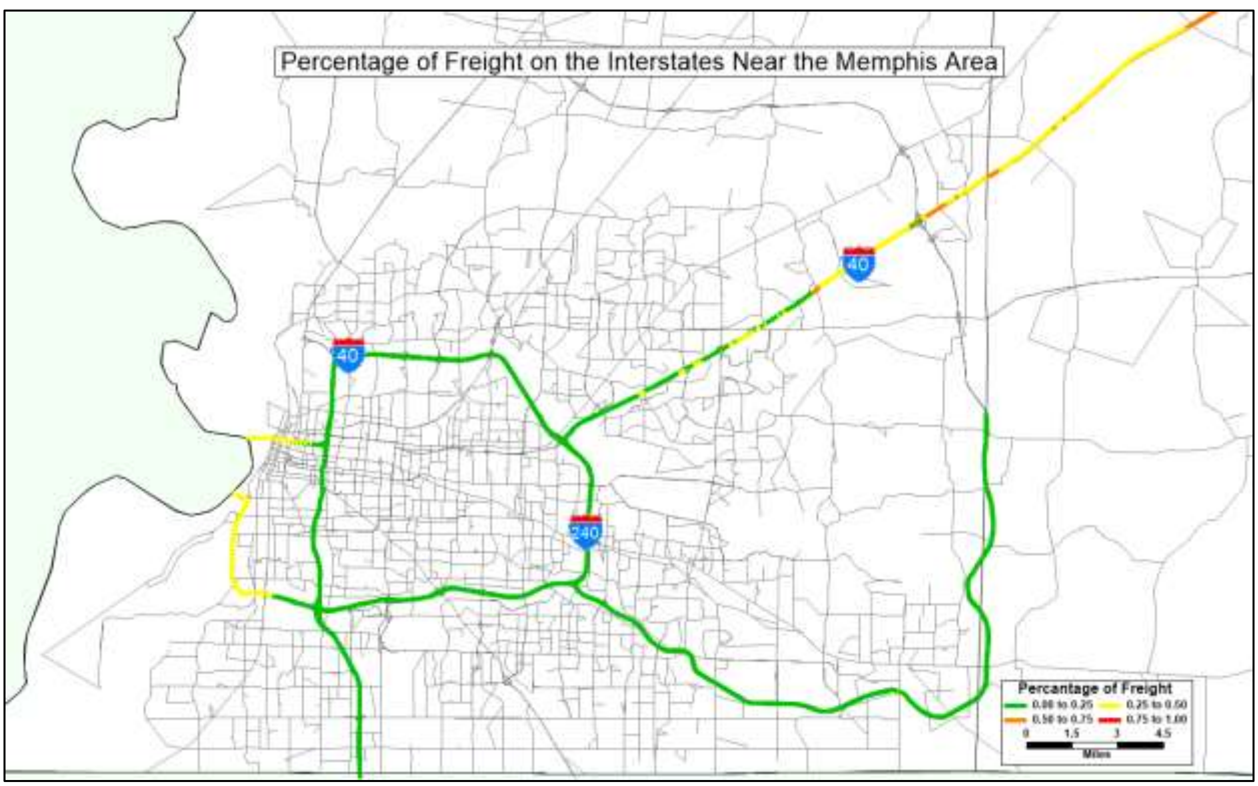


Figure 2.43. Nashville Percentage of Freight on Interstate, 2040

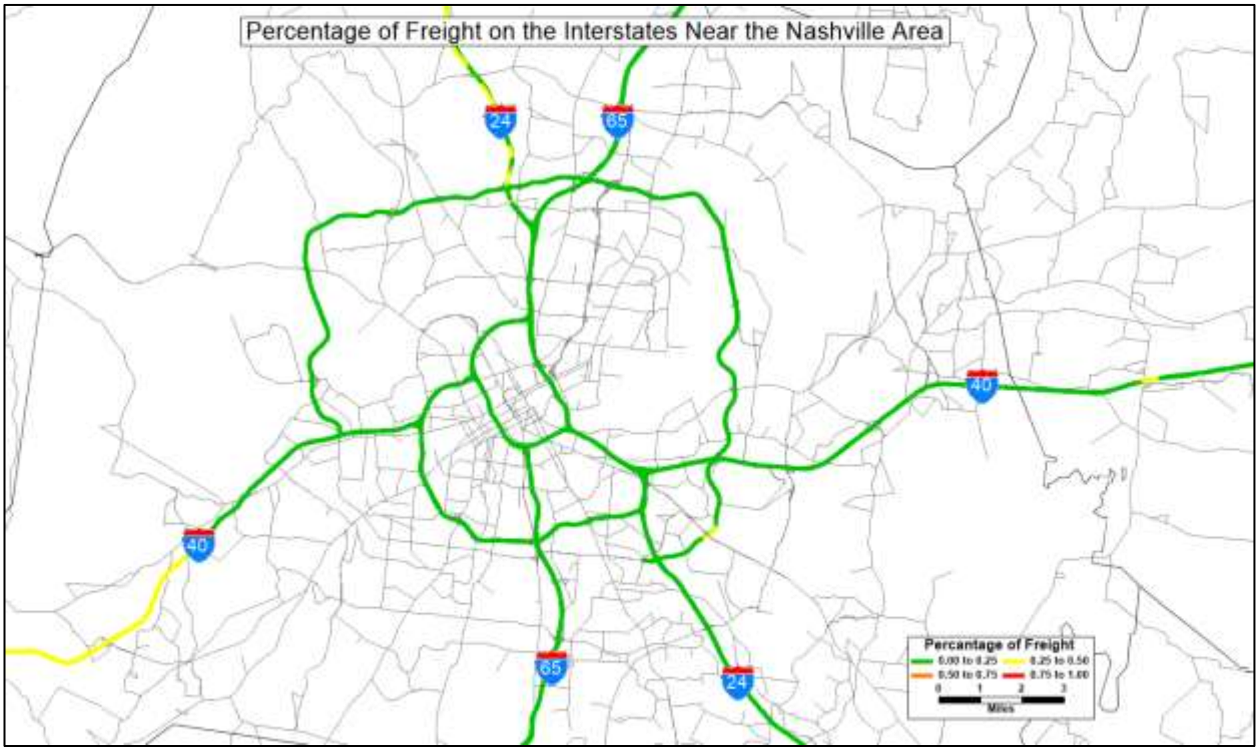


Figure 2.44. Chattanooga Percentage of Freight on Interstate, 2040

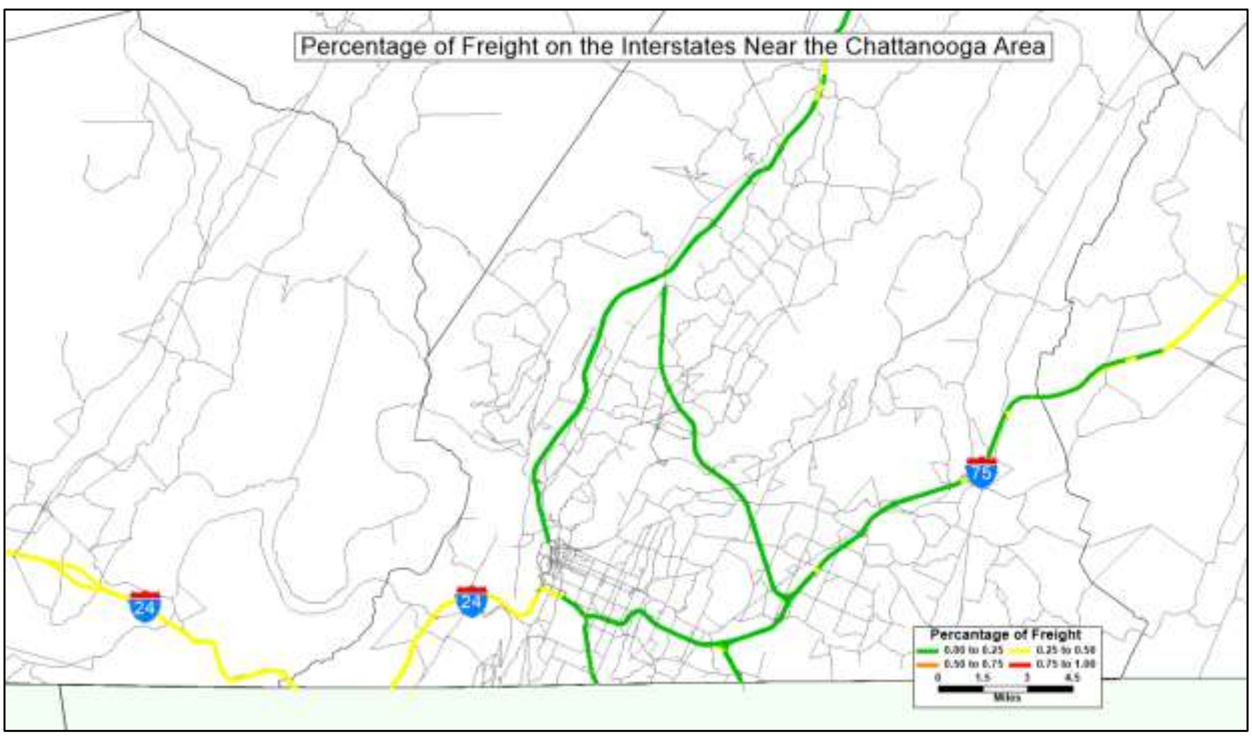
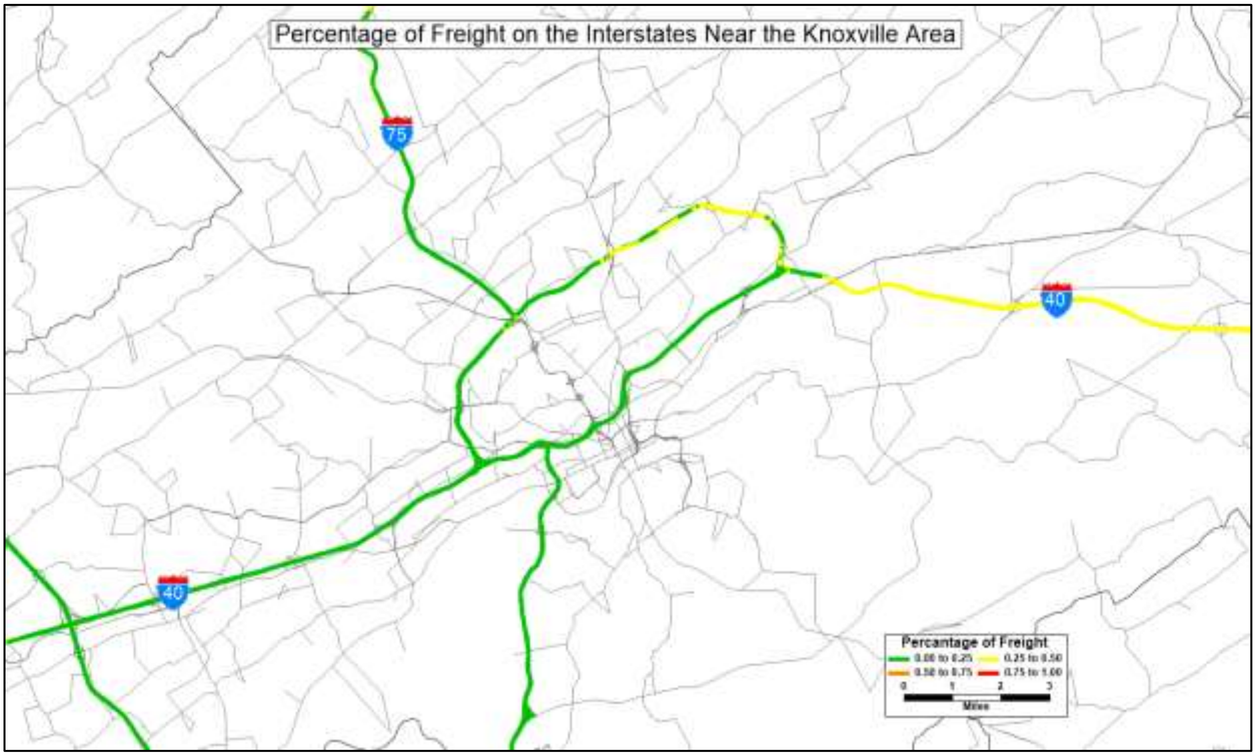


Figure 2.45. Knoxville Percentage of Freight on Interstate, 2040



When comparing the number of truck and passenger car volumes, the numbers of freight volumes are relatively low compared to the rest of the daily capacity used on the interstate system.   On the interstate system there are examples where freight movement account for one third of the total volumes. These are typically between major nodes or cities and are rural in nature connecting these major metropolitan areas as a high speed corridor. Combined with the fact that most people tend to gravitate toward major metropolitan areas for employment, the volumes are more car centric than freight related. Therefore, the percentage of freight movement truck will be higher on rural interstate communities than in the major urban and sub-urban areas.

2.5 Volume / Capacity Ratios

The next analysis that will be conducted on the interstates in Tennessee is to get the volume / capacity ratio for interstates. The volume / capacity ratio is a measurement of the operating capacity of a roadway or intersection where the number of vehicles passing through is divided by the number of vehicles that could theoretically pass through when at capacity. The following three equations were used to solve for each of the V/C ratios.

$$\text{Daily Peak Volume/Capacity} = \frac{TotFlow}{(AB\_DLYCap\ + BA\_DLYCap)}$$

$$\text{AM Peak Volume/Capacity} = \frac{AM\_TotFlow}{(AB\_AMCap\ + BA\_AMCap)}$$

$$\text{PM Peak Volume/Capacity} = \frac{PM\_TotFlow}{(AB\_PMCap\ + BA\_PMCap)}$$

Using these formulas and the selected interstates, the production of **figure 2.46** through **figure 2.75** is used to visualize the volume/capacity ratios in Tennessee on the interstate. To ensure that each of the three scenarios was weighed equally, there was a set scale used for the volume / capacity ratio. The following three categories were used to identify the congestion level of the road segment.

- ⇒ Uncongested *(green)* → 0.00 – 0.74
- ⇒ Congested *(yellow)* → 0.75 – 0.94
- ⇒ Highly Congested *(red)* → 0.95 – 1.00

The first section will look at the 2010 daily non-peak volume/capacity ratio, followed by the morning peak hours and the afternoon peak hours.

2010 Daily Non-Peak V/C Ratio

Figure 2.46. 2010 Tennessee Daily Non-Peak V/C Ratio

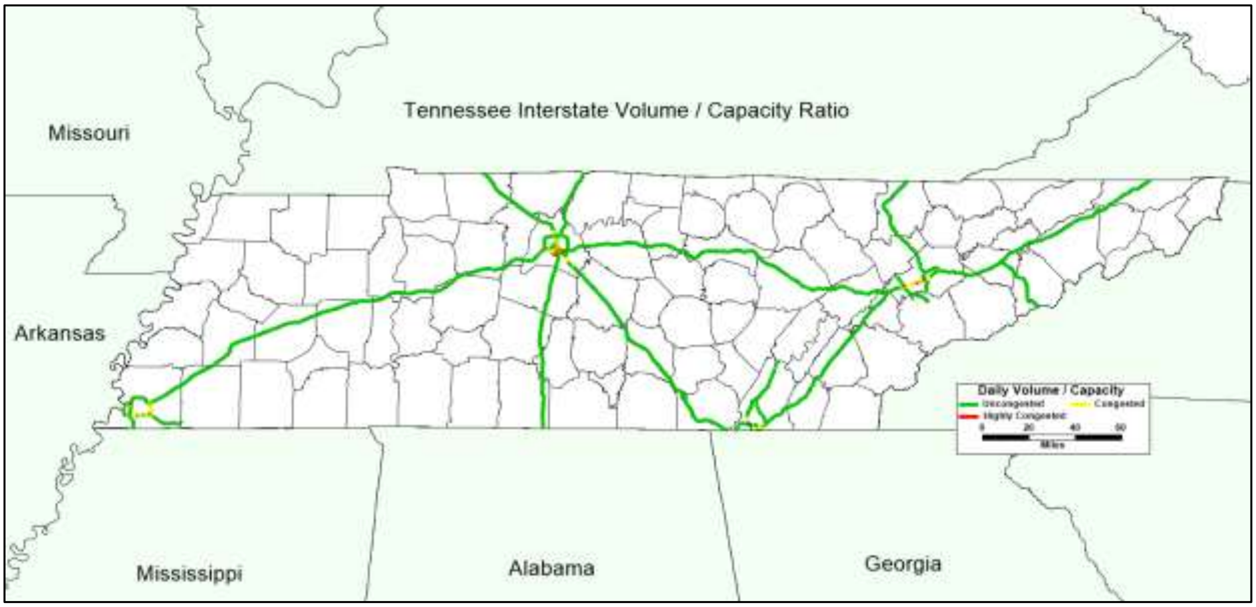


Figure 2.47. 2010 Memphis Daily Non-Peak V/C Ratio

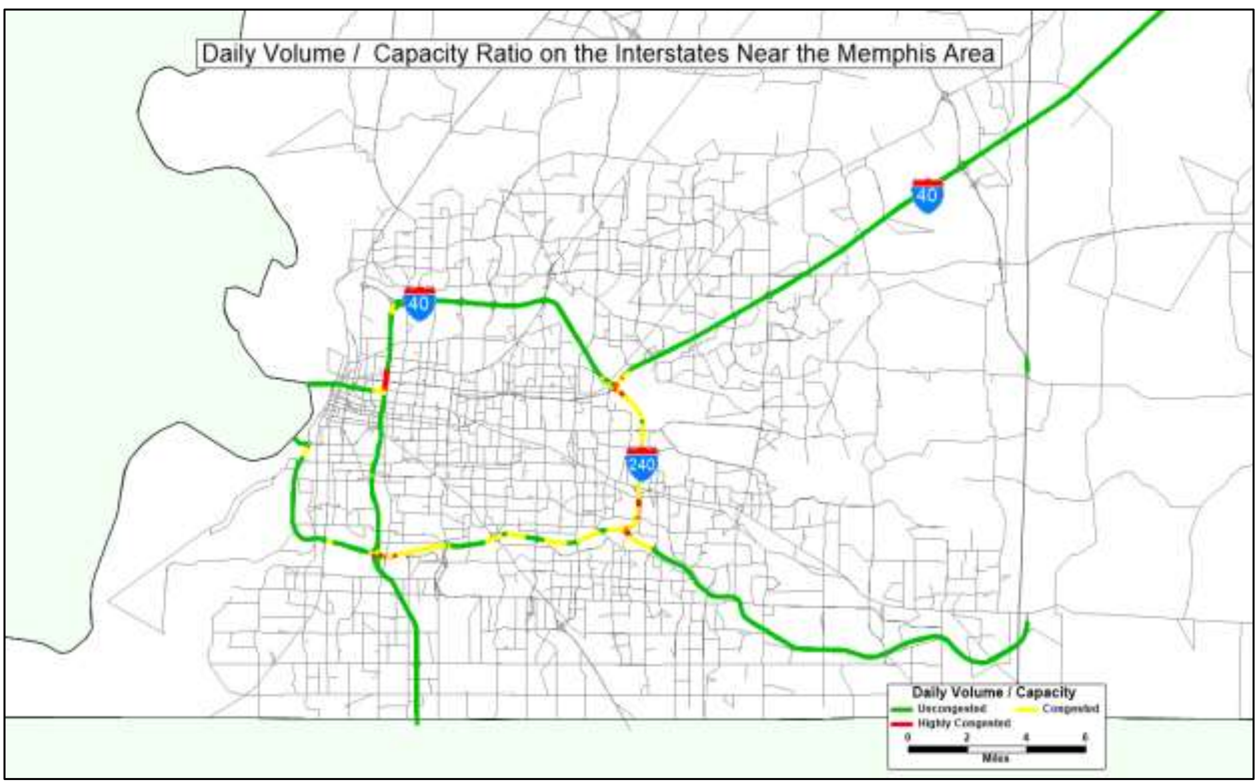


Figure 2.48. 2010 Nashville Daily Non-Peak V/C Ratio

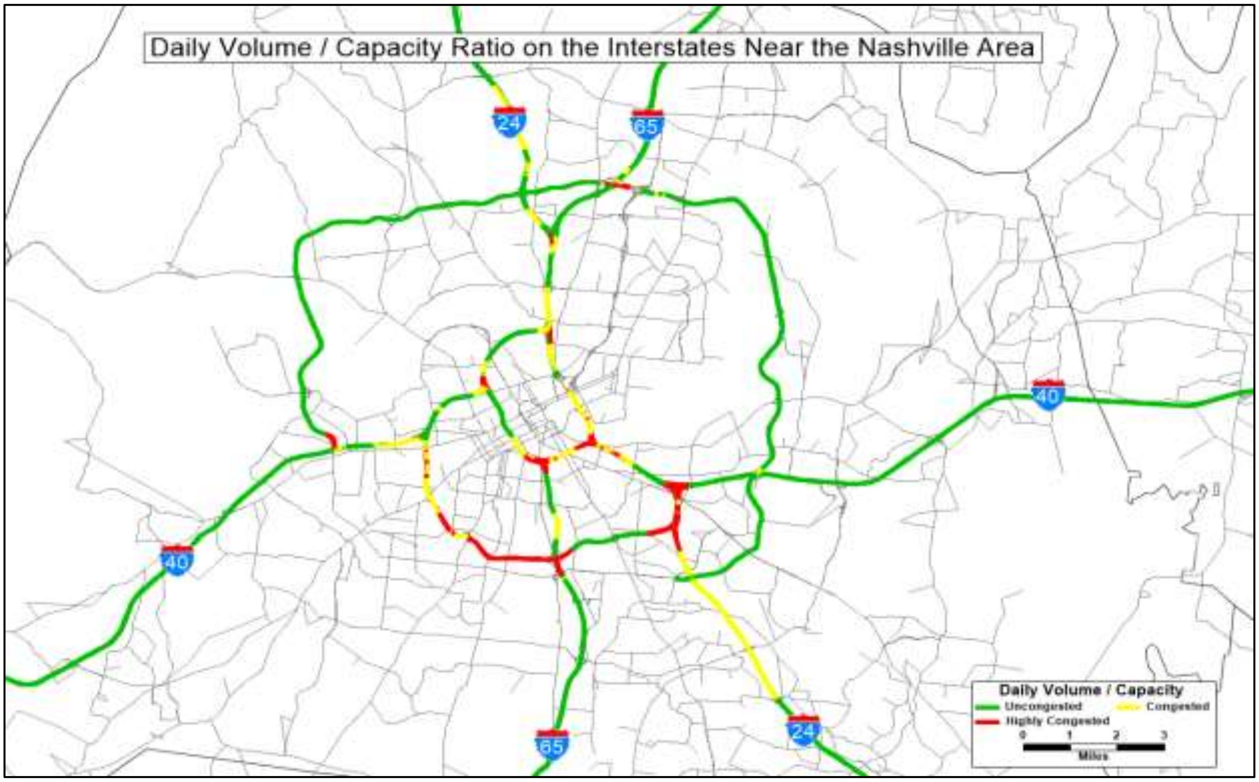


Figure 2.49. 2010 Chattanooga Daily Non-Peak V/C Ratio

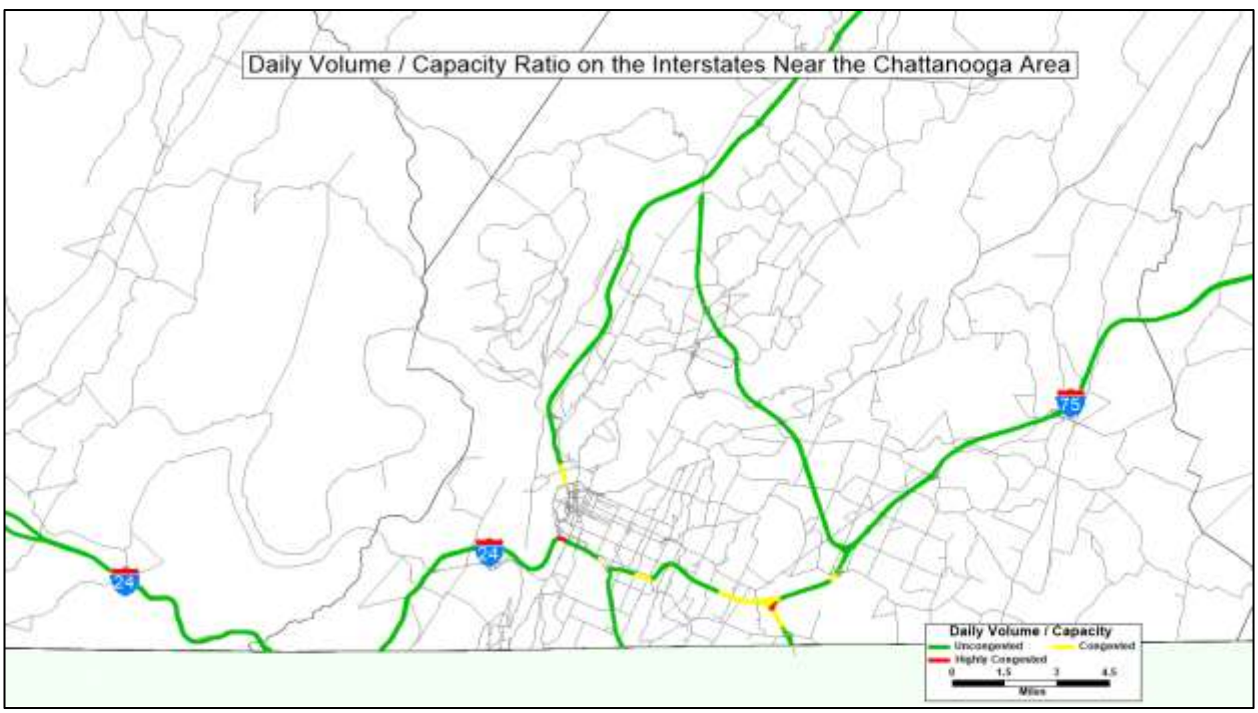
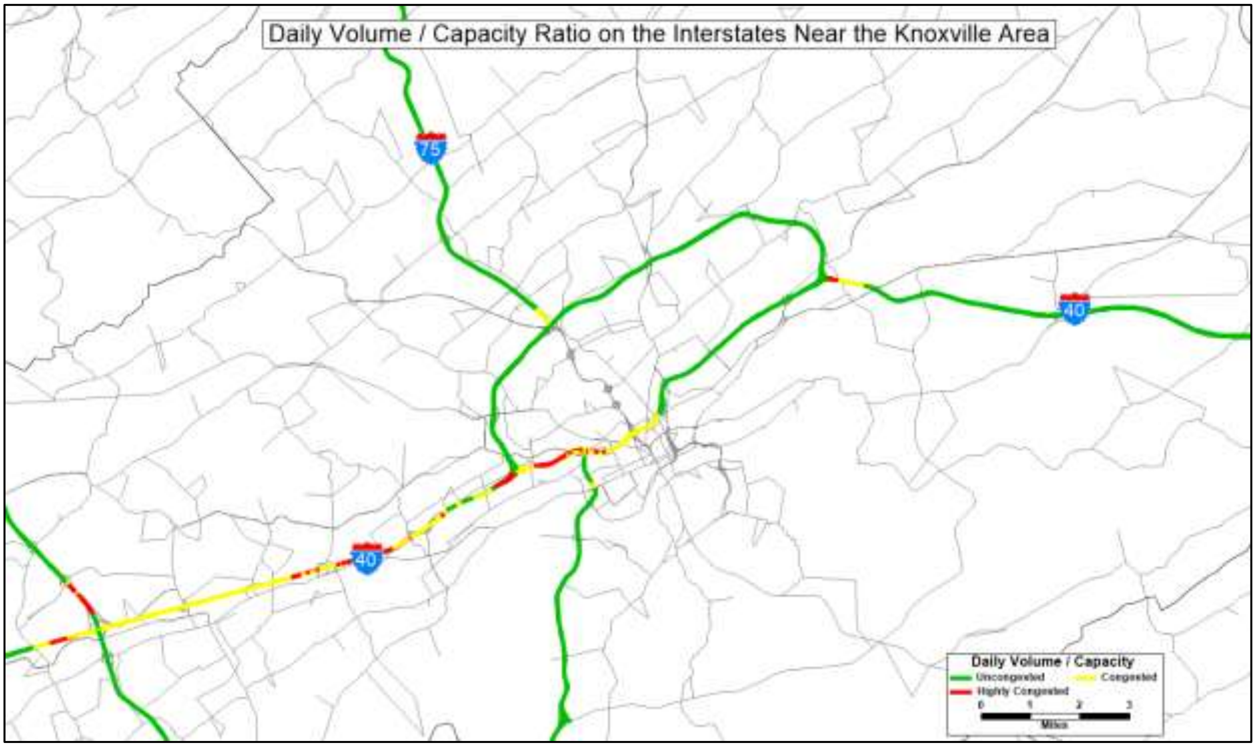


Figure 2.50. 2010 Knoxville Daily Non-Peak V/C Ratio



2010 Morning Peak V/C Ratio

Figure 2.51. 2010 Tennessee Morning Peak V/C Ratio

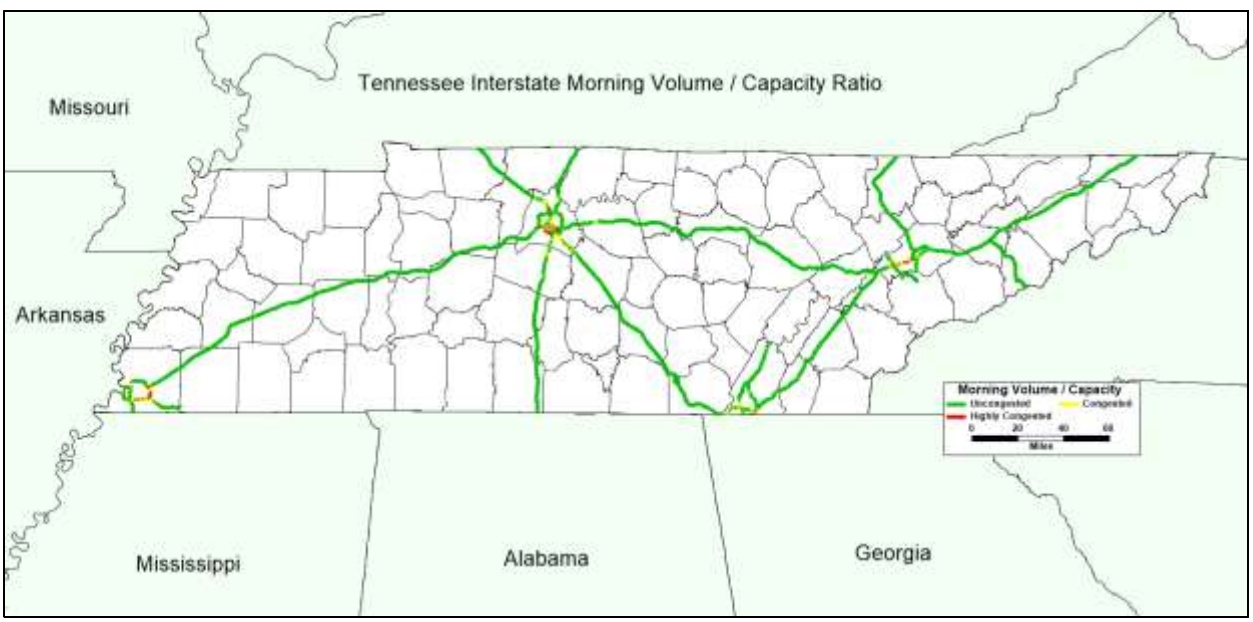


Figure 2.52. 2010 Memphis Morning Peak V/C Ratio

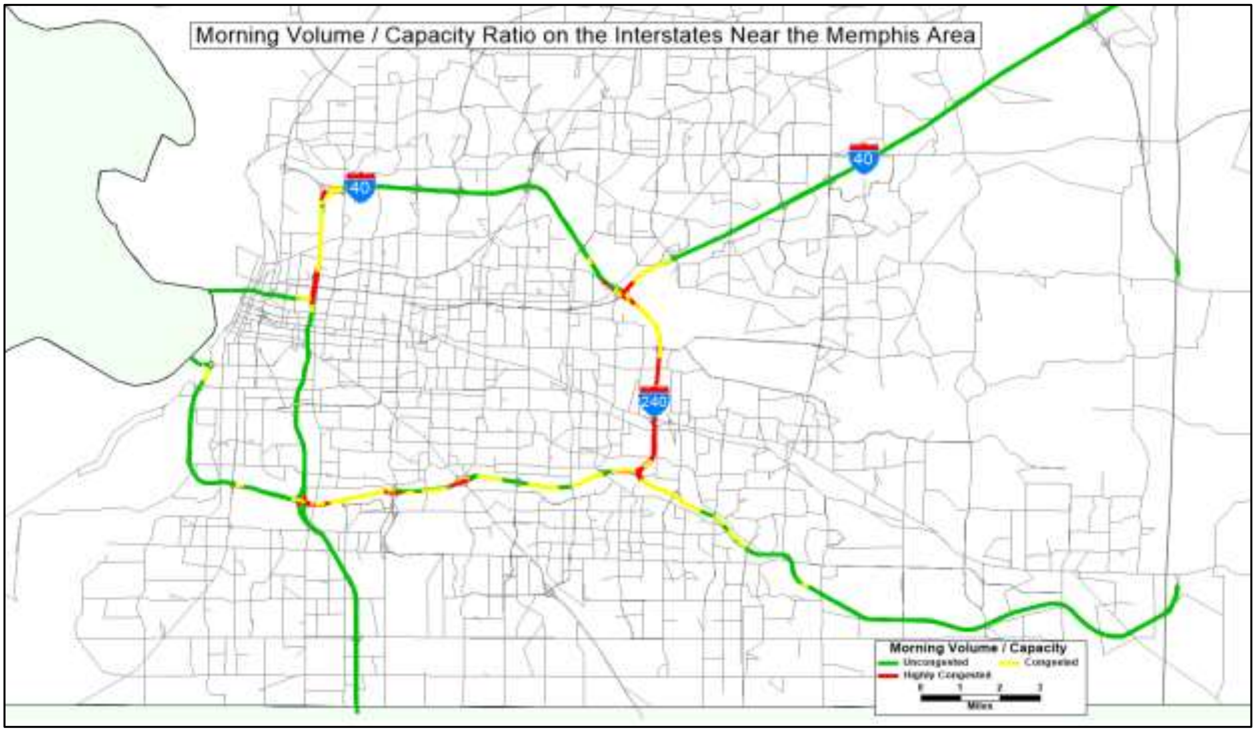


Figure 2.53. 2010 Nashville Morning Peak V/C Ratio

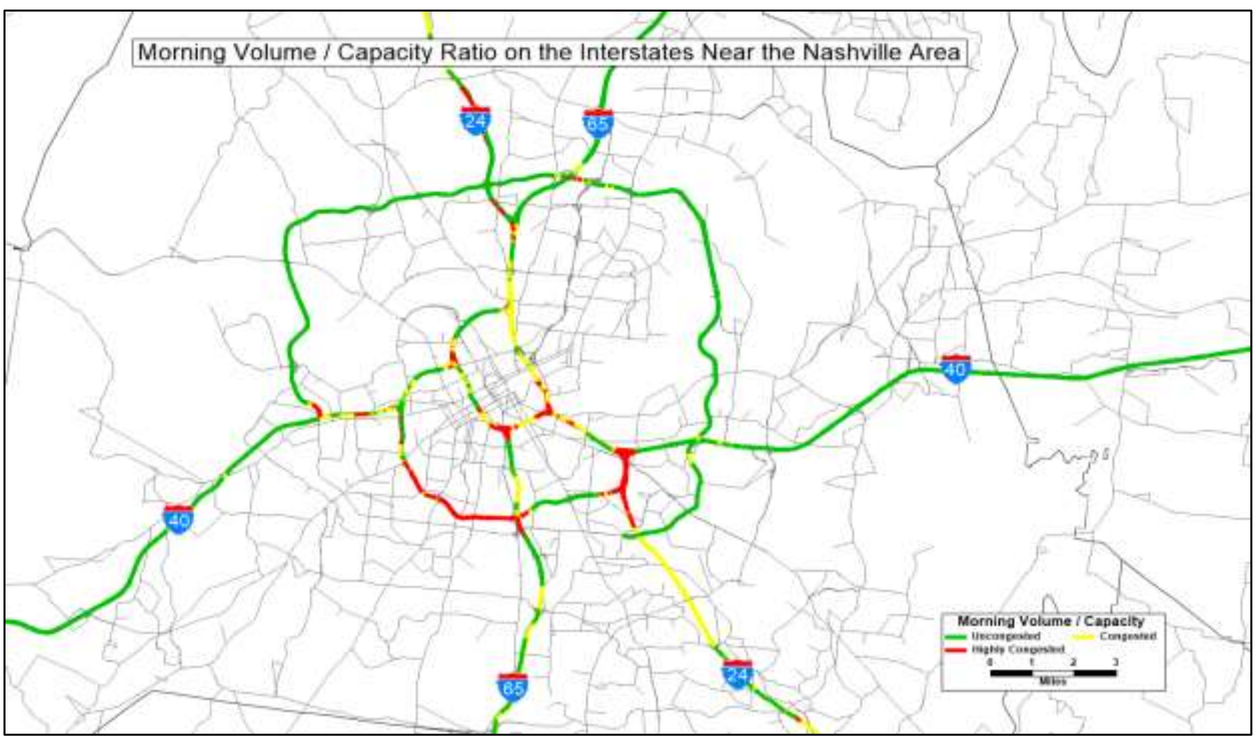


Figure 2.54. 2010 Chattanooga Morning Peak V/C Ratio

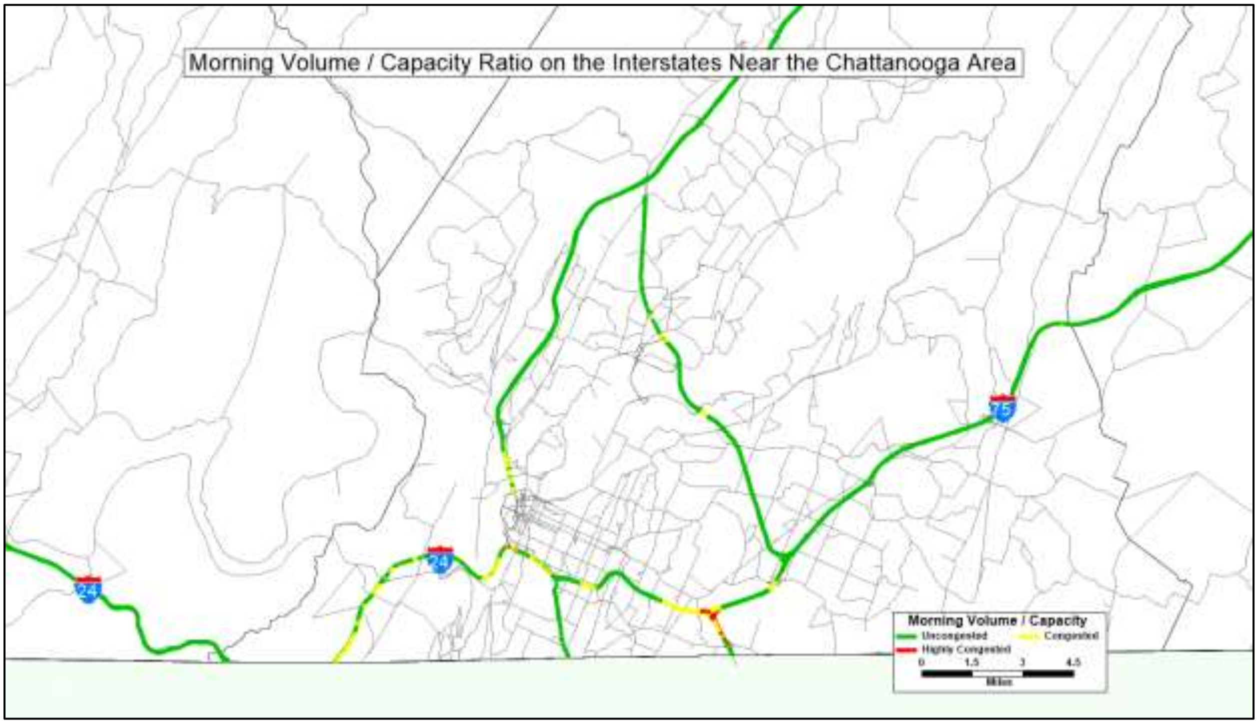
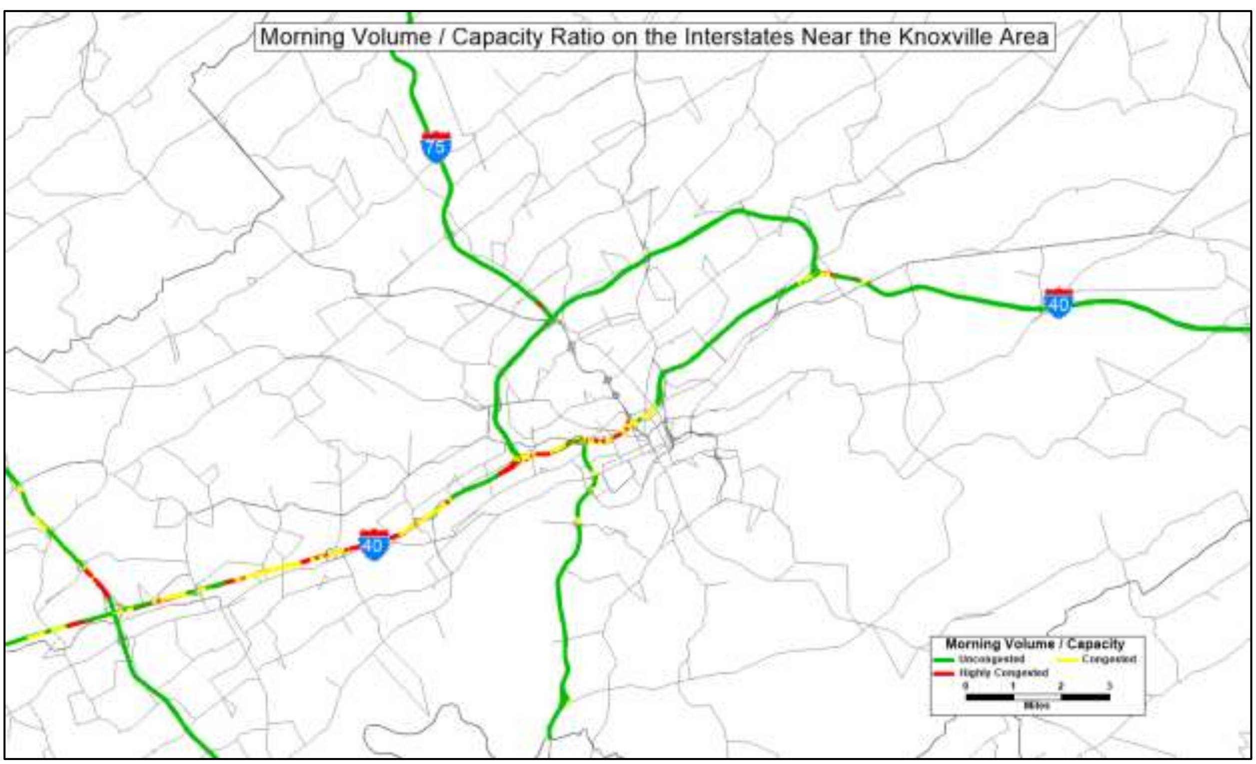


Figure 2.55. 2010 Knoxville Morning Peak V/C Ratio



2010 Afternoon Peak V/C Ratio

Figure 2.56. 2010 Tennessee Afternoon Peak V/C Ratio

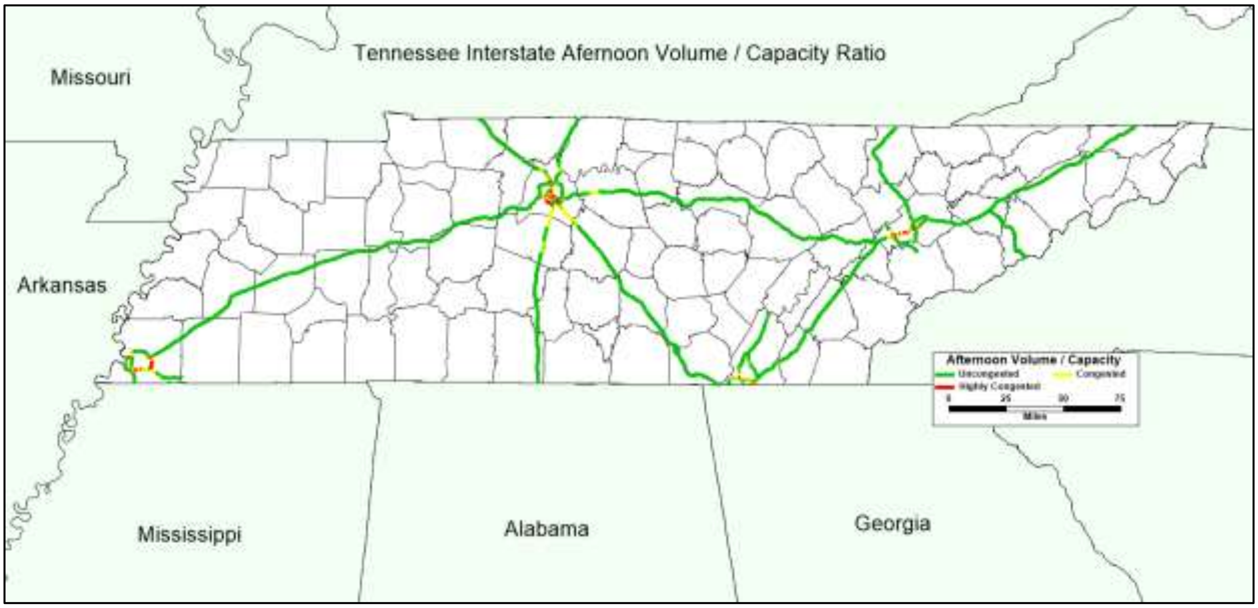


Figure 2.57. 2010 Memphis Afternoon Peak V/C Ratio

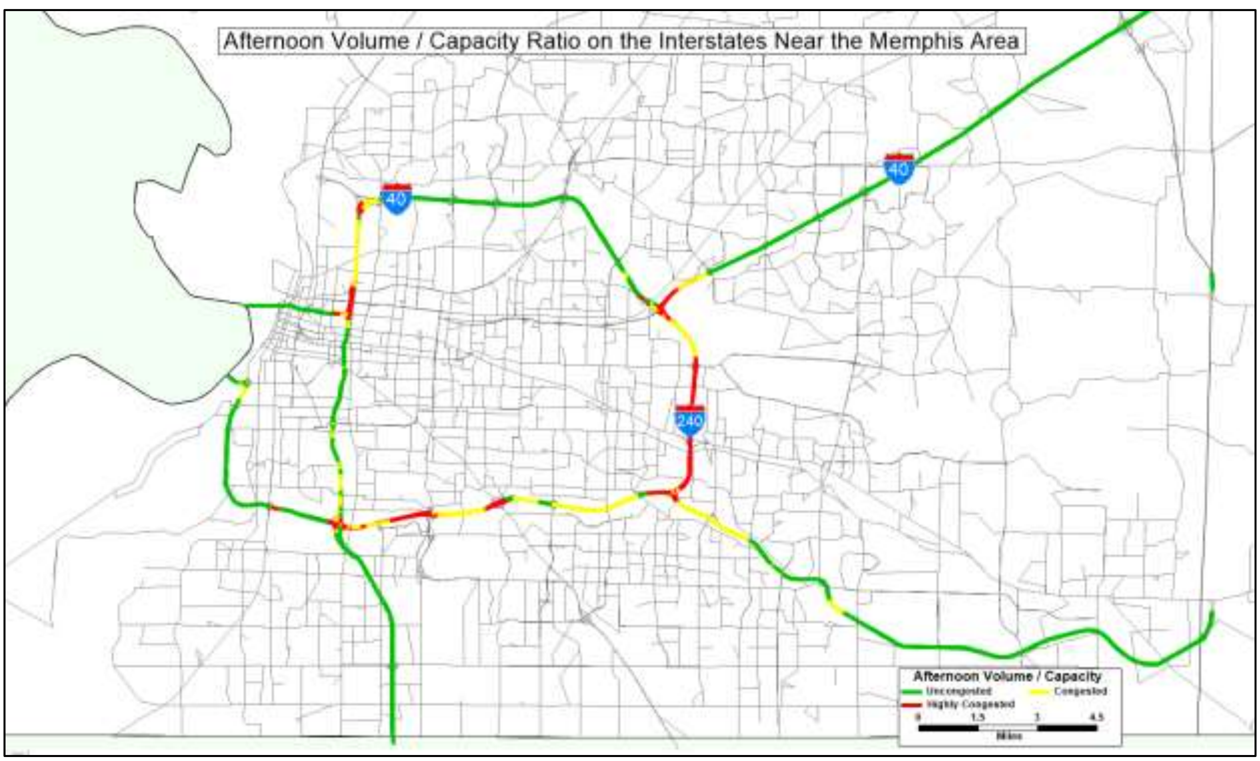


Figure 2.58. 2010 Nashville Afternoon Peak V/C Ratio

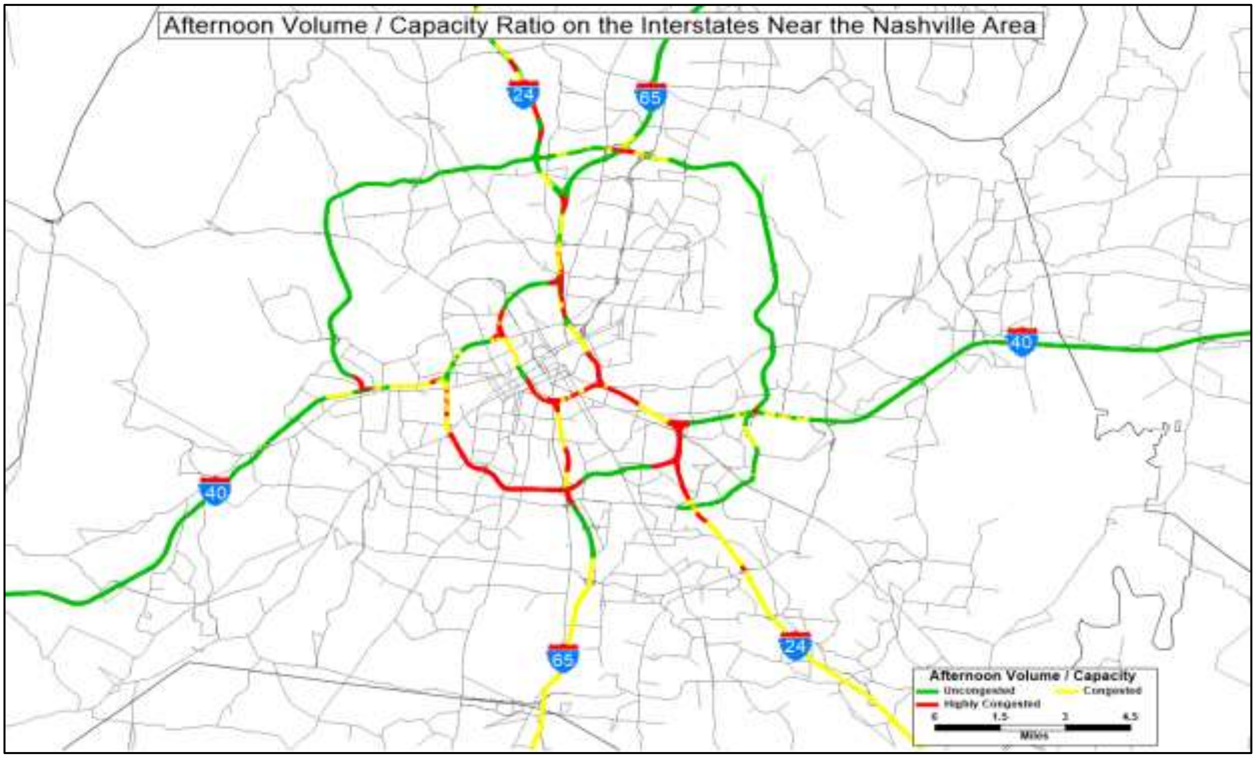


Figure 2.59. 2010 Chattanooga Afternoon Peak V/C Ratio

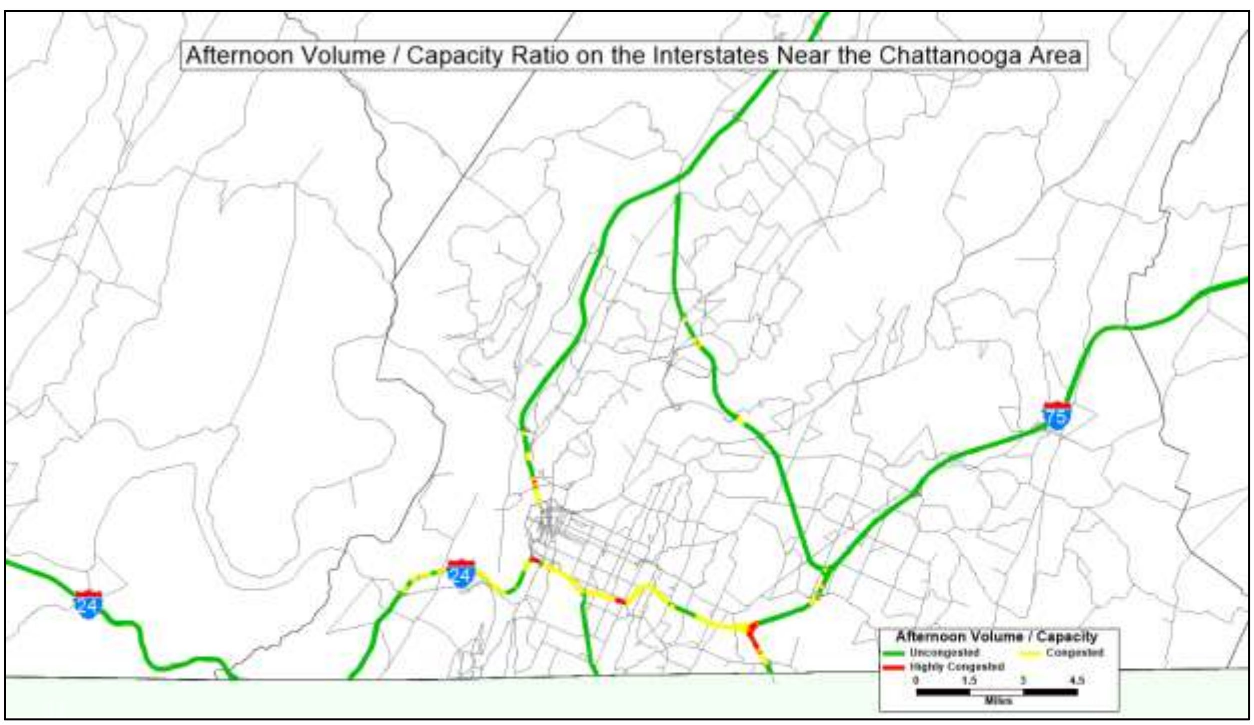
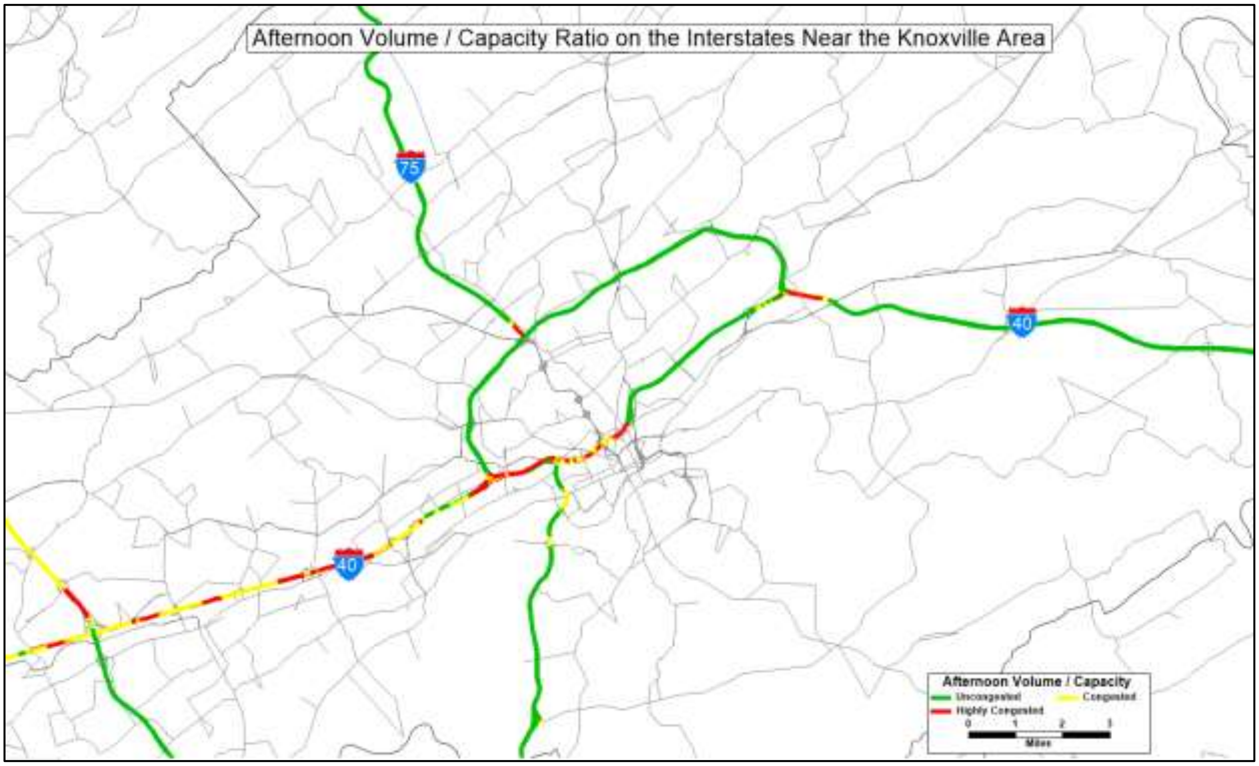


Figure 2.60. 2010 Knoxville Afternoon Peak V/C Ratio



2040 Daily Non-Peak V/C Ratio

Figure 2.61. 2040 Tennessee Daily Non-Peak V/C Ratio

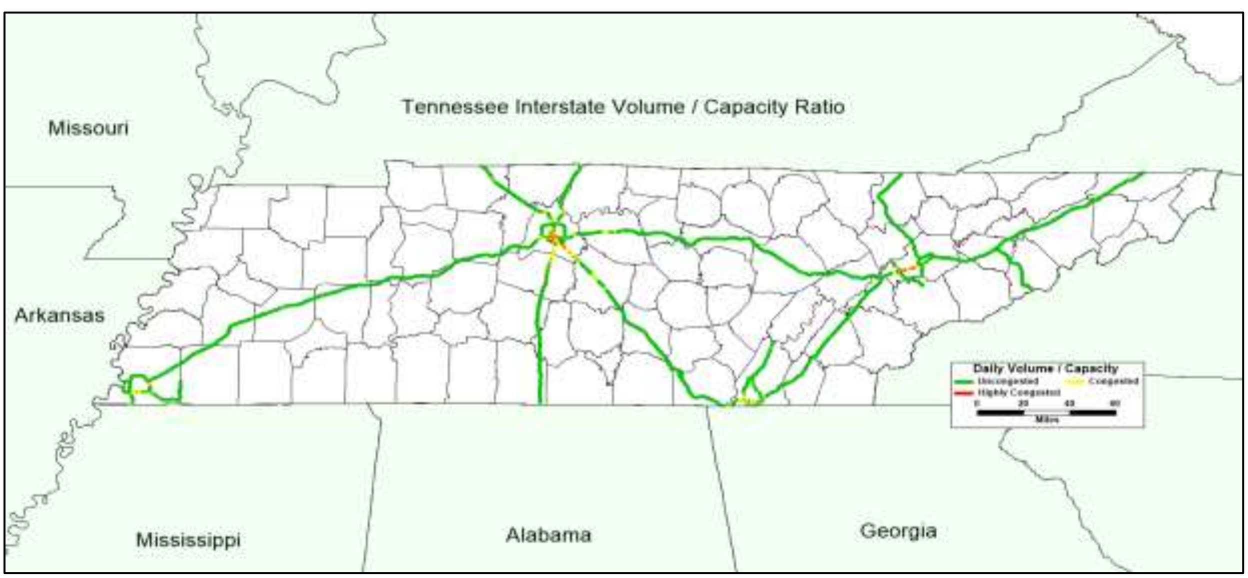


Figure 2.62. 2040 Memphis Daily Non-Peak V/C Ratio

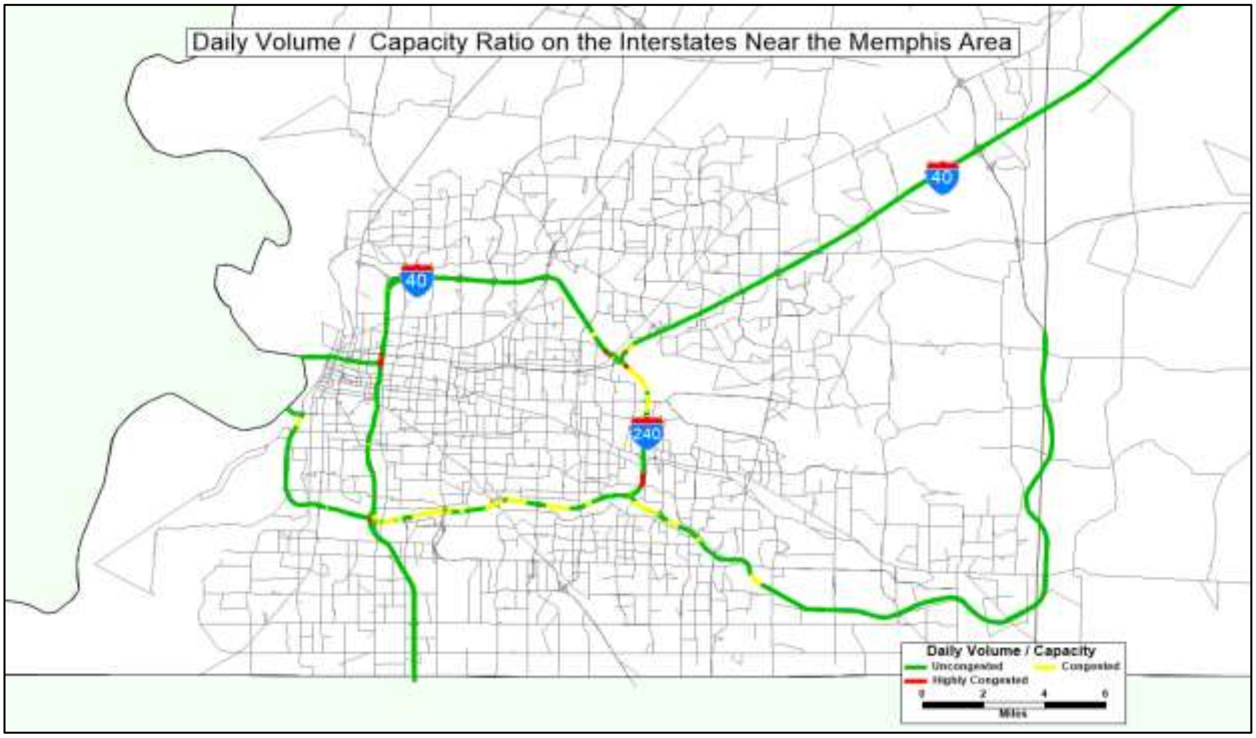


Figure 2.63. 2040 Nashville Daily Non-Peak V/C Ratio

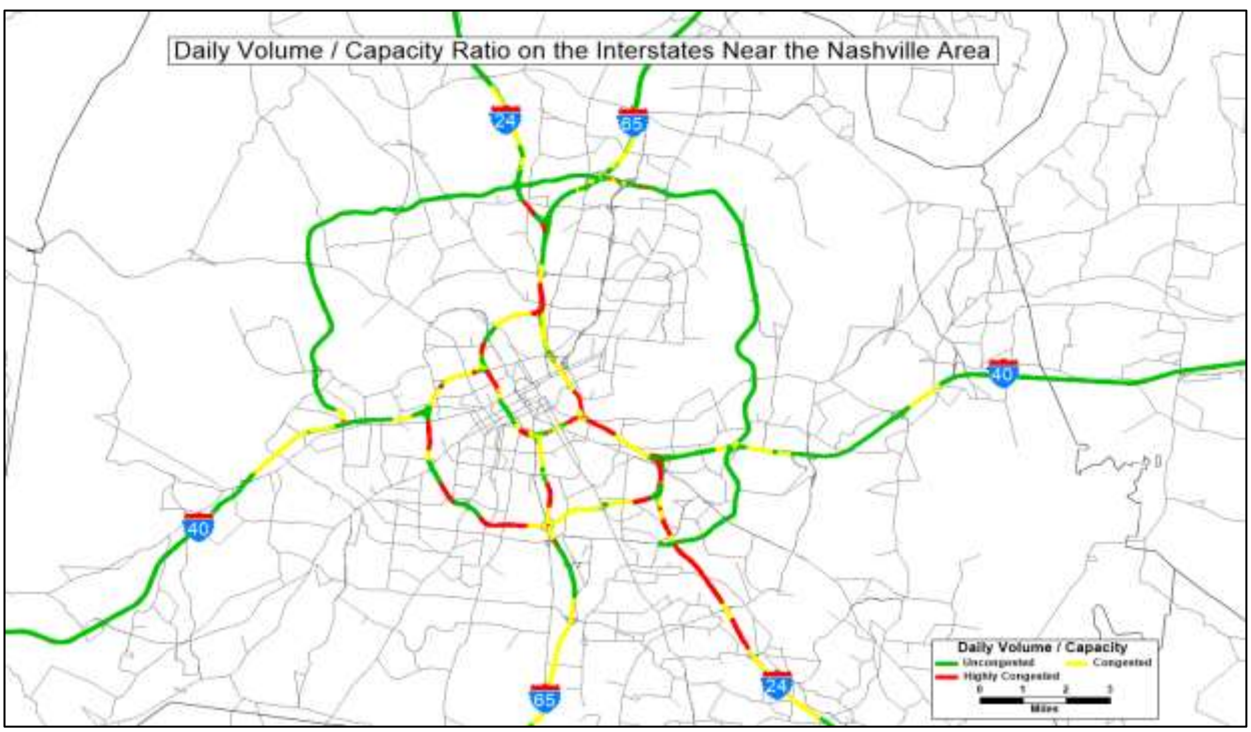


Figure 2.64. 2040 Chattanooga Daily Non-Peak V/C Ratio

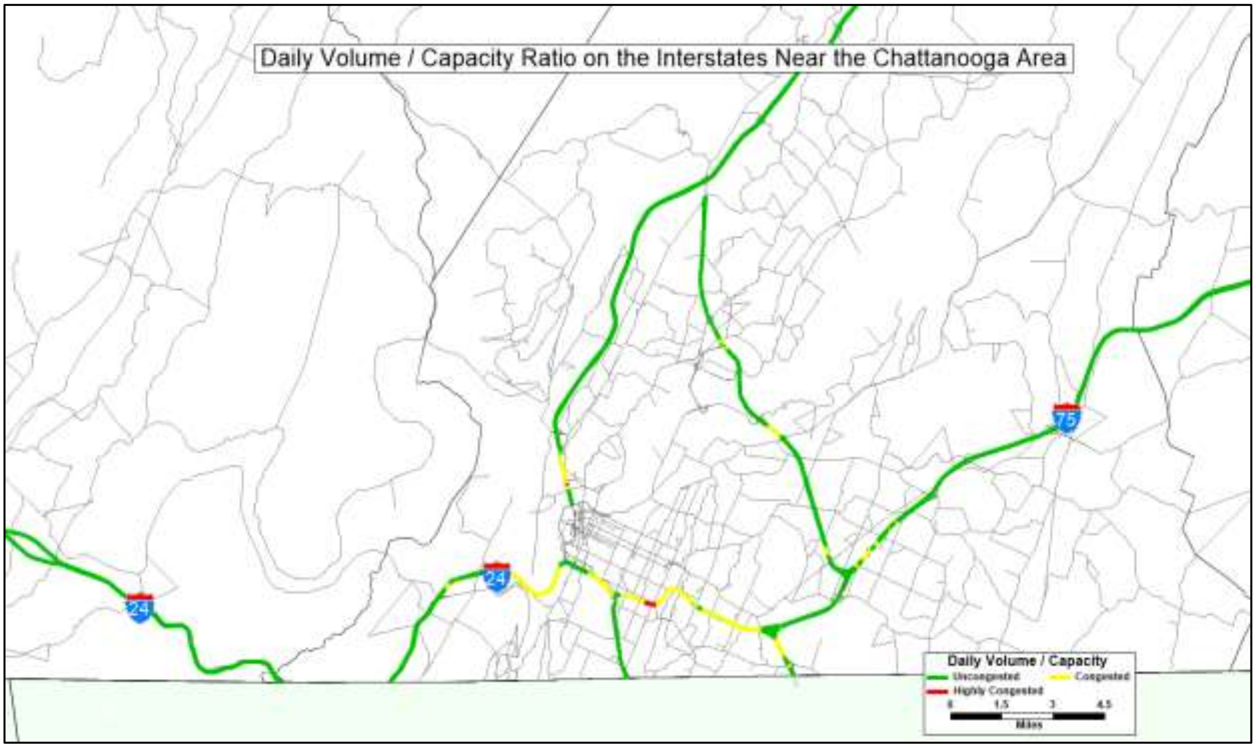
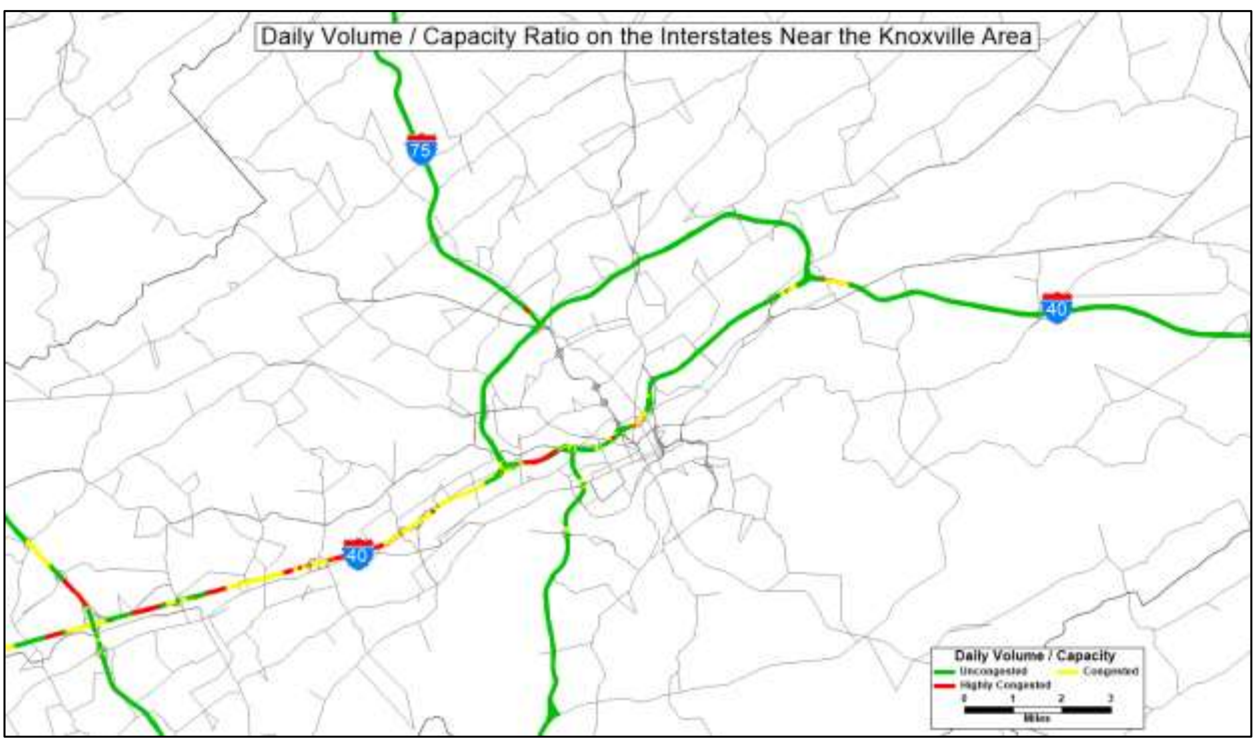


Figure 2.65. 2040 Knoxville Daily Non-Peak V/C Ratio



2040 Morning Peak V/C Ratio

Figure 2.66. 2040 Tennessee Morning Peak V/C Ratio

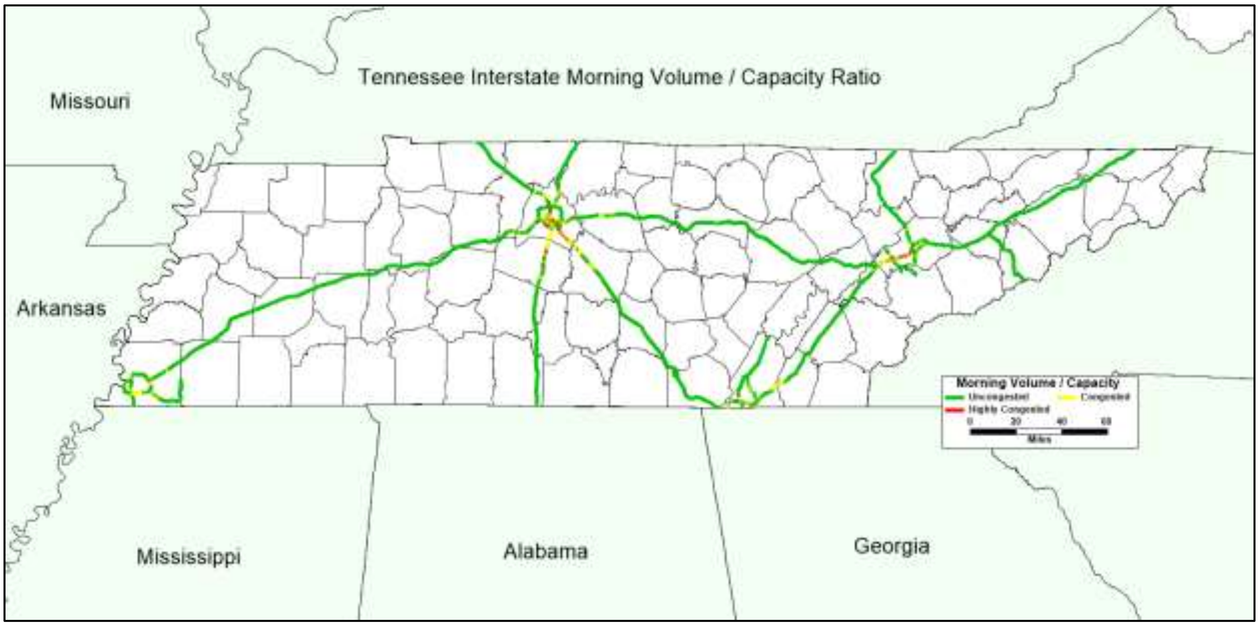


Figure 2.67. 2040 Memphis Morning Peak V/C Ratio

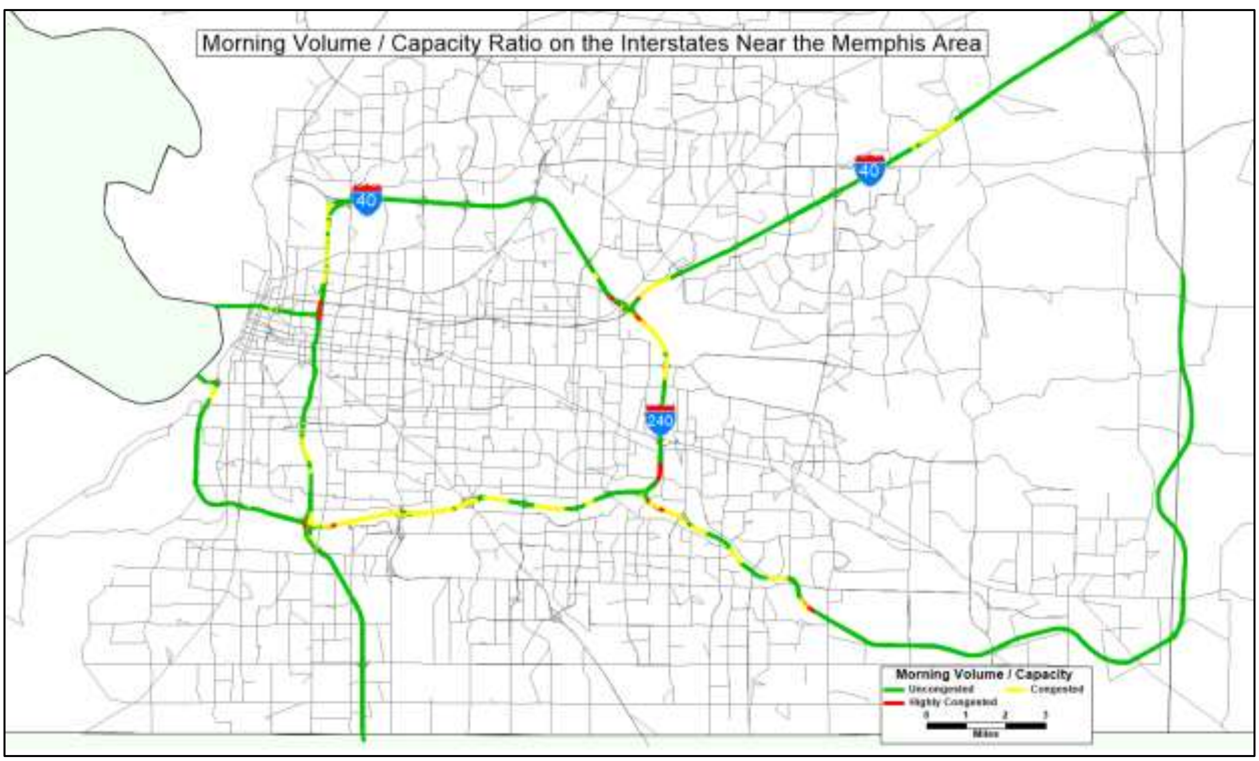


Figure 2.68. 2040 Nashville Morning Peak V/C Ratio

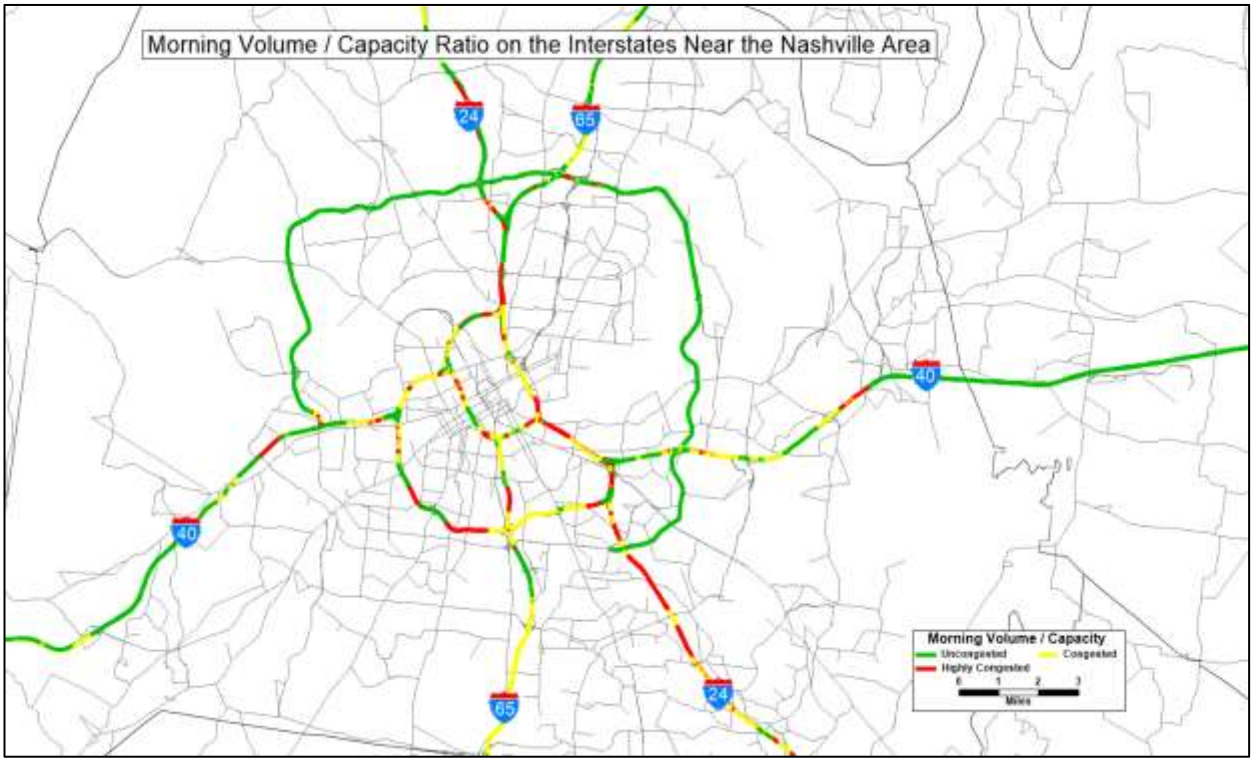


Figure 2.69. 2040 Chattanooga Morning Peak V/C Ratio

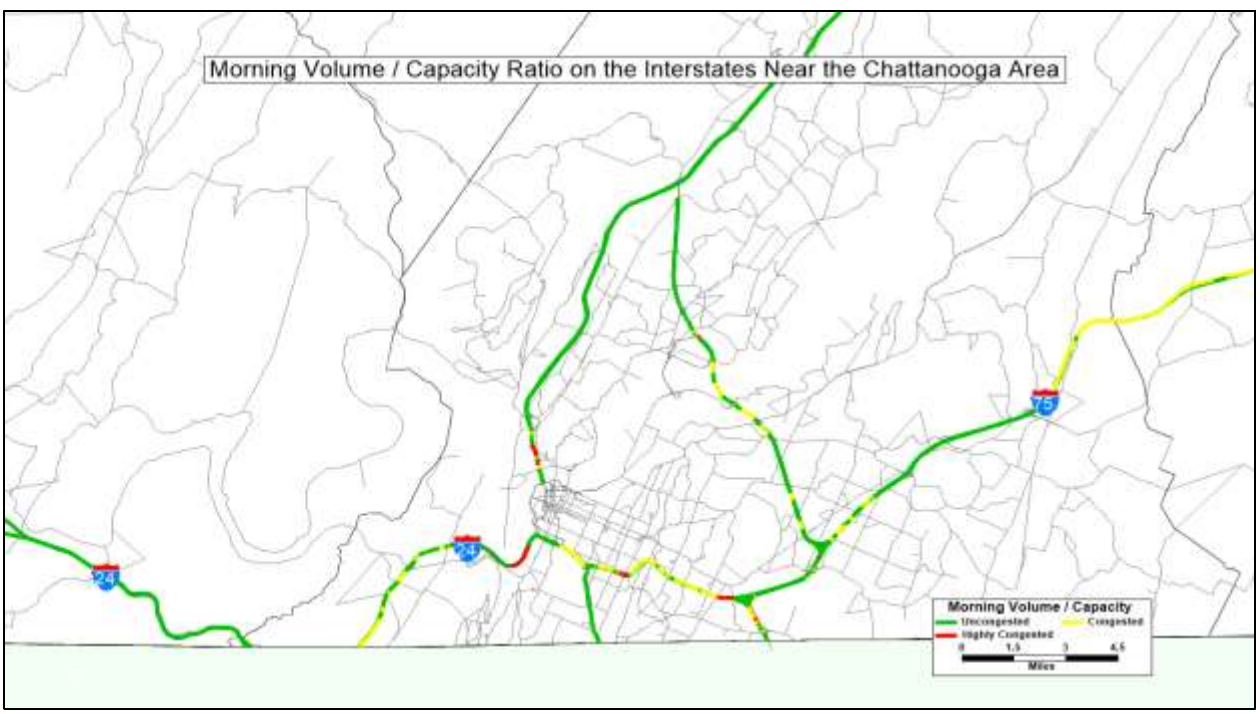


Figure 2.70. 2040 Knoxville Morning Peak V/C Ratio

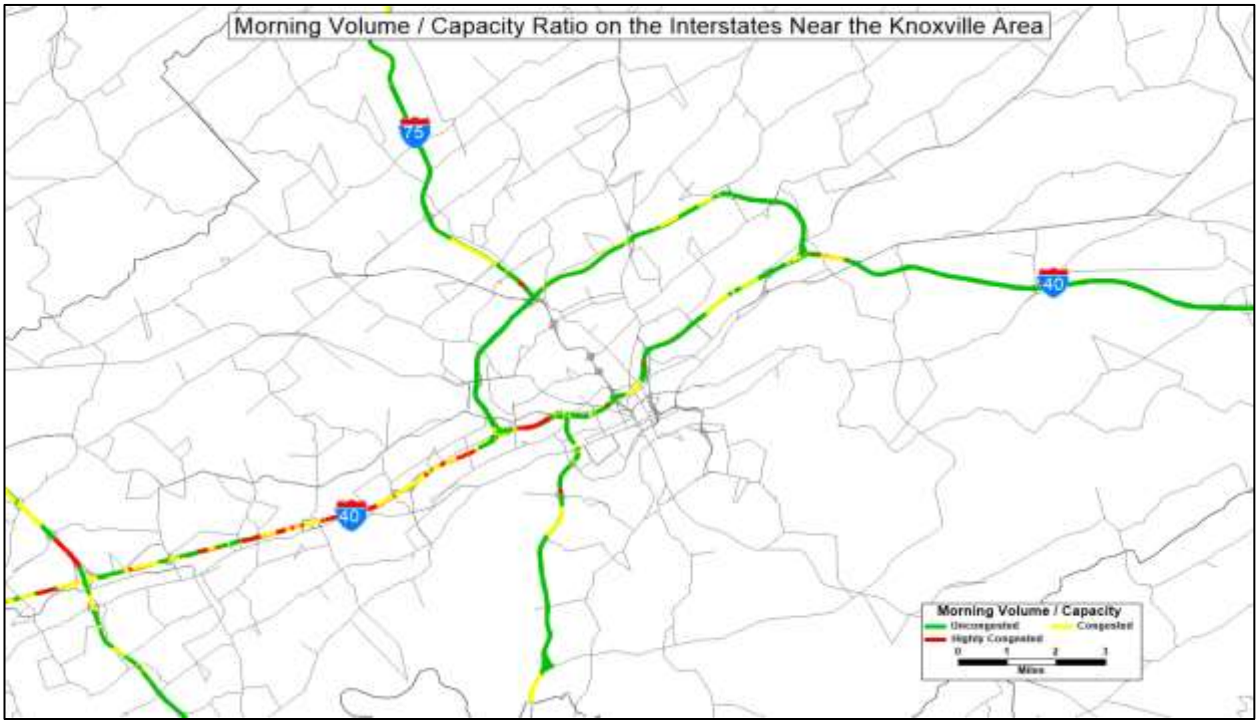


Figure 2.70. 2040 Knoxville Morning Peak V/C Ratio

2040 Afternoon Peak V/C Ratio

Figure 2.71. 2040 Tennessee Afternoon Peak V/C Ratio

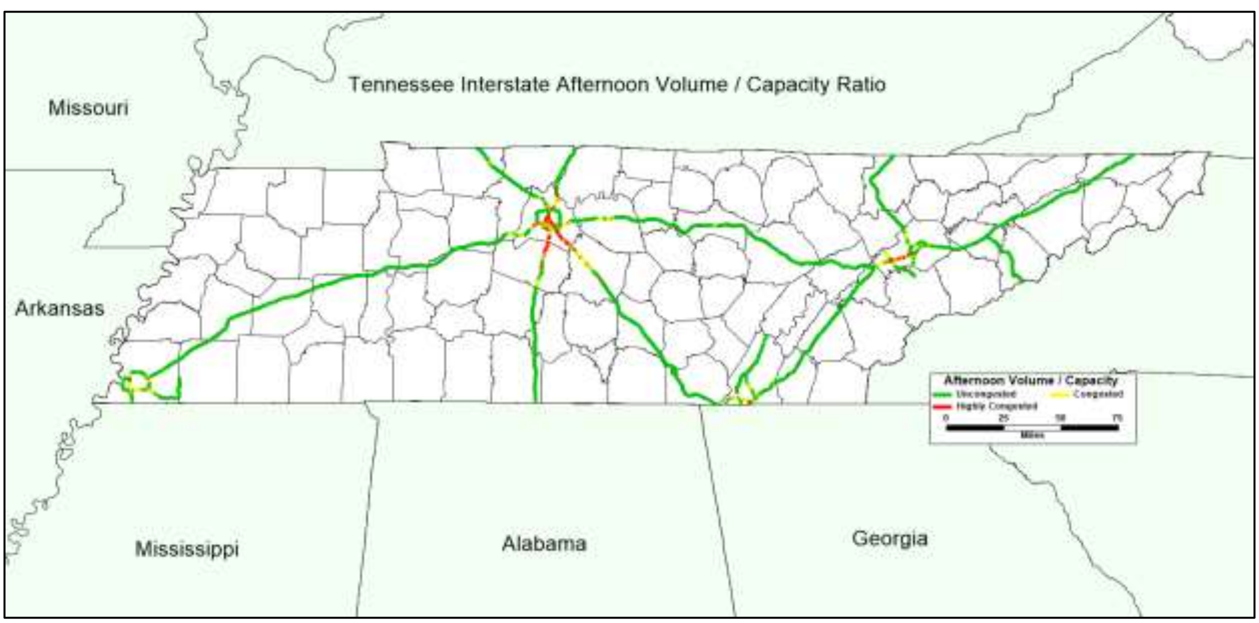


Figure 2.72. 2040 Memphis Afternoon Peak V/C Ratio

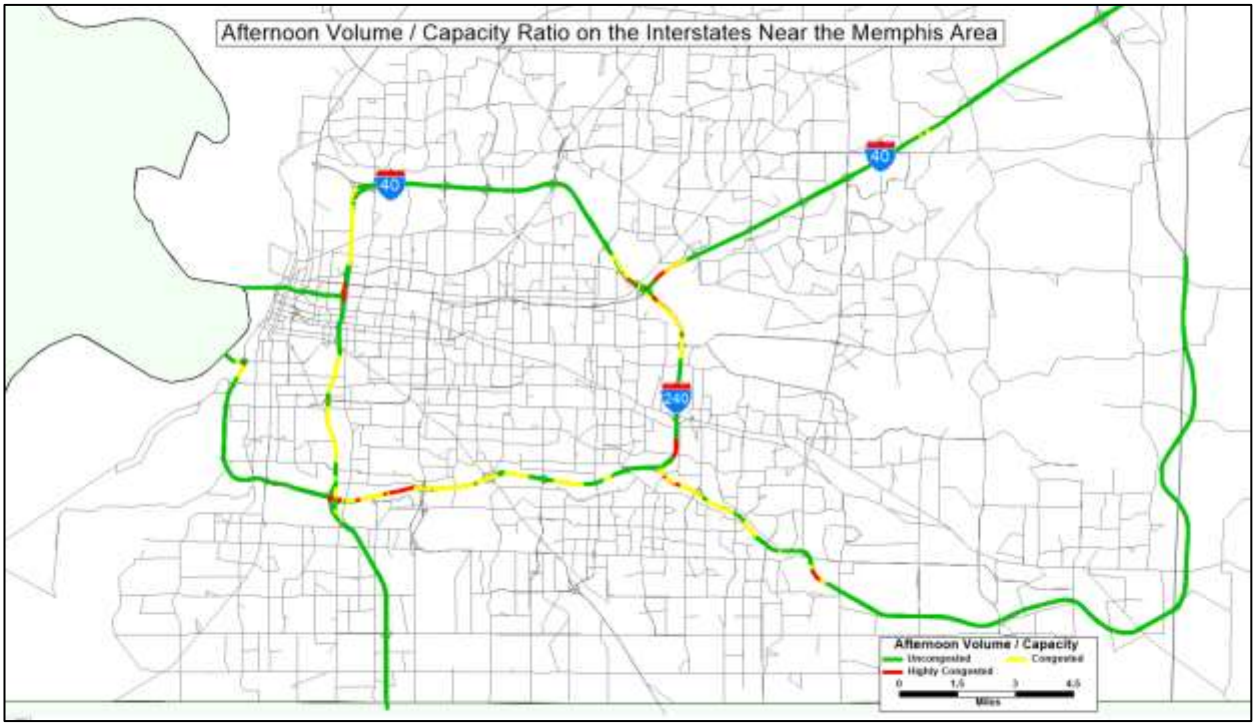


Figure 2.73. 2040 Nashville Afternoon Peak V/C Ratio

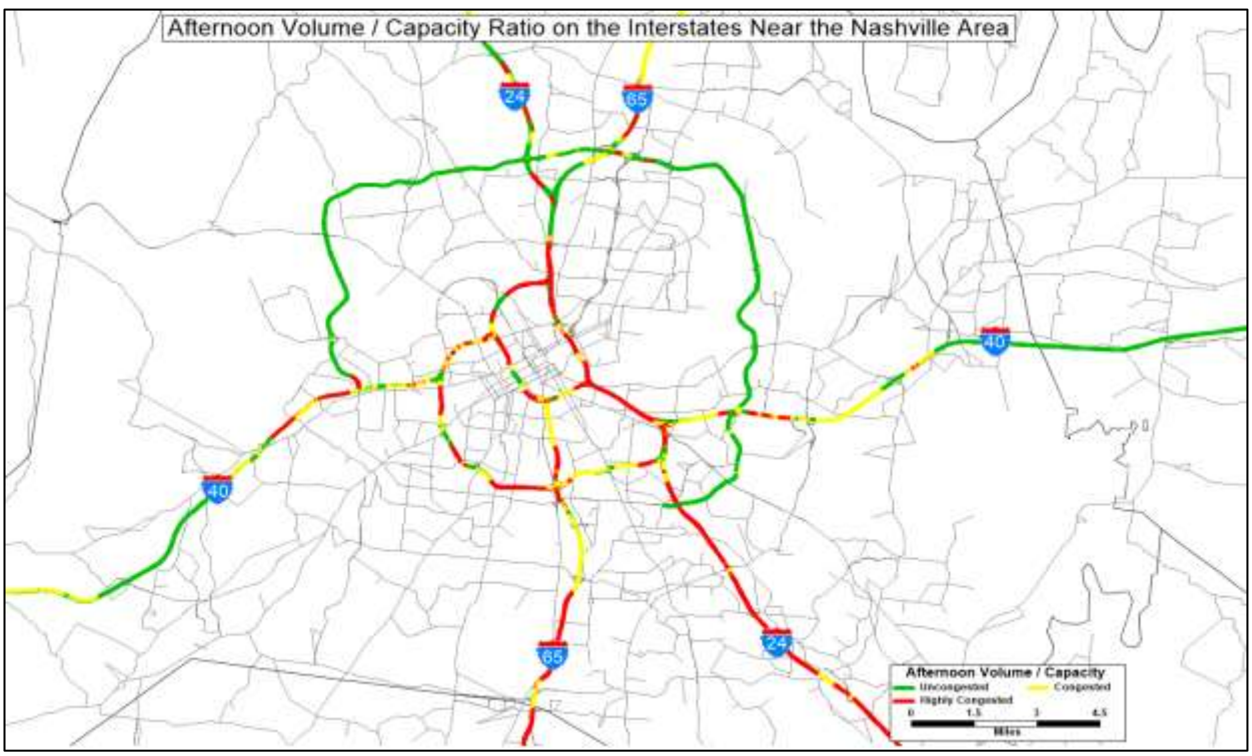


Figure 2.74. 2040 Chattanooga Afternoon Peak V/C Ratio

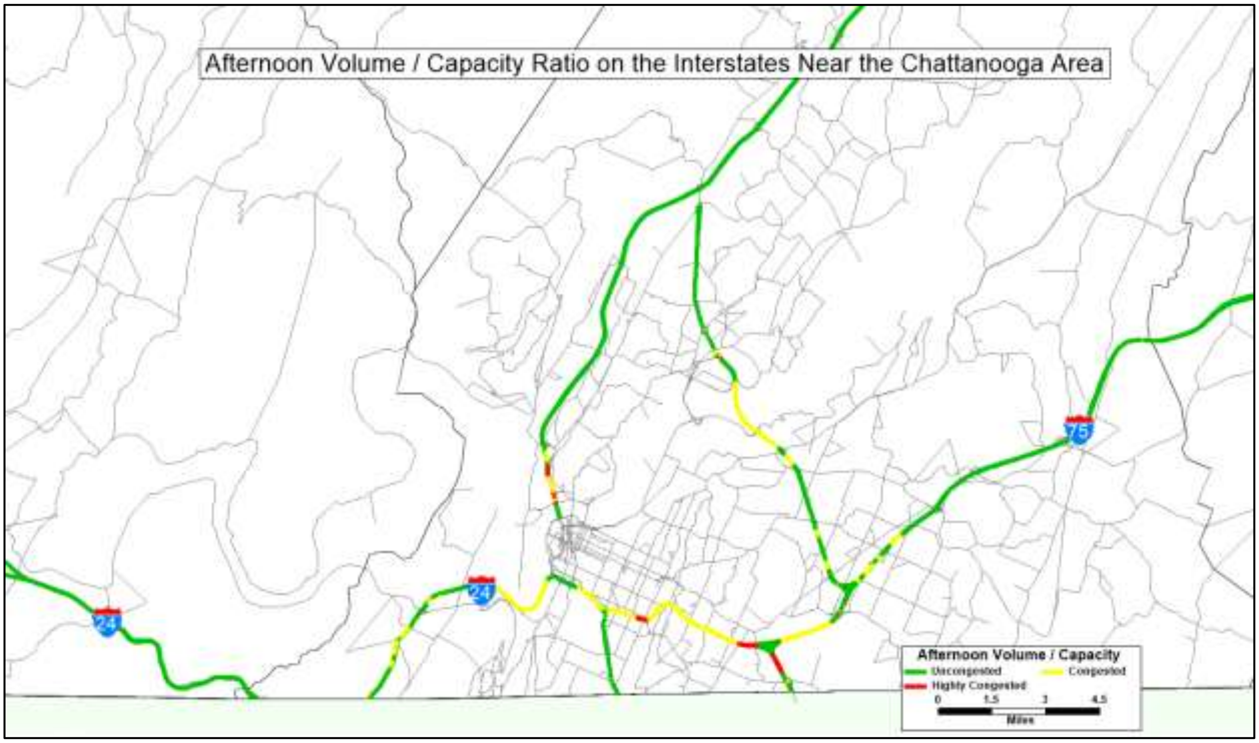
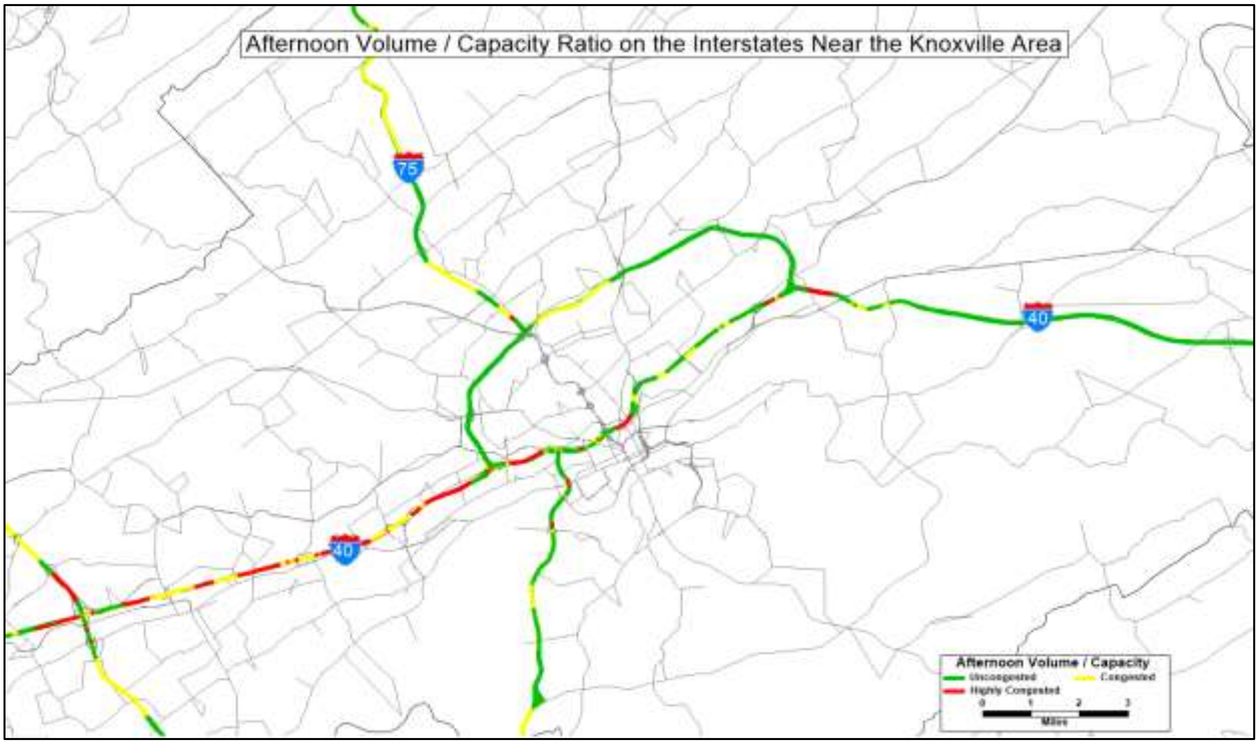


Figure 2.75. 2040 Knoxville Afternoon Peak V/C Ratio



According to the volume / capacity ratios for the base 2010 year and the future 2040 year there is a common area for where there is a high level of congestion. These areas are mainly in the urban areas where there is a higher level of population. However, these areas also show that they have more driving lanes compared to the rural interstate areas. However, the number of vehicles on the road is extremely higher in the urban areas than there is in the rural.

Conclusion

In conclusion of potential freight bottleneck locations on Tennessee interstates, there are two takeaways which can be inferred by the data. The first is that the majority of the bottlenecks are going to occur in or near major metropolitan areas or cities, as there are more potential indicators that have the opportunity to contribute to freight delay. The second is that the ramp location has a major influence on potential bottlenecks due to the issues with change in speed of free flowing traffic and merging into the traffic flows from vehicles entering and exiting the interstate system.

Chapter 3. 2017 Interstate Crash Report

The purpose of this chapter is to get an evaluation of the 2017 accidents in Tennessee that occurred on the interstates. The reasoning for evaluating the accidents on the interstates is to determine where the major clusters are for accidents and what factors are contributing to causing these accidents. In addition to the identifying the major locations for accidents, this analysis will also determine the number of accidents that occurred during certain periods throughout the day such as night time, day time, and dawn/dusk. For the purpose of this report the crashes on the interstates will be broken down into three categories:

- Fatal Crashes
- Minor Injury Crashes
- Serious Injury Crash *(non-fatal)*

The first thing to identify for this report is the number of accidents that happened in 2017 on the interstates in Tennessee. In the year of 2017 there were 5,418 crashes that were reported of being either fatal, minor injury or serious injury; with the majority of the accidents falling into the minor injury category (86% of crashes). **Figure 3.0** shows the breakdown of the number of each crash that occurred the three categories, with **figure 3.1** through **figure 3.3** showing where the crashes are located on the interstates.

Figure 3.0. Number of Crashes in Each Category Grouping

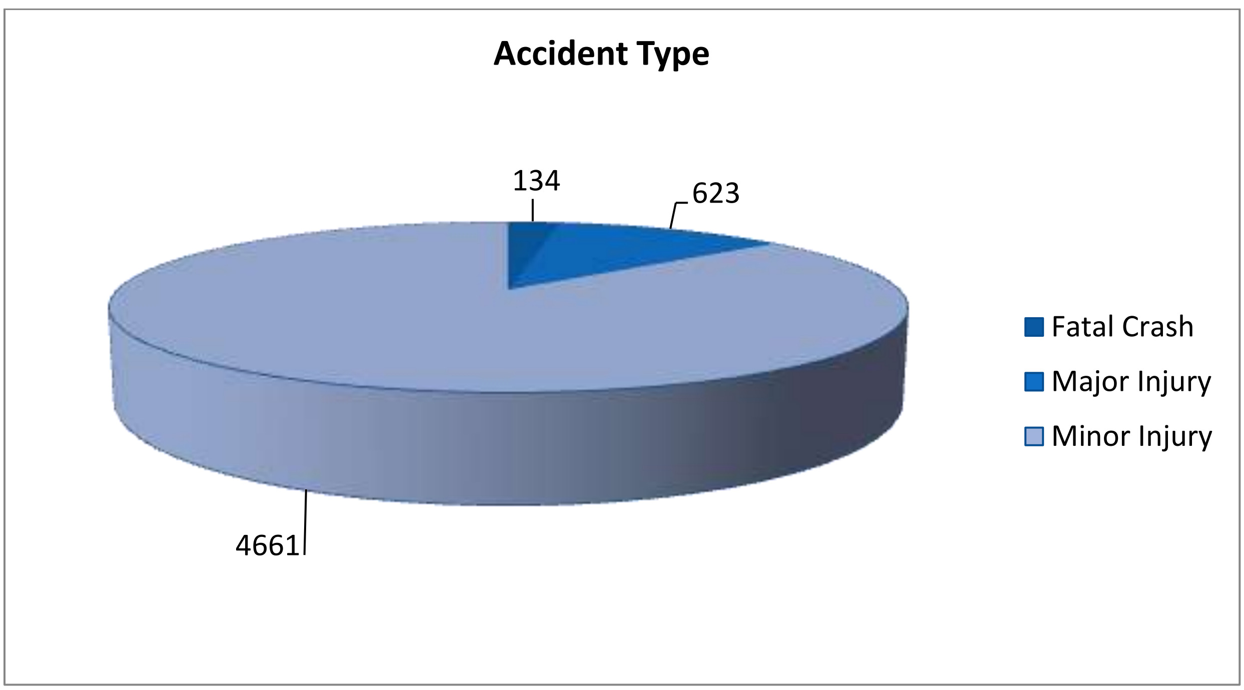


Figure 3.1. 2017 Fatal Crashes on Tennessee Interstates

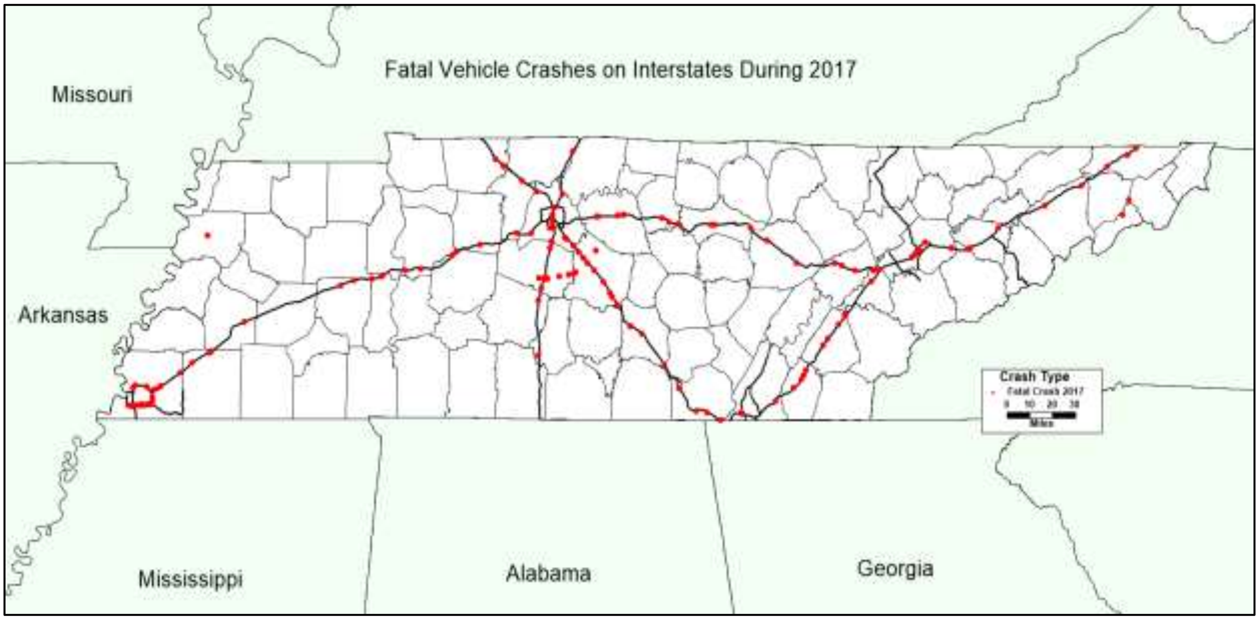
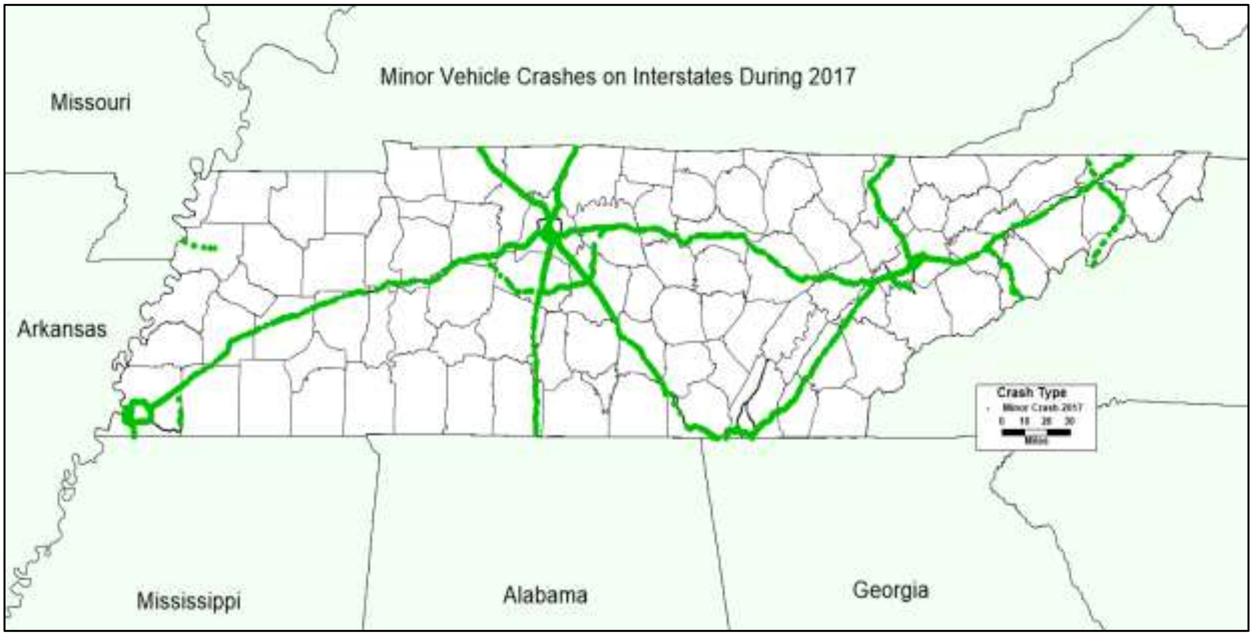


Figure 3.2. 2017 Serious Injury Crashes on Tennessee Interstates

Figure 3.3. 2017 Minor Injury Crashes on Tennessee Interstates



Knowing where each of the crashes are at based on the type of crash it is, the next step will be to dissect these crash types to determine further information about these locations that can help with understanding why these crashes are occurring and what can be done in the future to reduce the number of crashes that are occurring.

These next few sections are focused on the crashes that occurred in Tennessee on the interstates. Using the different types of crashes the following information will be analyzed:

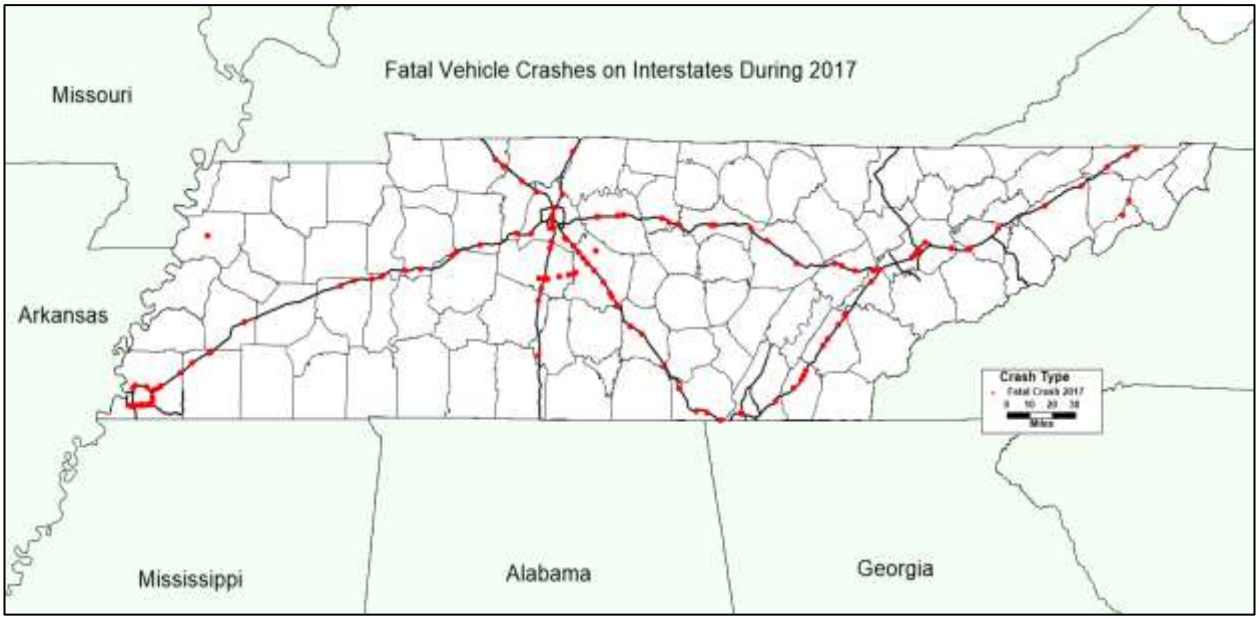
- The Location of the Accident
- Time of the Crash
- Total Number of Vehicles Involved
- Weather Conditions

Using these four characteristics, the goal will hopefully be to understand why these crashes are occurring in these regions and get a better understanding of the bottlenecks that are caused by crashes are more likely to occur.

3.0. 2017 Fatal Crash Evaluations

The first category that will be viewed at is the smaller group of crashes which are the crashes that resulted in a fatality. Fatal crashes in the interstates account for 2% of the total crashes, as shown in **figure 3.4** there are clusters of fatal crashes closer to the urban environments such as Memphis, where in the rural areas the accidents are more disperse.

Figure 3.4. Fatal Crash Cluster in Memphis Tennessee.



In addition to showing a major cluster of fatal crashes in Tennessee, **table 3.0** represents the top 5 counties in Tennessee that had the most number of fatal crashes on the interstates in 2017.

Table 3.0. Top 5 Ranked Counties for Fatal Crashes

Ranking	County	Number Crashes
1	Shelby	19
2	Davidson	13
3	Williamson	10
4	Knox	6
5	Marion	4
5	Bradley	4

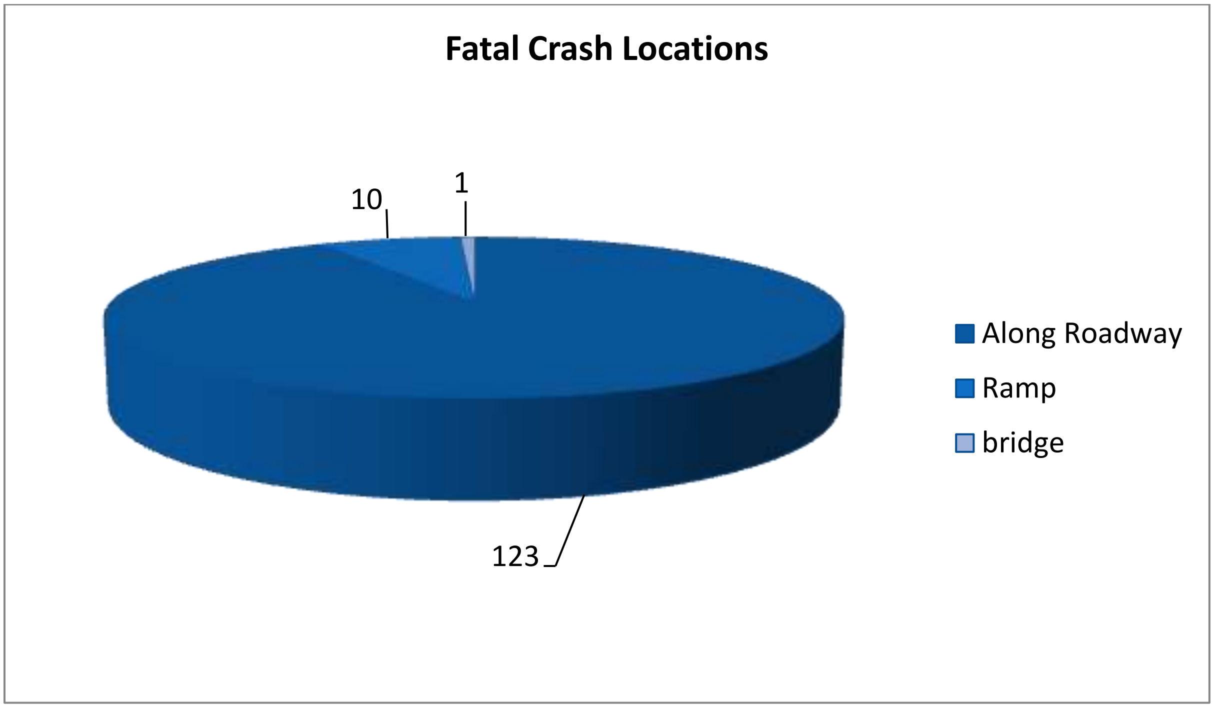
Looking at **table 3.0**, it is clear that the major counties that have large urban developments such as Memphis in Shelby County and Nashville in Davidson County are the top areas in which fatal accidents occur, which can be assumed that where there are urban areas there is a larger chance of being in a fatal accident. This can be argued that this is not true since the travel speeds are slower closer to the urban areas due to the increase in the number of people who are there, but then there is the side that because there is more people that there is a larger chance of being in an accident. Summarizing down to when there are fewer vehicles on the road there is a lower chance of being in a fatal accident.

3.0.1: The Location of Fatal Crashes in 2017

The first factor that will be looked at for the 2017 fatal accidents is the location in which the crashes area occurring in. This information will provide a visual of the road infrastructure in which these accidents are occurring on, which can later be evaluated to determine if infrastructure changes are needed in order to reduce the number of accident that are occurring in a location. **Figure 3.5** shows the location in which the fatal crashes for 2017 have occurred, showing that 92% of the fatal crashes happen along the open roadway and 7% of the area near the interstate ramps.

Figure 3.5. 2017 Fatal Crash Locations

Figure 3.6. Fatal Crash Location Breakdown



Using the location of the crashes it can be determined that when it comes to a fatal crash there is a higher chance of being involved in one when traveling on the open road at a higher speed than when traveling on or off of an interstate ramp. An explanation for why there is an increase in the number of fatal crashes on the open road is being drivers may become less aware of their surrounding on the road because they are not near an interstate ramp, which could result in them colliding with another vehicle. Another reason is that the traveling speeds are usually faster when there is not an interstate ramp near, which could result in a vehicle losing control of their vehicle and colliding with another at a higher speed. The next step will be to look at how large these crashes are when it comes to the number of vehicles that are involved.

3.0.2: The Number of Vehicles Involved in the Crash

This second analysis for the fatal crashes looks at how many vehicles were involved in the crash. This analysis can be used to determine the either how congested the road way was based on the number of vehicles that where involved in the crash or can be used to determine how close vehicles were traveling. If there are a large number of vehicles involved in the crash it can be assumed that the traveling distance between vehicles was lower since there are more vehicles being impacted, and the opposite for crashes with fewer vehicles. **Figure 3.7** shows the fatal crashes and the number of vehicles that were involved in the crash, showing that the majority of the fatal crashes on the interstates had fewer than 4 vehicles involved.

Figure 3.7. Number of Vehicles Involved in Fatal Crashes

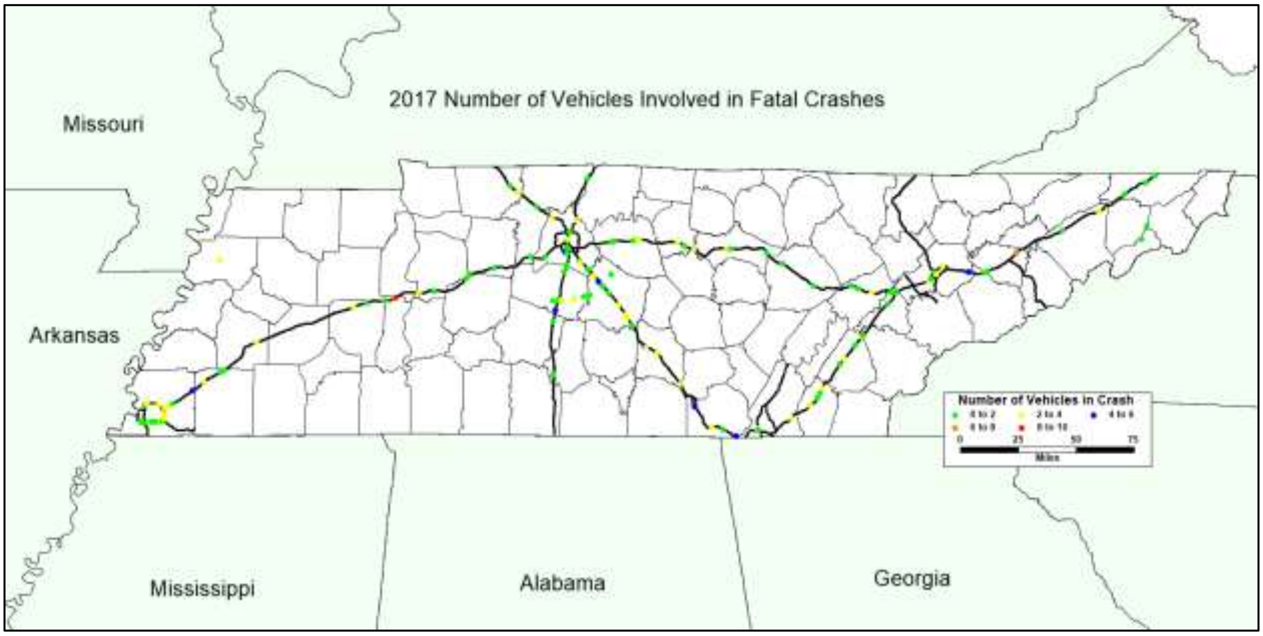
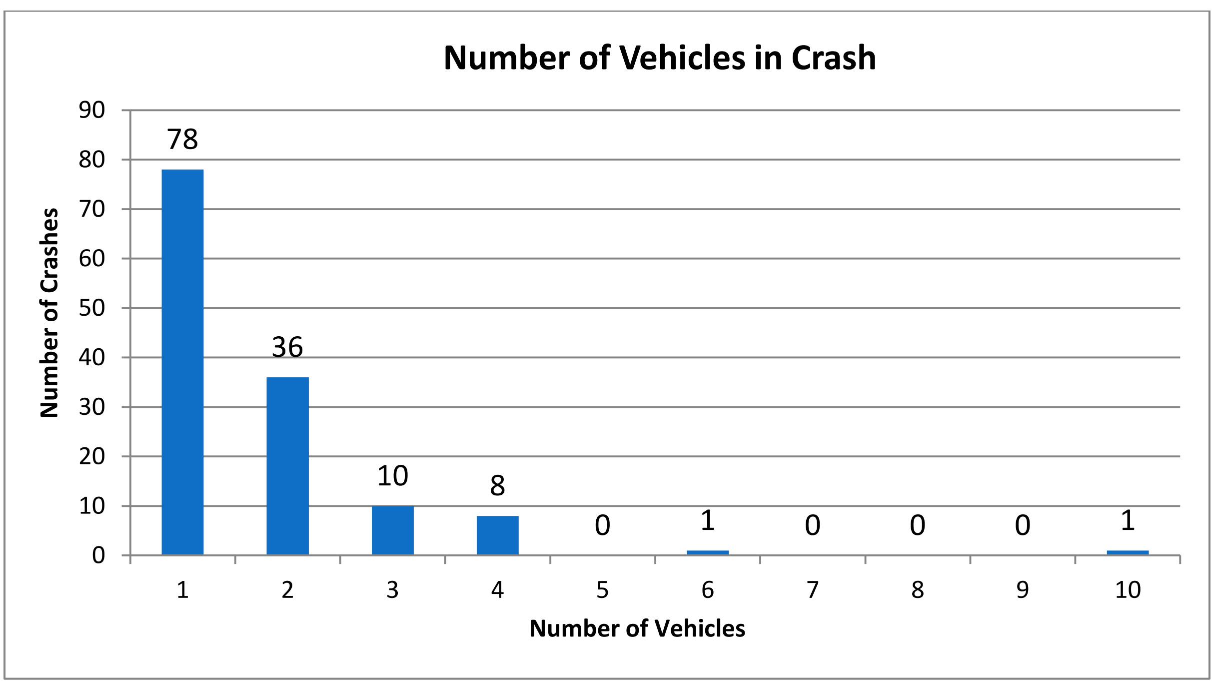


Figure 3.8. Number of Vehicles in Fatal Crashes 2017



Using the data in **figure 3.7** and in **figure 3.8** there is a clear visual that when it comes to fatal crashes 58% of them only involve one vehicle and 27% of them involve two vehicles. Showing that 85% of the fatal crashes on the interstate involve two vehicles or less. This could be interpreted that when it comes to a fatal crash on the interstate vehicles seem to not be traveling in close proximity to each other. It can also be shown from **figure 3.8** that the locations with the larger number of vehicles involved in fatal accidents occur closer to the urban areas, due to the number of vehicles that are on the road.

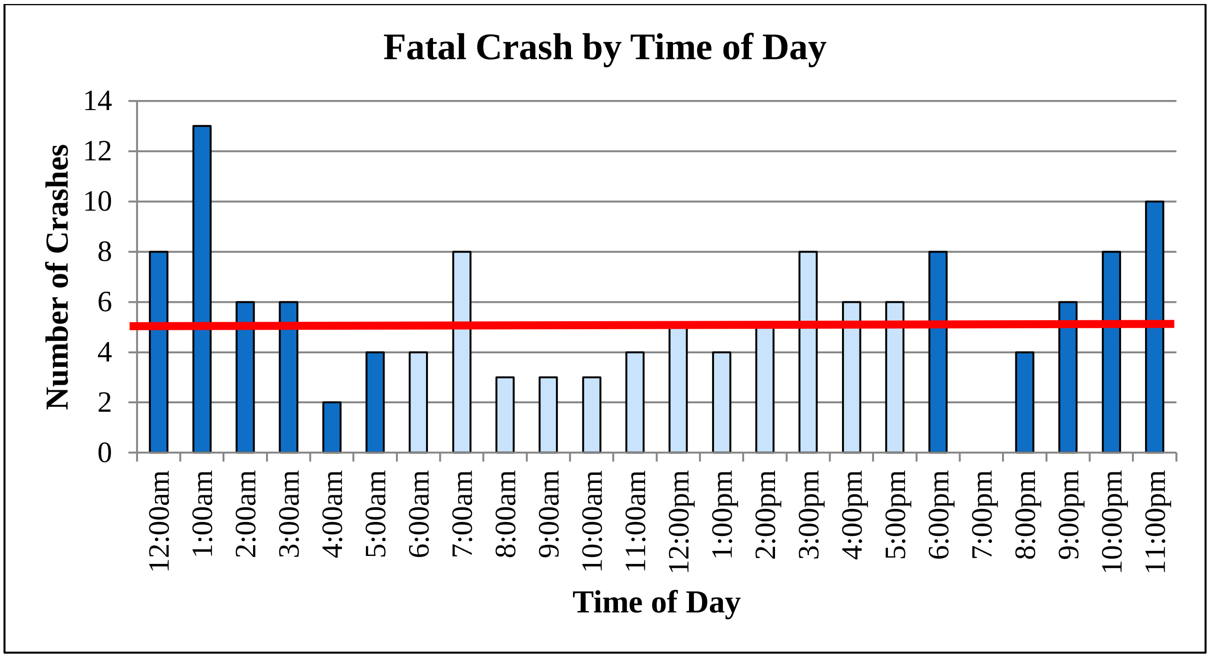
3.0.3: Time of the Crash

This third analysis of the fatal crashes is to look at the time in which they are occurring to determine if a fatal crash is more likely to occur in the day time or the night time. The time of day for day time will be from 6am to 6pm and night time will be 6pm to 6am, giving each time a 12 hour period. **Figure 3.9** shows the location of the fatal crashes based on the time of day in which it is.

Figure 3.9. Fatal Crash by Time of Day

Looking at the map provided in **figure 3.9** there is a close amount of the number of fatal crashes that occurred in the day time as the night time. However, there were slightly more fatal crashes at night time than in the day time, with there being 56% of the crashes occurring during the night hours. **Figure 3.10** shows the 24 hour time frame and the number of crashes that occurred in each of those hours.

Figure 3.10. Number of Fatal Crashes by Time of Day



Evaluating the number of fatal crashes that occurred during each of the hours of the day, figure 2.6 shows that 1:00am has the most fatal crashes during 2017. For the year of 2017 there was an average of 5 fatal accidents on average per hour for the entire year. This is not saying that there were 5 fatal crashes every hour for each day of the year but rather there were on average 5 fatal crashes at each hour for 365 days. The horizontal blue line in figure 2.6 represents the average of five fatal crashes, showing that 50% of the hours in the day were over 5 fatal crashes, with those hours being more in the night time than in the day time.

3.0.4: Weather Conditions

The final analysis for the fatal crashes on the interstates for 2017 is to evaluate what the weather conditions were like during the time of the crash. The reasoning for this analysis is to determine if the weather plays a critical role when it comes to fatal crashes on the interstate. The weather conditions in **figure 3.11** that are being looked at in the weather condition analysis are:

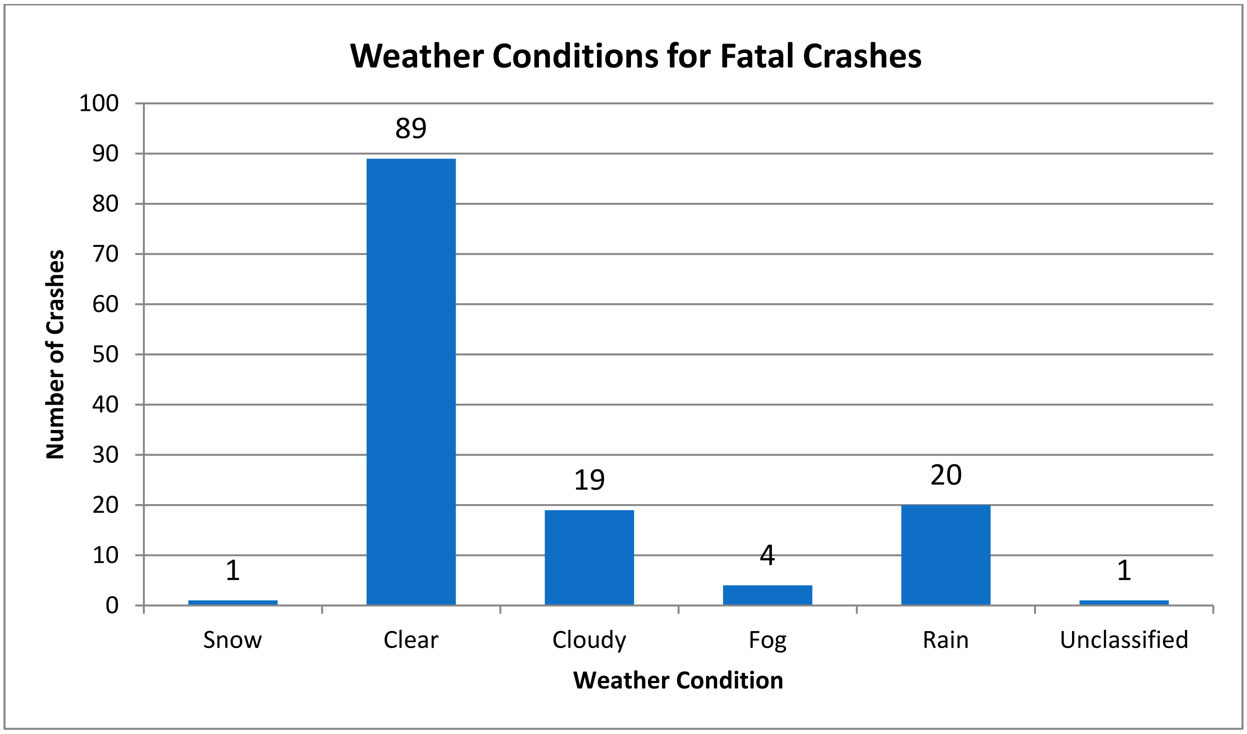
- Snowing

- Clear
- Cloudy
- Fog
- Rainy
- Unclassified

Figure 3.11. Fatal Crashes Based on the Weather Conditions

Looking at the map in **figure 3.11** there is a clear visual that the majority of the fatal accidents occur when the weather is clear, **figure 3.12** shows the breakdown of how many fatal accidents occurred during each weather condition.

Figure 3.12. Number of Fatal Crashes Based on Weather Conditions



It would have been anticipated that when it came to fatal crashes that rain would have been a major contributor to crashes, however based on the data collected 15% of the fatal crashes occurred during raining weather conditions.

3.0.5: Key Findings from 2017 Fatal Crash Data

The following section summarizes the key findings from the analysis that was done on the fatal crashes, so that it can be compared to each of the other crash types to determine if there are similarities between them. The following list of bullets summaries the key findings from each of the characteristics that were analyzed for fatal crashes.

- Fatal accidents seem to be clustered closer to the urban environments on the interstates.
- The majority of fatal crashes does not occur near ramps and are more open road crashes.
- When it comes to the number of vehicles involved in fatal crashes the majority of the crashes involve two of fewer vehicles.

- The time of day between night and day are close when it comes to the number of crashes, but there are slightly more fatal crashes in the night time than day time.
- Rain has a small impact when it comes to fatal crashes, and they are more likely to occur when the weather is clear.

3.1. 2017 Serious Crash Evaluations

The second category that will be evaluated when it comes to crashes is the serious crashes. These crashes are defined as an injury which sustained by a person in an accident and which

- Requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received; or
- Results in a fracture of any bone (except simple fractures of fingers, toes or nose); or
- Involves lacerations which cause severe haemorrhage, nerve, muscle or tendon damage; or
- Involves injury to any internal organ; or
- Involves second or third degree burns, or any burns affecting more than 5 per cent of the body surface; or
- Involves verified exposure to infectious substances or injurious radiation.

Figure 3.13 shows the interstate locations in which a serious crash occurred in 2017.

Figure 2.13. Serious Crash Locations

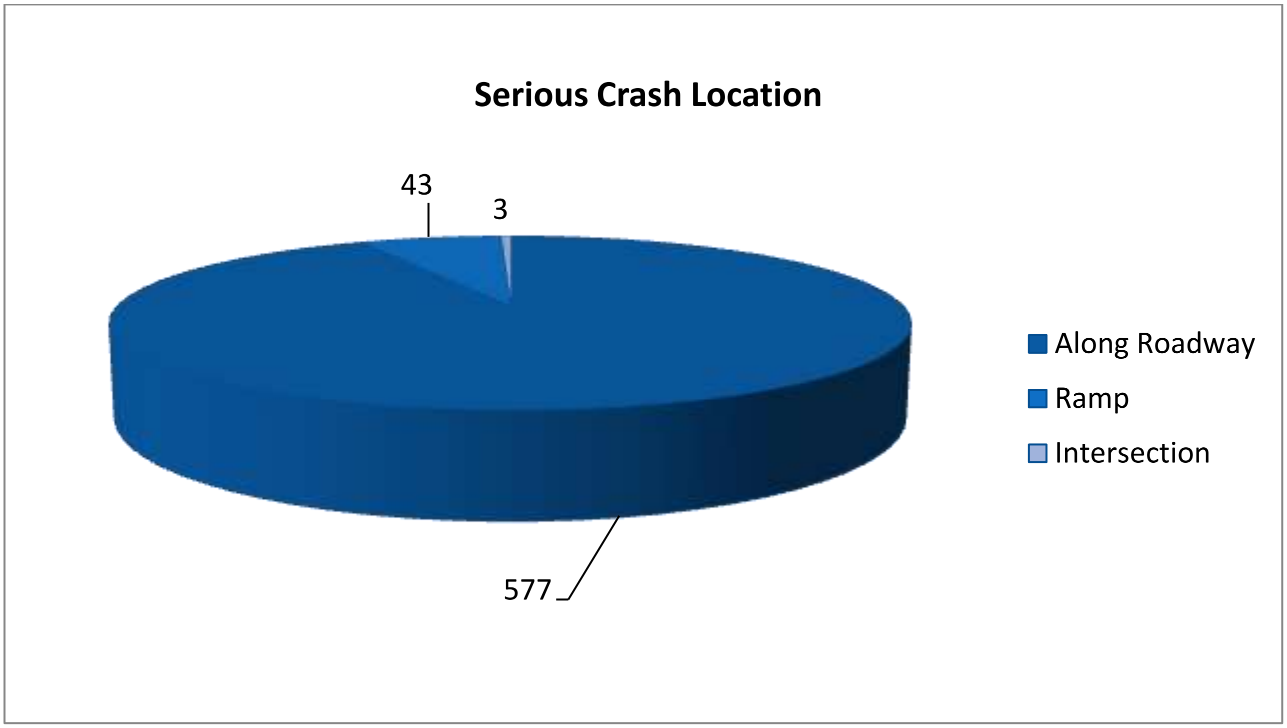
Looking at the serious accidents and where they are mainly located throughout the interstates in Tennessee, there is a clear pattern showing that there are large clusters of serious crashes in the urban areas. This pattern was seen also in the fatal crashes. Based on these two types of crashes it can be anticipated that drivers are more likely to be in a major crash when they are traveling within or near an urban environment.

3.1.1: The Location of Serious Crashes in 2017

The first factor that will be looked at for serious crashes is the location in which they occurred. **Figure 3.14** shows a map of the serious crashes and the locations in which they occurred. The location classification for the serious crashes is defined differently than the fatal crashes, as the locations are either, at a ramp, along the roadway, or at an intersection.

Figure 3.14 Locations of Serious Crashes on the Interstates

Figure 3.15. Serious Crash Location Breakdown



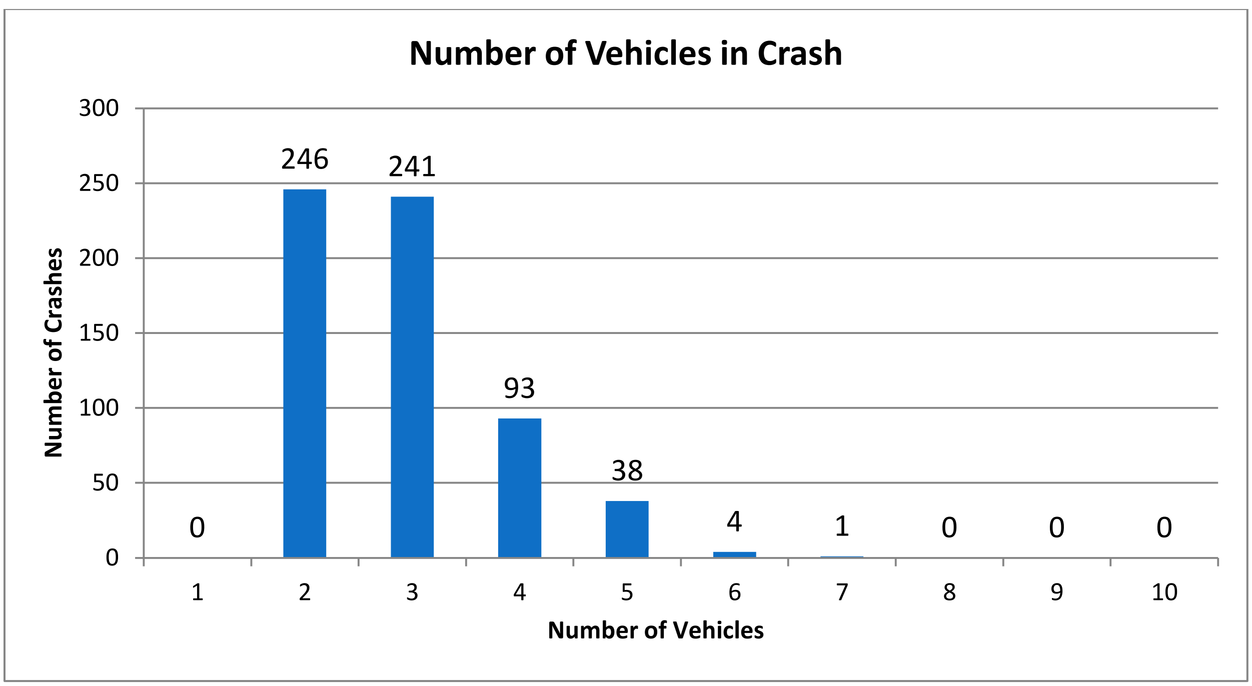
Analyzing the locations in which the serious crashes on the interstates occurred there is a clear indication that serious crashes happen more along the roadway and not near the interstates ramps. Of the 623 serious crashes on the interstate, 93% of them occurred along the roadways where 7% of the serious crashes happened near interstate ramps. This same pattern was seen in the fatal crashes as the ramps produced very little impact on the crashes, where the open road caused a large number of the crashes.

3.1.2: The Number of Vehicles Involved in the Crash

The second analysis is to look at the number of vehicles that were involved in the crash; this will be compared to the number of vehicles that were involved in the fatal crashes to determine if there are more vehicles involved in serious crashes than there are in fatal crashes. **Figure 3.16** shows the serious accidents on the interstates broken down based on the number of vehicles that are involved in the crash. The serious crashes showed the same pattern that the fatal crashes had and that the majority of the crashes involved four or less vehicles. **Figure 3.17** expresses the exact number of crashes that occurred based on the number of vehicles that were involved.

Figure 3.16. Number of Vehicles Involved in Serious Crashes

Figure 3.17. Number of Vehicles in Serious Crashes 2017

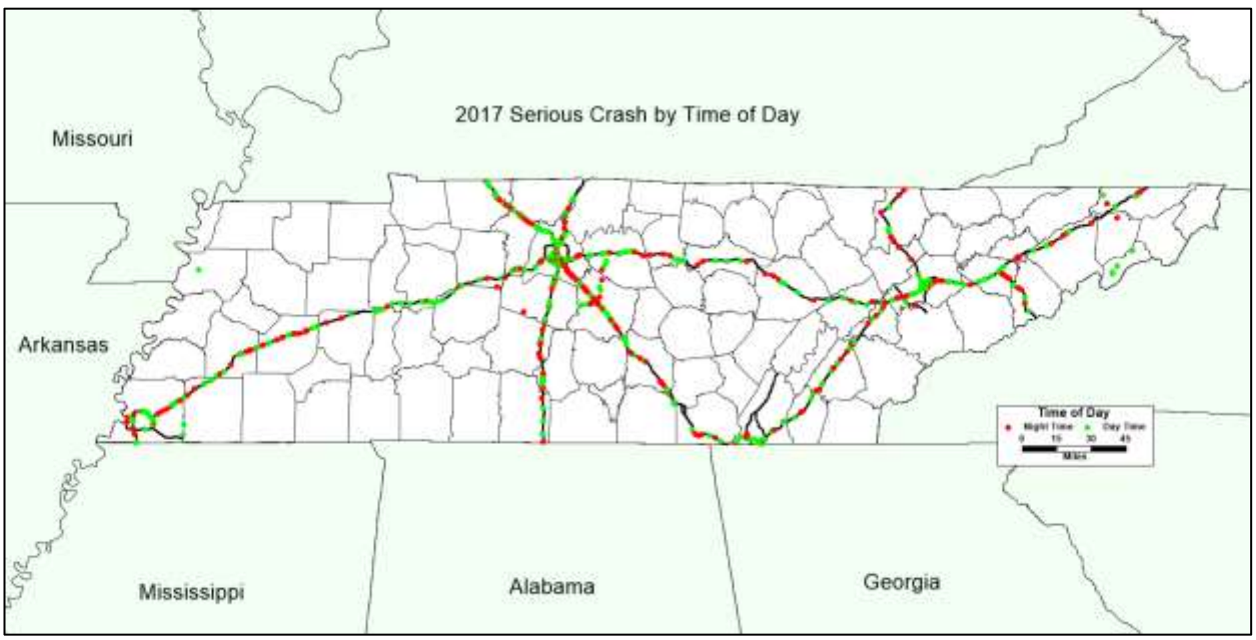


According to **figure 3.16** and **figure 3.17**, 95% of the total serious crashes had four or less vehicles involved in it. This pattern was seen in the fatal crashes that when there was a fatal crash there was a higher chance that there were few vehicles involved, the same thing that is seen in the serious crashes.

3.1.3: Time of the Crash

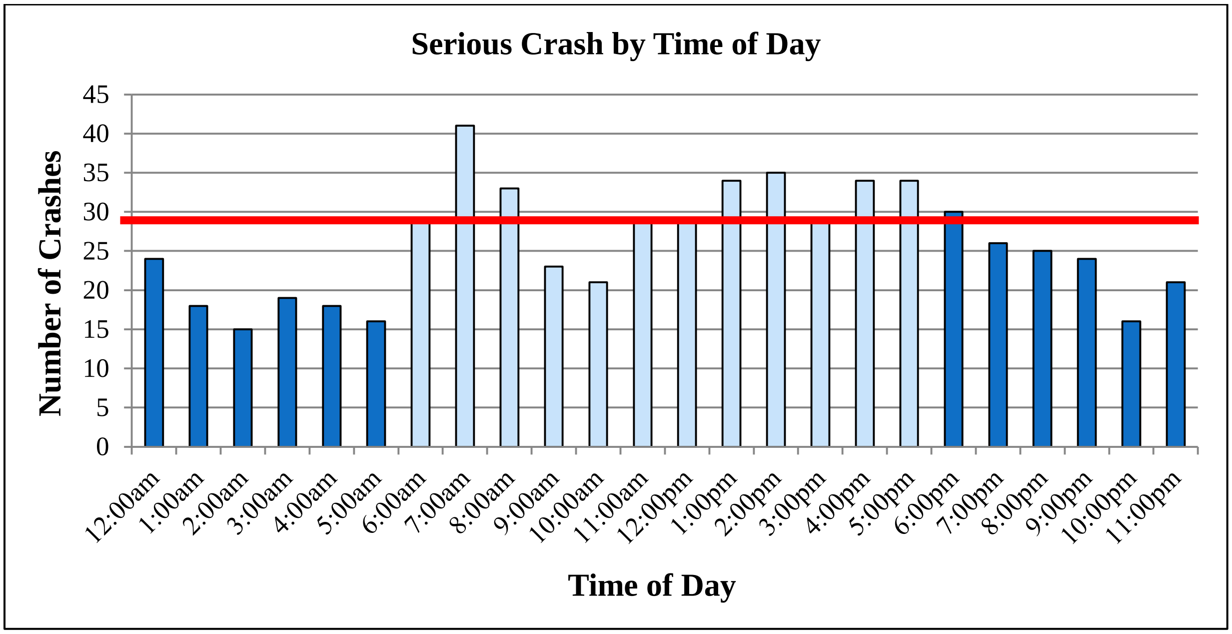
The third analysis that is being looked at is the time in which the serious crashes occurred. Based on the previous two analyses it can be anticipated that the time of day for the serious crashes will follow the same pattern that the fatal crashes did and that there will be more crashes during the night time than during the day time. The time of day for day time will be from 6am to 6pm and night time will be 6pm to 6am, giving each time a 12 hour period. **Figure 3.18** shows the location of the fatal crashes based on the time of day in which it is.

Figure 3.18. Time of Day for Serious Crashes



Based on the illustration in **figure 3.18** it can be seen that there are more green dots than red dots meaning that there are fewer serious crashes during the night time period than there is during the day time period. This is the opposite pattern that the fatal crashes showed, which showed that there were more crashes during the night time. **Figure 3.19** breaks down the number of serious crashes by hour to determine which hour has the largest and least number of crashes.

Figure 3.19. Number of Serious Crashes by Time of Day



After evaluating the number of serious crashes on the interstates in Tennessee based on the average number of crashes for each hour, there is a clear indication that when it comes to serious crashes 7:00am is the top time for a crash like this to occur. With the serious crashes the average per hour for the year for a serious crash to occur is 26 crashes an hour. Comparing each hour to the average number of crashes, 46% of the average hours have a the number of crashes over the 26 crashe average. A large majority of these time zones fall within the day time hours, where the night time hours are below average for the number of serious accidents.

3.1.4: Weather Conditions

The final analysis for the serious crashes on the interstates for 2017 is to evaluate what the weather conditions were like during the time of the crash. The reasoning for this analysis is to determine if the weather plays a critical role when it comes to serious crashes on the interstate. The weather conditions in **figure 3.20** that are being looked at in the weather condition analysis are:

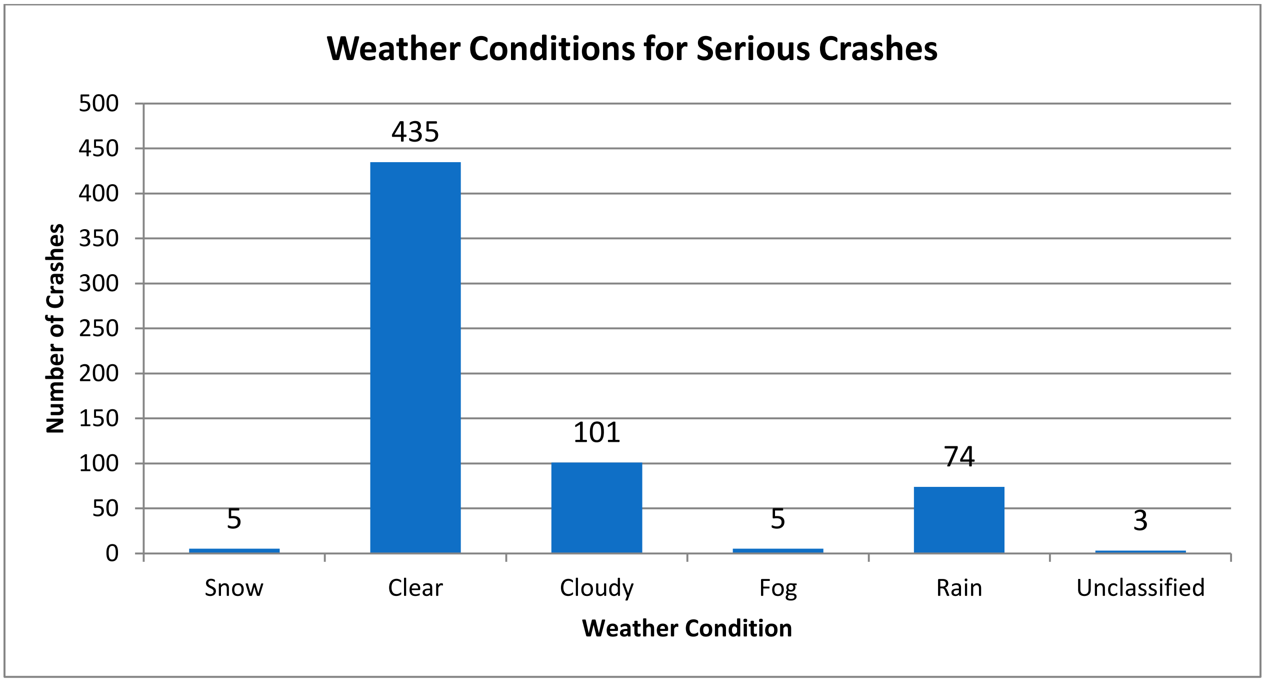
- Snowing
- Clear
- Cloudy
- Fog
- Rainy

- Unclassified

Figure 3.20. Serious Crashes Based on the Weather Conditions

After evaluating the weather conditions in **figure 3.20** for the serious crashes, there is a clear visual that the majority of the serious crashes happen when the weather conditons are clear, this was the same situation with the fatal crashes. Using **figure 3.21** to obtain a better visual of the number of crashes that happen during each weather condition.

Figure 3.21. Number of Serious Crashes Based on Weather Conditions



3.1.5: Key Findings from 2017 Fatal Crash Data

The following section summarizes the key findings from the analysis that was done on the serious crashes, so that it can be compared to each of the other crash types to determine if there are similarities between them. The following list of bullets summaries the key findings from each of the characteristics that were analyzed for serious crashes.

- Serious crashes share a similar pattern to fatal crashes and that they are both clustered in the urban environments
- The majority of the serious crashes happen on the open road
- When it comes to the number of vehicles involved in serious crashes the majority of the crashes involve two of fewer vehicles.
- The time of day between night and day are close when it comes to the number of crashes, but there are slightly more serious crashes in the day time than day time.
- Rain has a small impact when it comes to serious crashes, and they are more likely to occur when the weather is clear.

3.2. 2017 Minor Crash Evaluations

The final crash type that will be evaluated is the minor crashes that happened on the interstates in Tennessee. A minor crash for this report is going to be any crash that does not contain a fatality or harm in which someone was hospitalized. **Figure 3.22** shows the minor crashes that occurred on the interstate for 2017. Looking at this image it is difficult to make out exact locations because of the large number of minor crashes that did occur.

Figure 3.22. Minor Crash Location on Interstates

Using just the image in **figure 3.22** it is extremely complex to determine where these minor crashes are happening at, but hopefully by breaking down the minor crashes based on different characteristics there will be a more defined understanding of the minor crashes on the interstates in Tennessee.

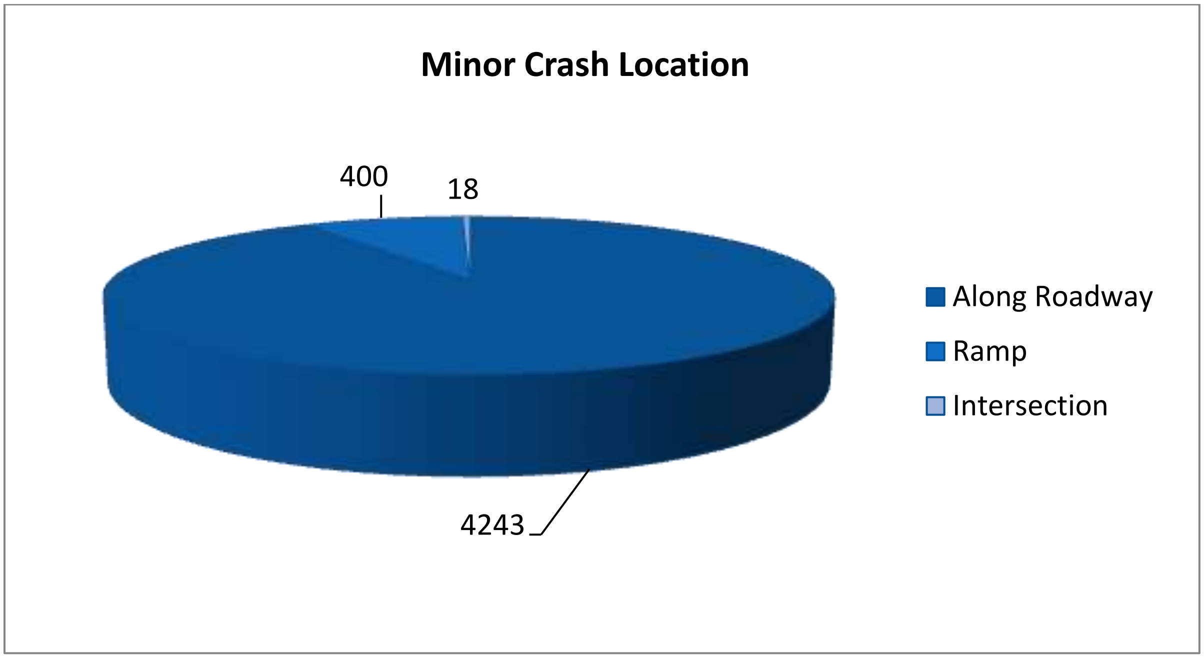
3.2.1: The Location of Minor Crashes in 2017

The first set of information that will be viewed at for the minor crashes in 2017 is the location in which these crashes occurred. With the previous two crashes the majority of the crashes happened along the open roadways and not near any particular infrastructure change such as a ramp or an intersection. With these crashes being minor it can be anticipated that there will be an increase in the number of crashes near ramps due to there being slow exit and entrance speeds, which will cause less vehicle damage when there is a collision. **Figure 3.23** shows the locations for the minor crashes on the interstates. The information provided in **figure 3.24** is complicated to read in the urban areas because of the large number of crashes that have occurred in those regions.

Figure 3.23. Location of Minor Crashes on the Interstates

With the data being complicated to read due to the high number of minor crashes, **figure 3.23** will be used to break down the crashes showing how many crashes happened for each location. Showing that of the 4,661 minor crashes; 4,243 (91%) of them occurred on the roadways and 8.6% of the crashes happened along ramps, which is an increase in the number of crashes on ramps when compared to the other two crash types.

Figure 3.24. Breakdown of Minor Crash Locations

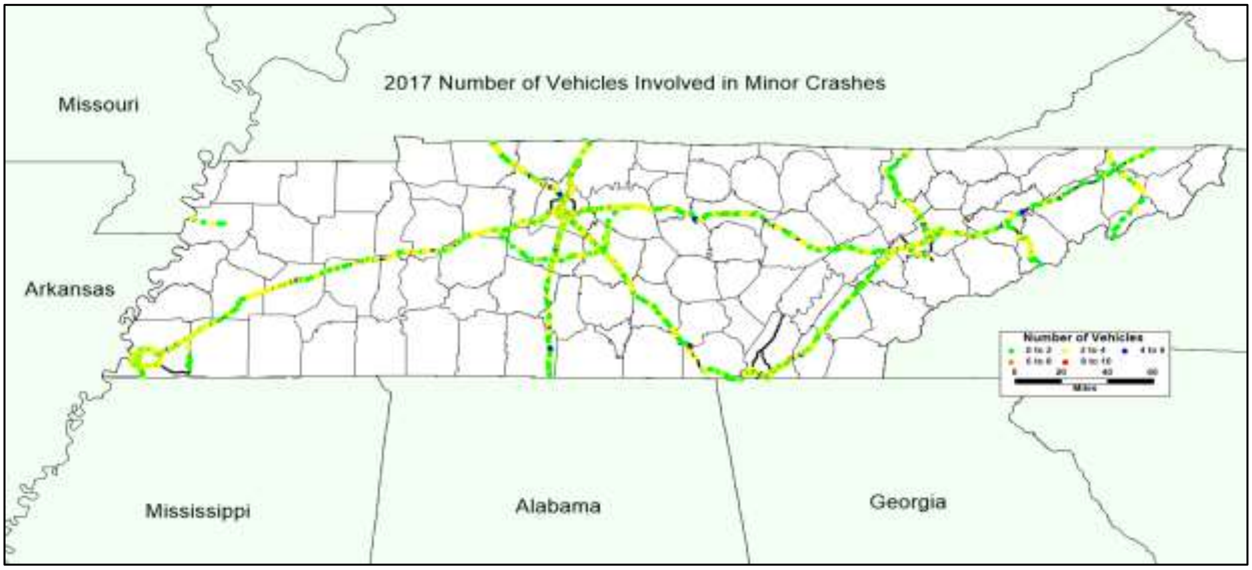


The common shared characteristic between the three types of crashes is that the majority of the crashes have occurred on the open roadway areas and not near the ramps or the intersections. The second thing is that as the type of crash decreases from fatal → Serious → Minor the number of crashes that happen near the interstates ramps increases.

3.2.2: The Number of Vehicles Involved in the Crash

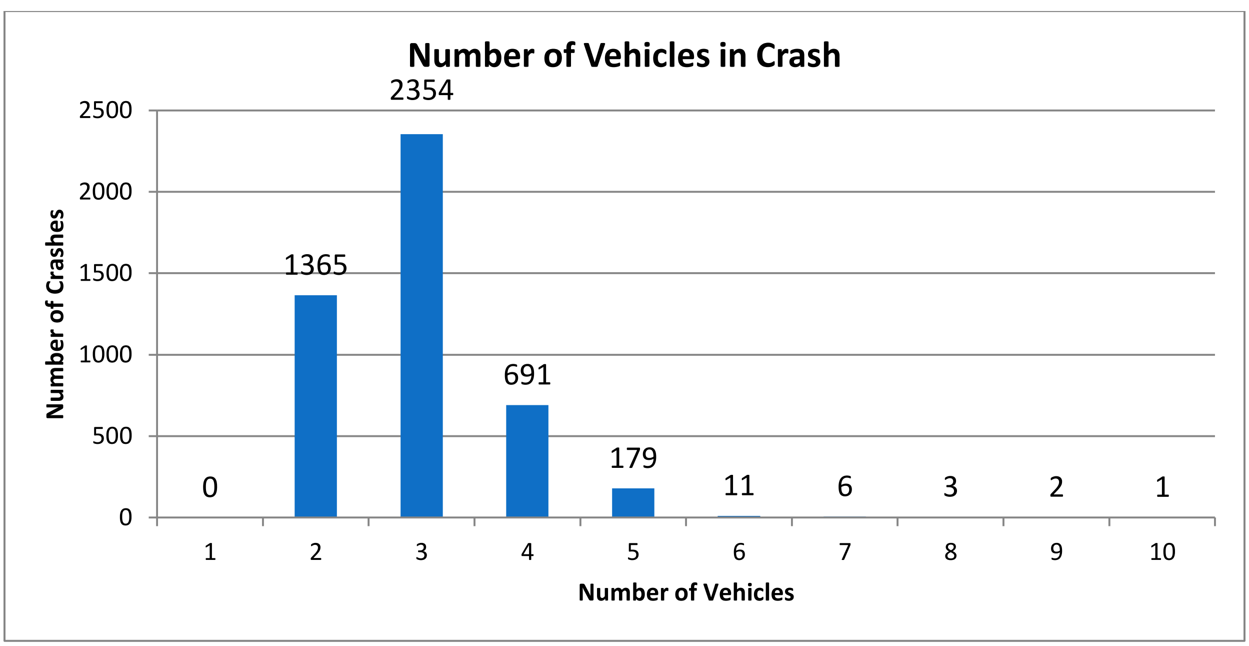
The next set of data that will be looked at when it comes to the minor crashes is the number of vehicles that are involved in the crash. For the fatal and serious crashes the large majority of the crashes had 4 or less vehicles involved. It can be anticipated that with the minor crashes the same pattern will be shown and the more of the crashes will involve two or les vehicles. **Figure 3.25** shows the display of the number of vehicles involved on the interstates in Tennessee, which again has difficulties deciphering due to the high number of minor crashes.

Figure 3.25. Number of Vehicles Involved in Minor Crashes



Referring to **figure 3.25** there is a dominating cluster of green and yellow dots, showing that the majority of the minor crashes are involving four or less vehicles, which was anticipated based on how intense a minor crash is. **Figure 3.26** shows the breakdown of the exact number of vehicles that are involved in the minor crashes.

Figure 3.26. Number of Vehicles in Minor Crashes



According to the data provided in **figure 3.26**, the most common vehicles count for vehicles involved in a minor crash is 3, with 51% of the crashes happening with three vehicles. As anticipated 96% of the minor crashes occurred with having four or fewer vehicles.

3.2.3: Time of the Crash

The next analysis that will be done it the evaluation of the time of day for the minor crashes. From the previous two crashes, there was a difference in the time of day in which the majority of crashes occurred. For the fatal crashes there was more during the night hours, but for the serious crashes there were more during the day time hours. Based off these two crash types it can be states that the more sever a crash is the more likely it is to happen at night time, and then can be anticipated that there be more minor crashes in the day time than there will be at night time. **Figure 3.27** shows the map image of the minor crashes by time of day where **figure 3.28** breaks down each of the hours in the day.

Figure 3.27. Illustrate of the Minor Crash by Time of Day

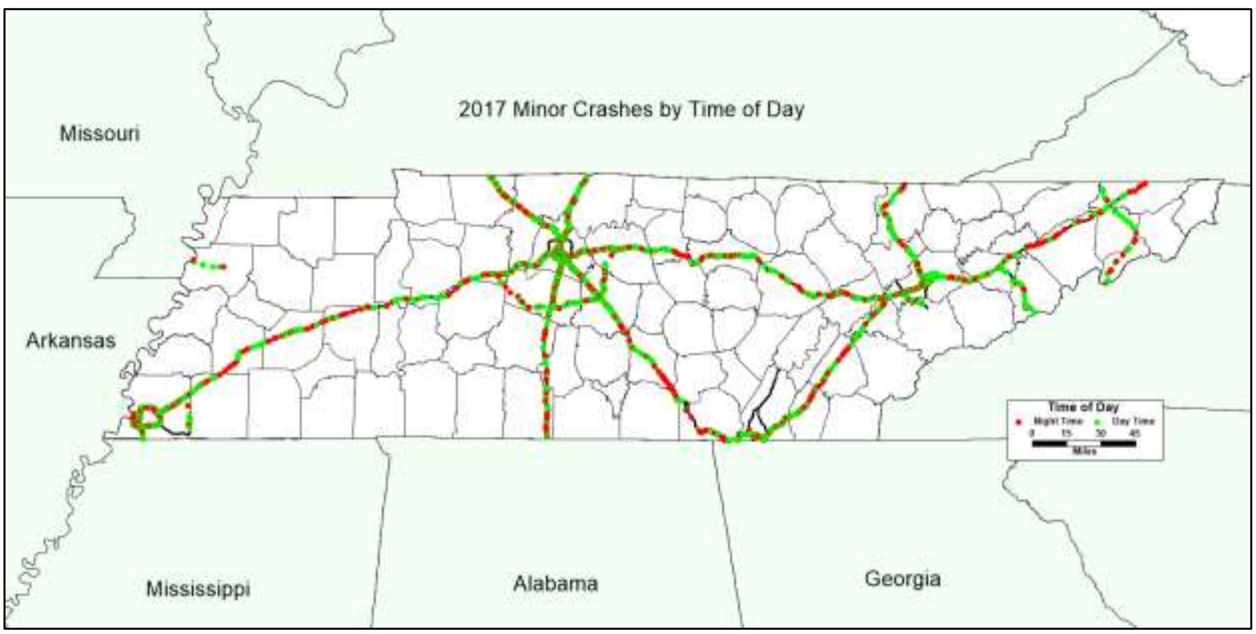
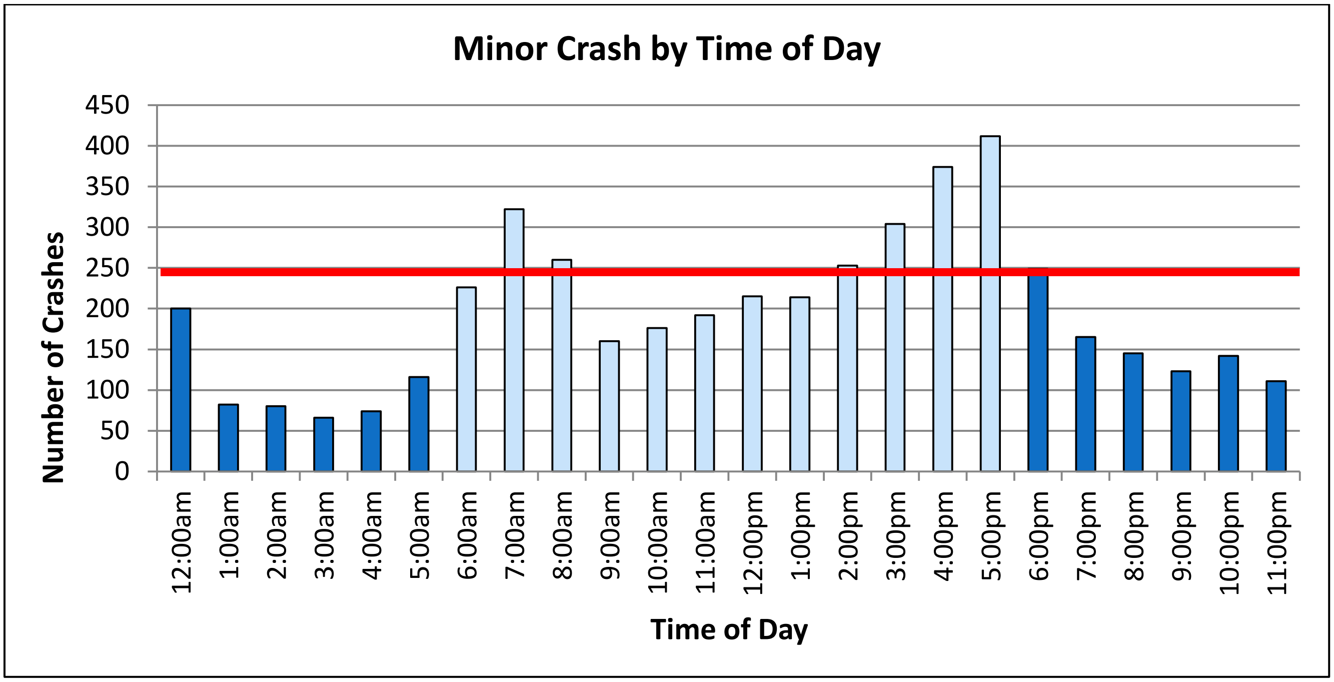


Figure 3.28. Minor Crash Breakdown by each Hour



Using the data in **figure 3.28** and the hourly average of 194 minor accidents per hour, there is a clear indication that the hours that fall within the day time above the average for the entire day. This also shows that a minor crash is more likely to happen during the day time than during the night time. This supports the pervious indication that less sever crashes are more likely to happen during the day time than they are at night.

3.2.4: Weather Conditions

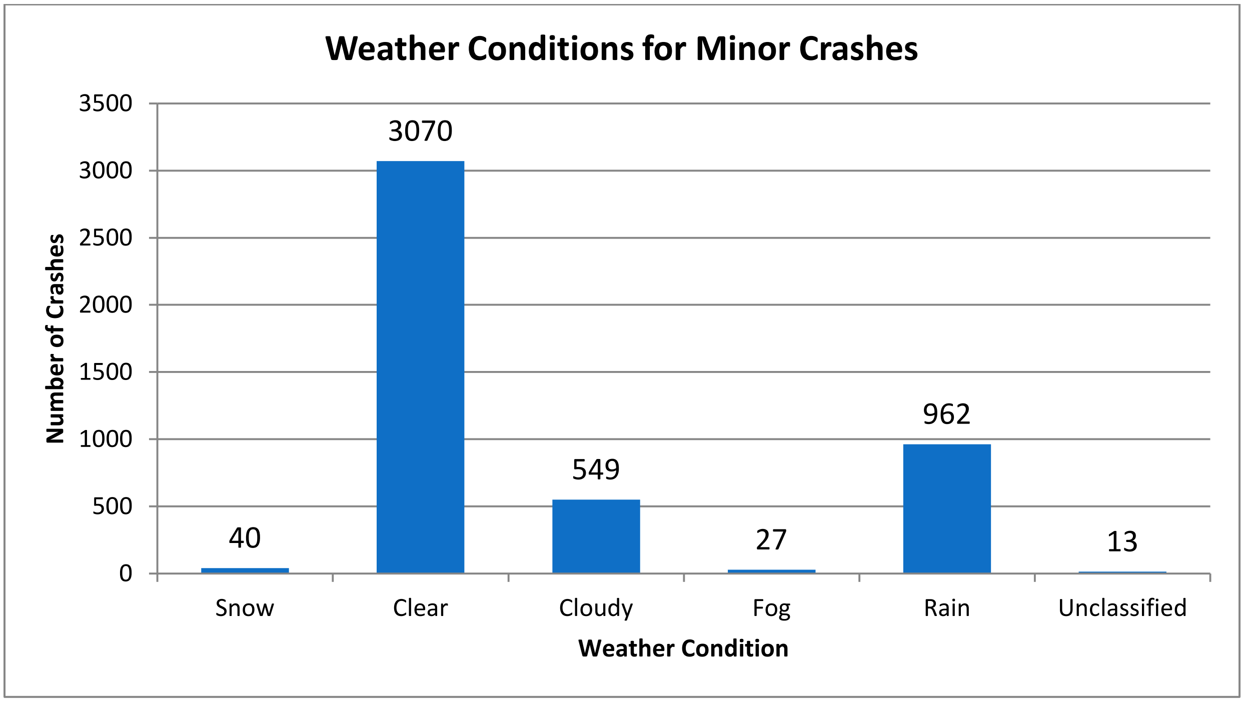
The final analysis for the minor crashes on the interstates for 2017 is to evaluate what the weather conditions were like during the time of the crash. The reasoning for this analysis is to determine if the weather plays a critical role when it comes to minor crashes on the interstate. The weather conditions in **figure 3.29** that are being looked at in the weather condition analysis are:

- Snowing
- Clear
- Cloudy
- Fog
- Rainy
- Unclassified

Figure 3.29. Weather Conditions during Minor Crashes

Based on the data provided in **figure 3.29** the majority of minor crashes occur during a clear day and not during the rain. This pattern was shown throughout all three of the crash types, which was not anticipated, as I could be assumed that rain would have a major impact on the number of crashes that occur due to vehicles hydroplaning and losing control. **Figure 3.30** displays the breakdown of the number of crashes based on the weather conditions that were present during the time of the crash.

Figure 3.30. Breakdown of Minor Crashes during Weather Conditions



3.2.5: Key Findings from 2017 Minor Crash Data

The following section summarizes the key findings from the analysis that was done on the minor crashes, so that it can be compared to each of the other crash types to determine if there are similarities between them. The following list of bullets summaries the key findings from each of the characteristics that were analyzed for minor crashes.

- Minor crashes share a similar pattern to serious and fatal crashes and that they are clustered in the urban environments
- The majority of the minor crashes happen on the open road, but are found more at ramps than the other two crash types
- When it comes to the number of vehicles involved in minor crashes the majority of the crashes involve three or fewer vehicles.
- The time of day between night and day, there are more minor crashes in the day time than in the night time. Showing that the less sever a crash is the more likely it is to happen in the day time
- Rain has a small impact when it comes to minor crashes, and they are more likely to occur when the weather is clear.

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Chapter 4. Percentage of Freight on Interstates

The purpose of this chapter is to look at the interstates in Tennessee and determine what percentage of the total travel flow is freight and what percent is auto. Not only will this part focus on the interstates but also the ramps to determine how much freight is actually using the ramps. This is important because an area could look like a large bottleneck for freight based on the characteristic of the infrastructure, but when compared to the amount of freight that is actually using the infrastructure, it might turn out to be a low bottleneck. The data will be displayed in the 2010 and the future 2040 years for the freight percentage on the interstates and the ramps. **Figure 4.0** through **figure 4.4** show the percent daily percent of freight on the interstates for 2010, where **figure 4.5** through **figure 4.9** show the future 2040 percentage of freight on the interstates. The percentage of freight movement is calculated using the total number of freight trips that are being made by the total trips for all modes of transportation (bus, car, motorcycle, etc.).

Figure 4.0. Percent of Interstate Capacity that is Freight Movement, 2010

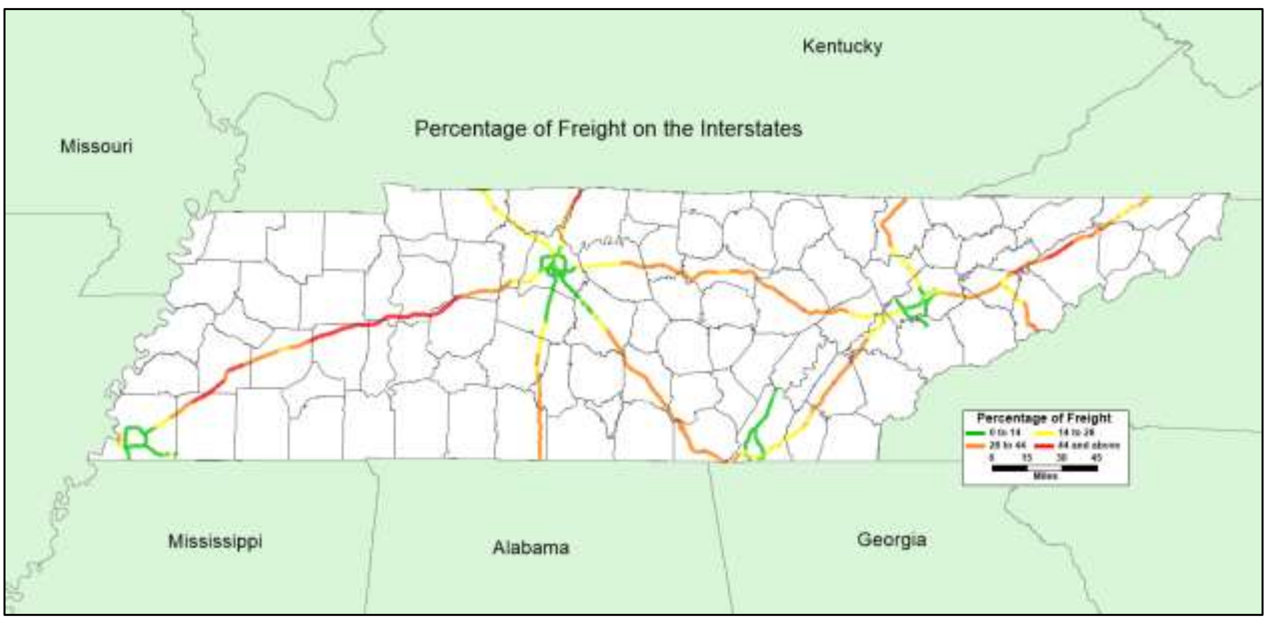


Figure 4.1. Memphis Percent of Interstate Capacity that is Freight Movement, 2010

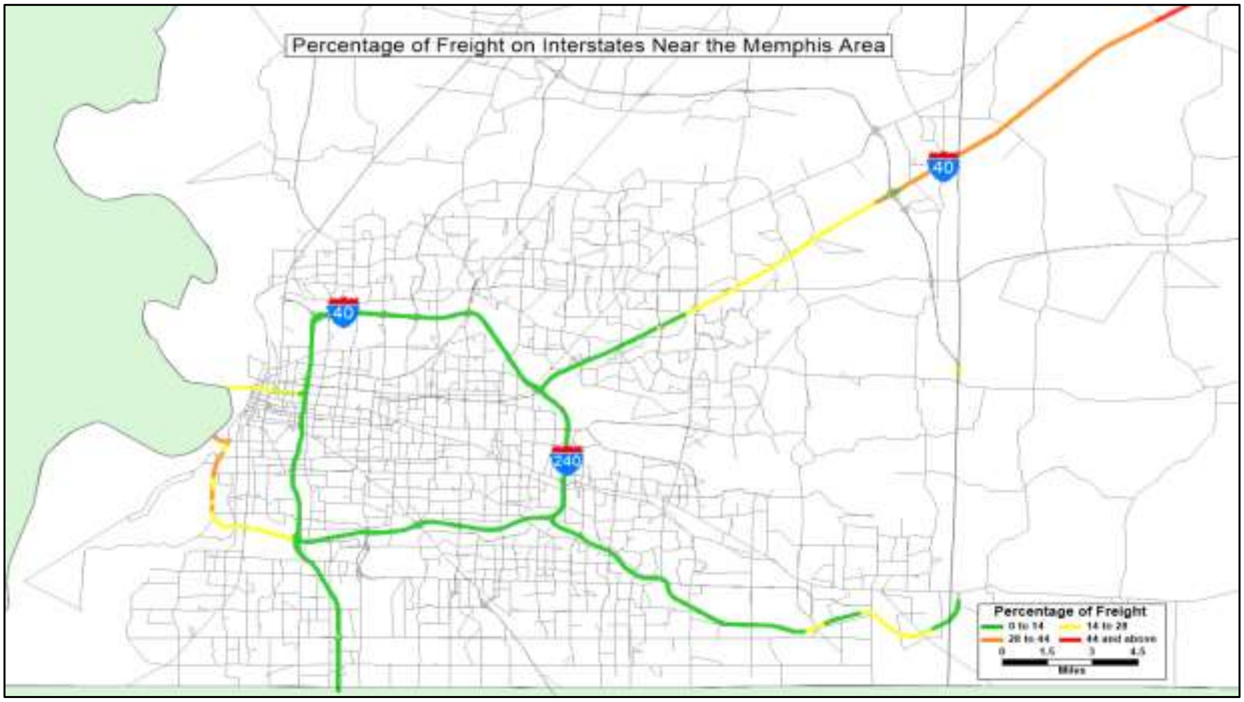


Figure 4.2. Nashville Percent of Interstate Capacity that is Freight Movement, 2010

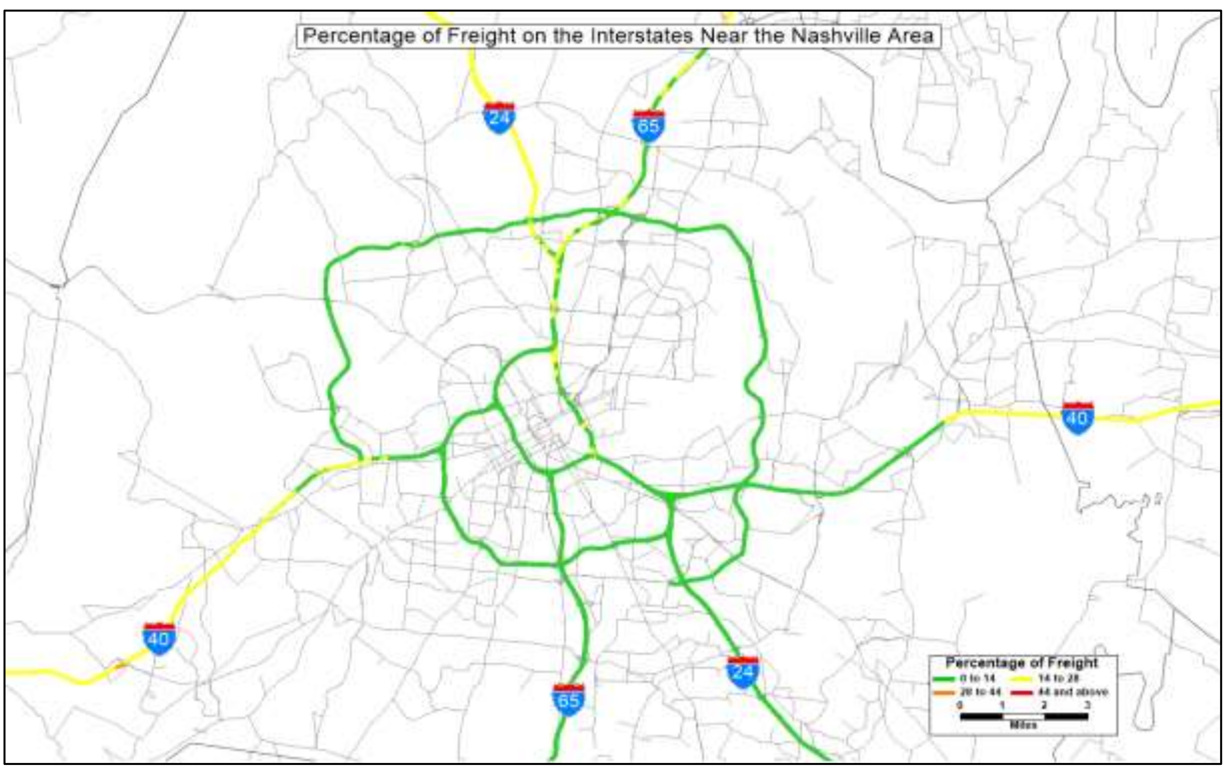


Figure 4.3. Chattanooga Percent of Interstate Capacity that is Freight Movement, 2010

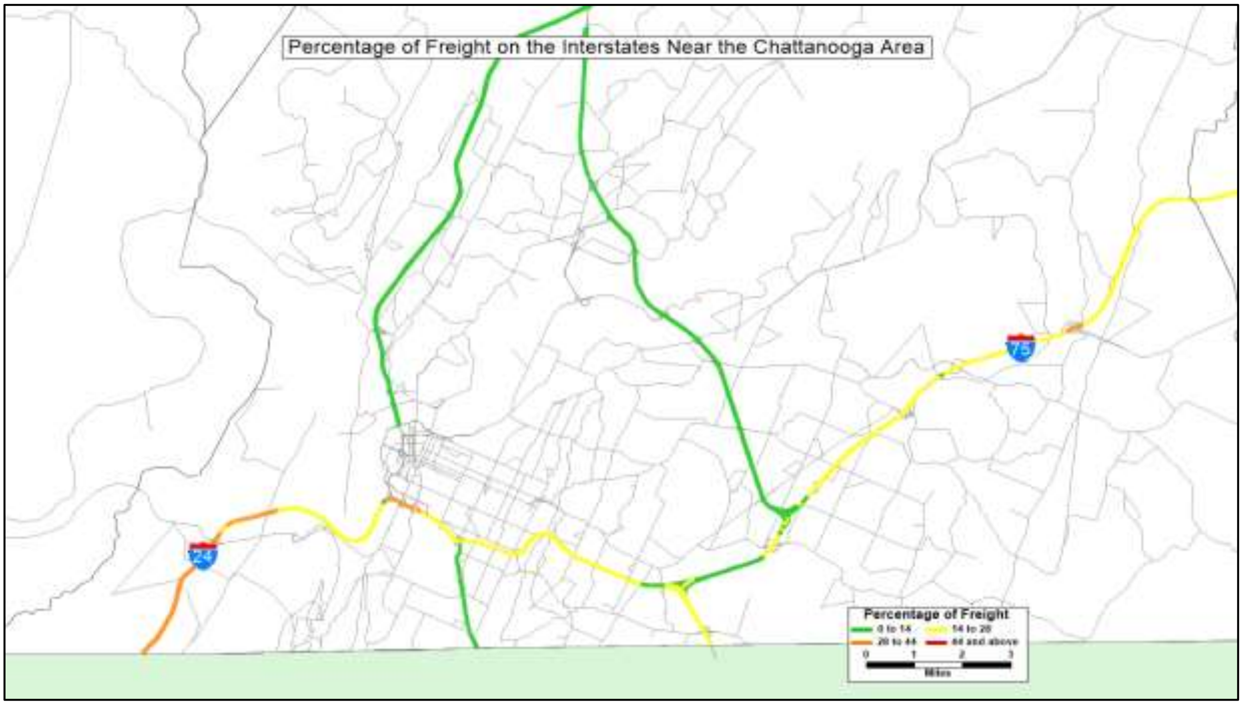


Figure 4.4. Knoxville Percent of Interstate Capacity that is Freight Movement, 2010

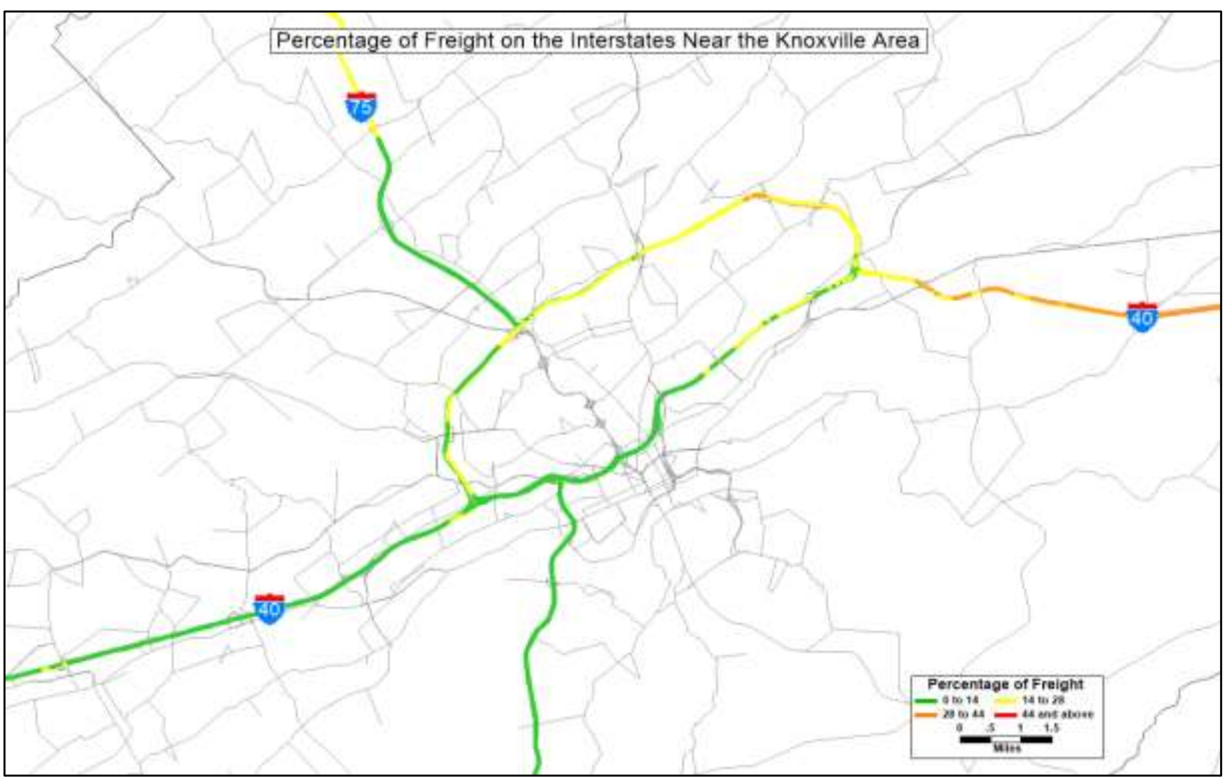


Figure 4.5 Percent of Interstate Capacity that is Freight Movement, 2040

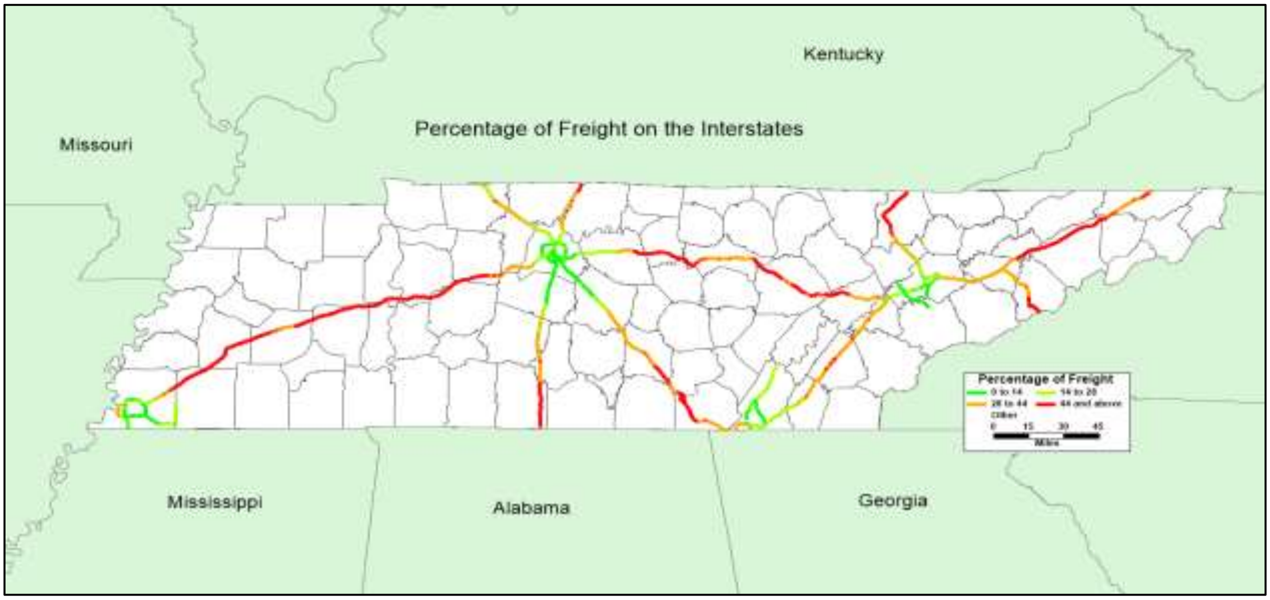


Figure 4.6. Memphis Percent of Interstate Capacity that is Freight Movement, 2040

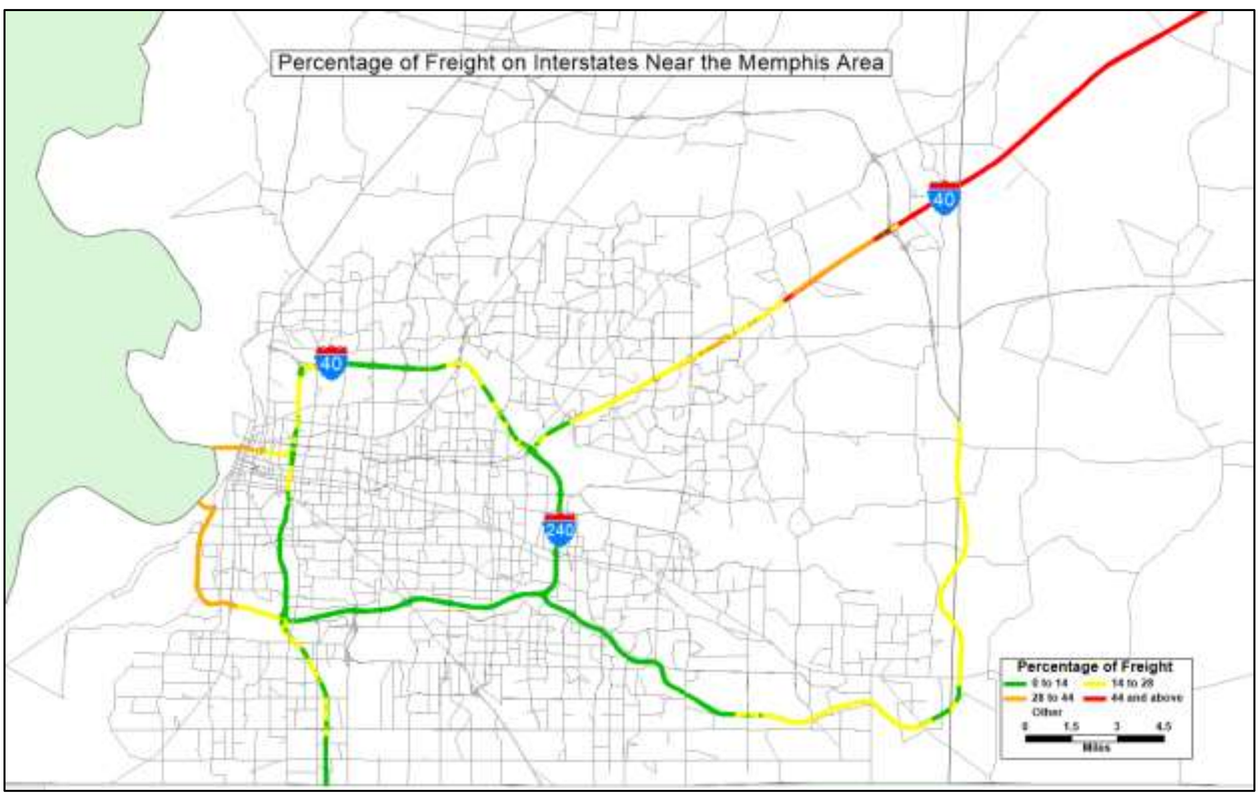


Figure 4.7. Nashville Percent of Interstate Capacity that is Freight Movement, 2040

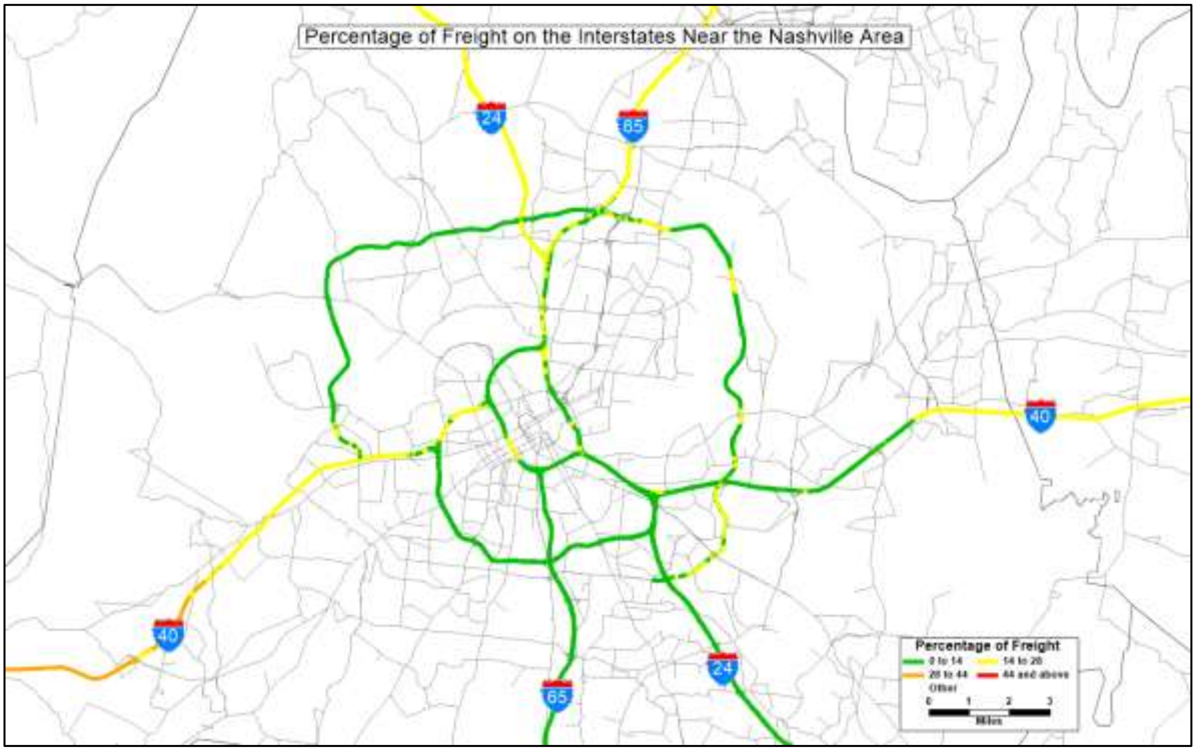


Figure 4.8. Chattanooga Percent of Interstate Capacity that is Freight Movement, 2040

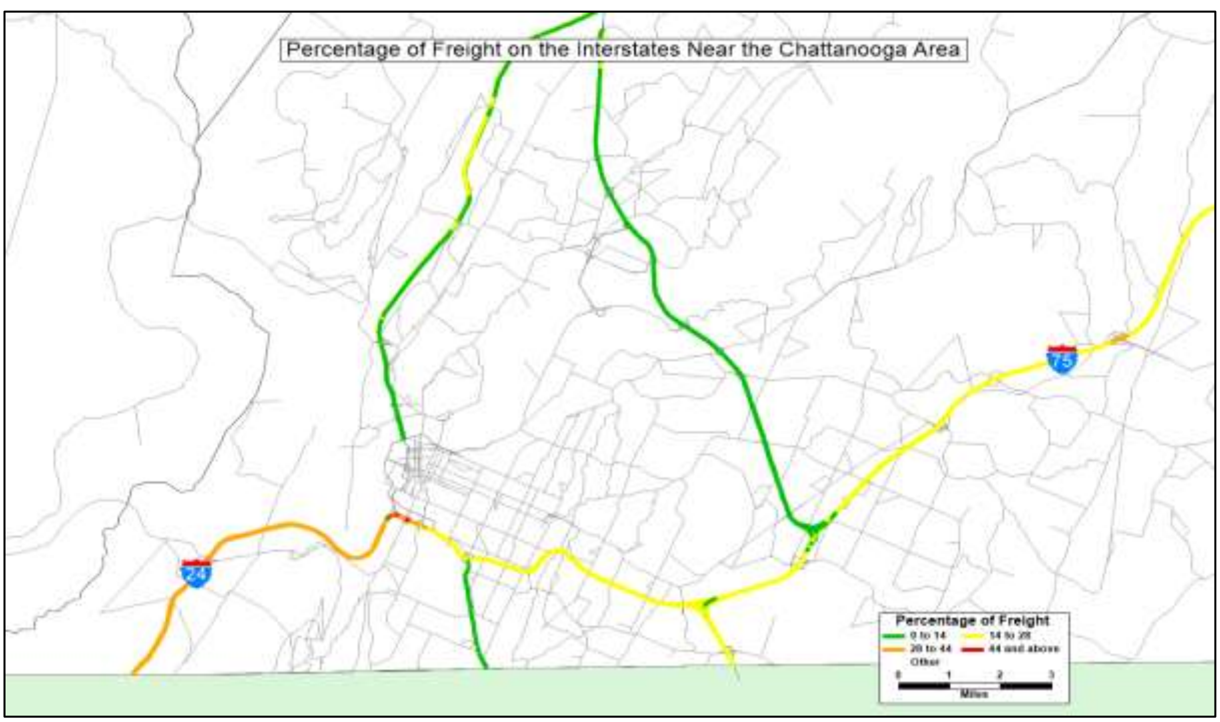
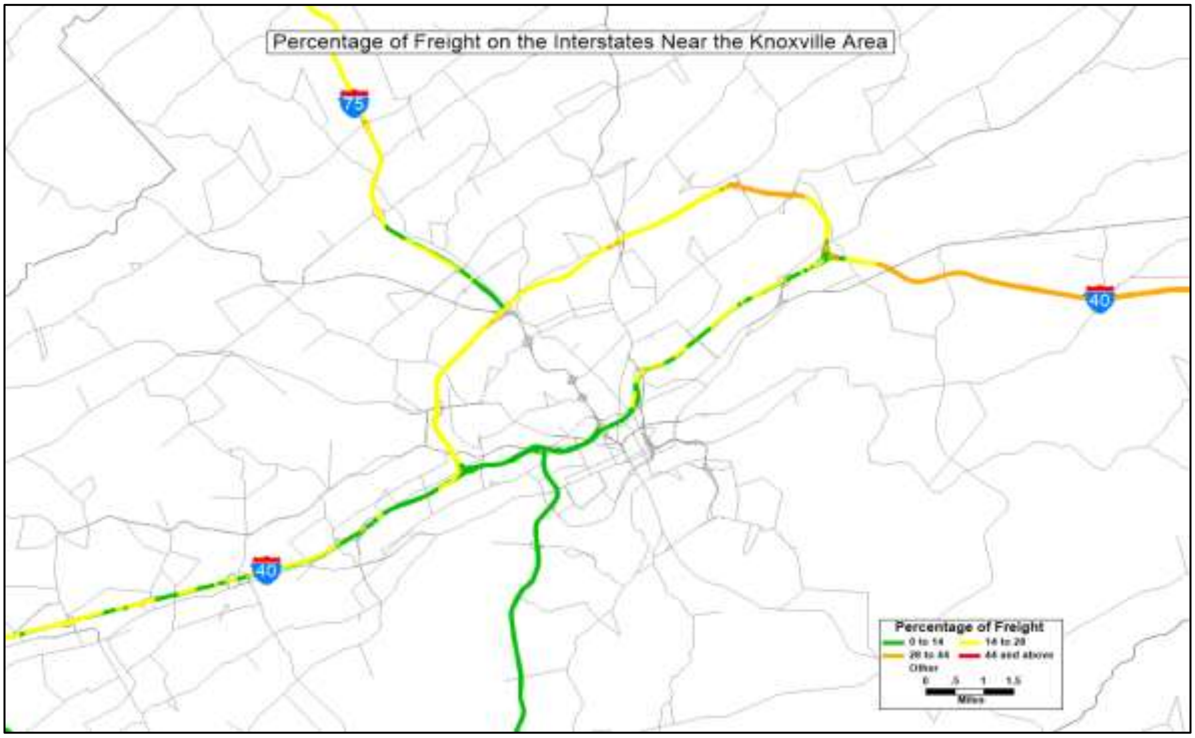


Figure 4.9. Knoxville Percent of Interstate Capacity that is Freight Movement, 2040



With the figures displaying the percentage of freight on the interstates near the major cities, showing that the closer the interstates get to the urban areas the less freight is on the roads. Two reasonable explanations for this are that in the urban areas there is a high level of population, which means there will be more vehicles. This would mean that freight isn't really decrease just there is more personal vehicles in these areas than there is in the rural areas. The second explanation is that there the drop of locations for freight is located outside of the cities and that is why the percentage of freight decreases with distance to urban areas. The second analysis will look at the percentage of freight on the ramps that are located on the interstates to determine if there is the same relationship with the amount of freight on the ramps as there is on the interstates. **Figure 4.10** through **figure 4.14** shows the freight percentage on ramps for 2010, where **figure 4.15** through **figure 4.19** shows the future 2040. The reasoning for looking at the percentage of freight on the ramps it because ramps are one of the indicators that have the potential to cause a freight bottleneck. Knowing which ramps have a large amount of volume will be critical when it comes to identifying freight bottleneck locations that are within proximity of a ramp.

Figure 4.10. Percentage of Freight on Tennessee Ramps, 2010

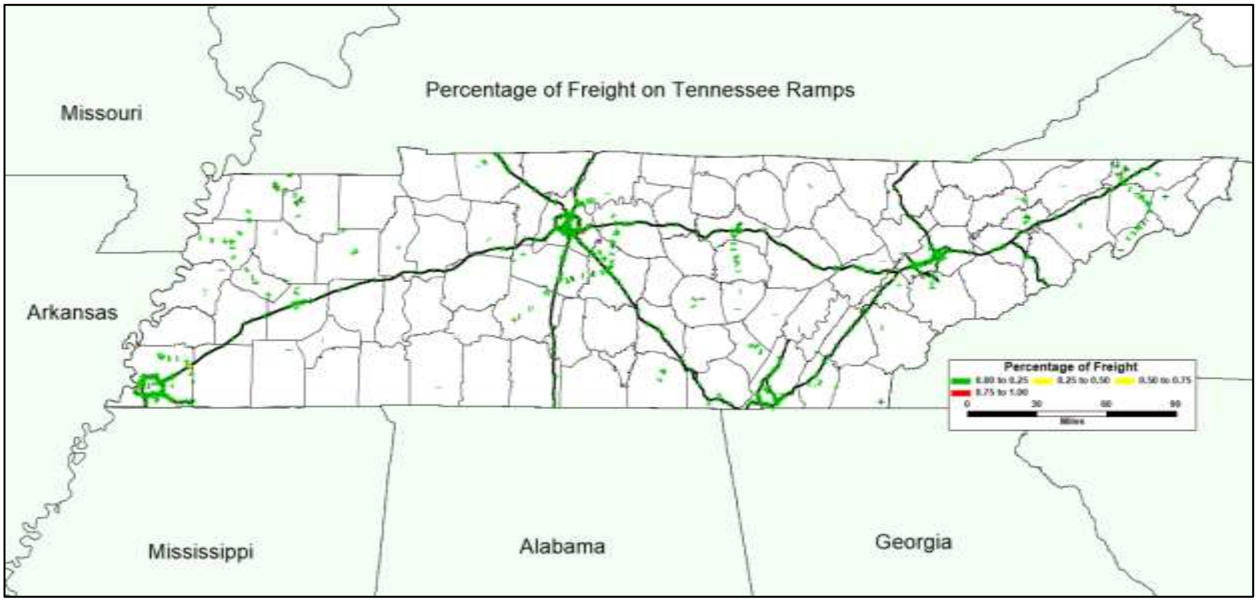


Figure 4.11. Percentage of Freight on Memphis Ramps, 2010

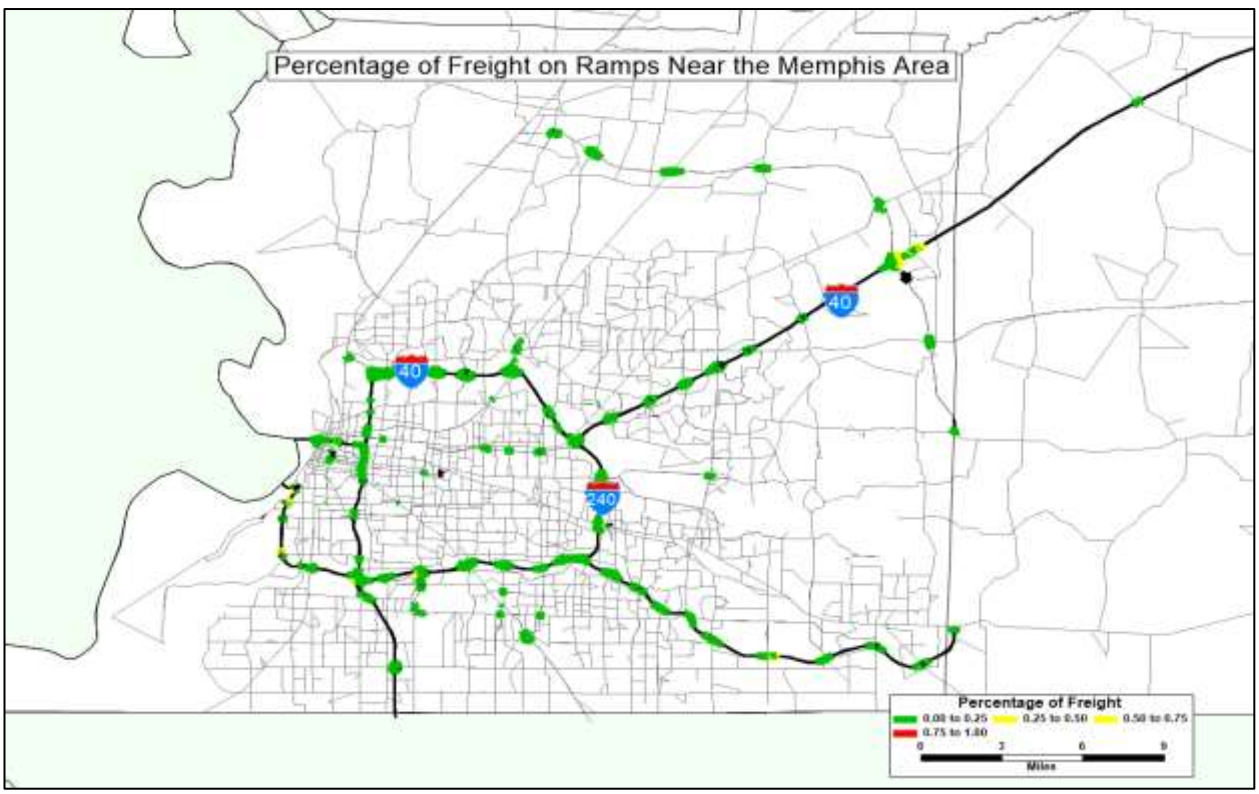


Figure 4.12. Percentage of Freight on Nashville Ramps, 2010

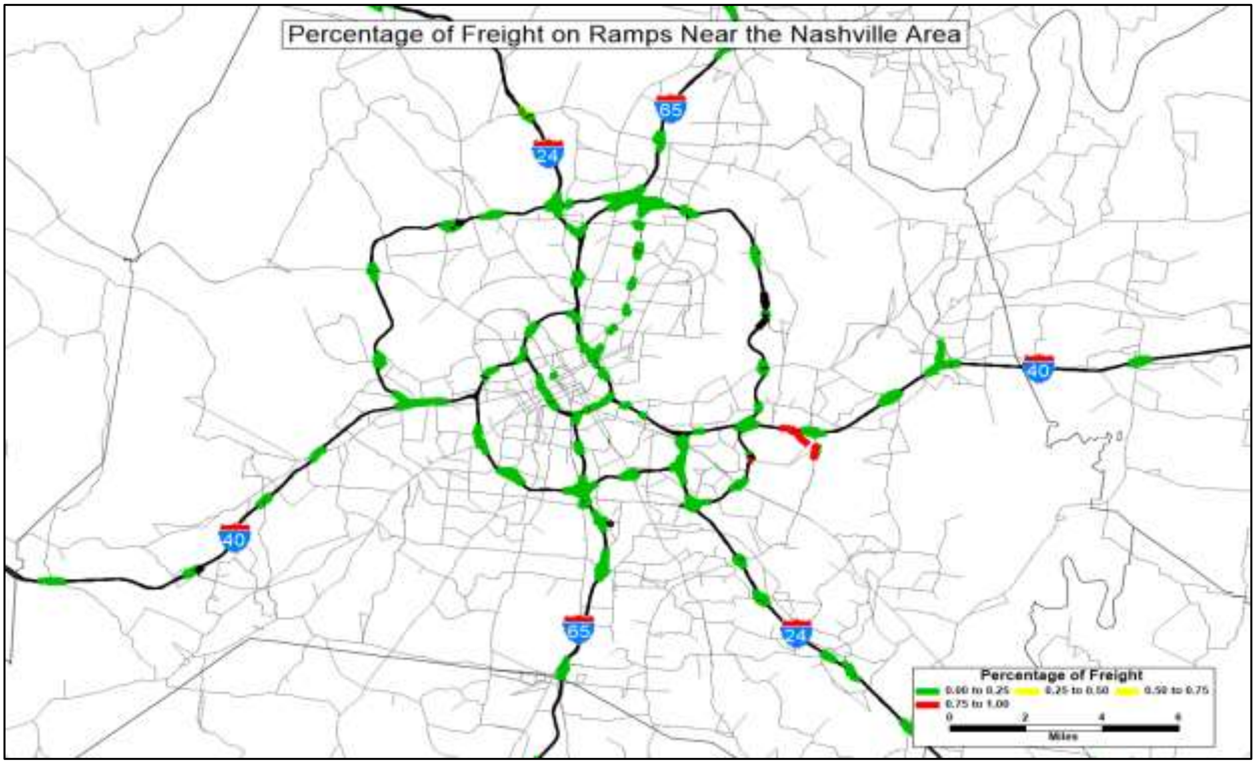


Figure 4.13. Percentage of Freight on Chattanooga Ramps, 2010

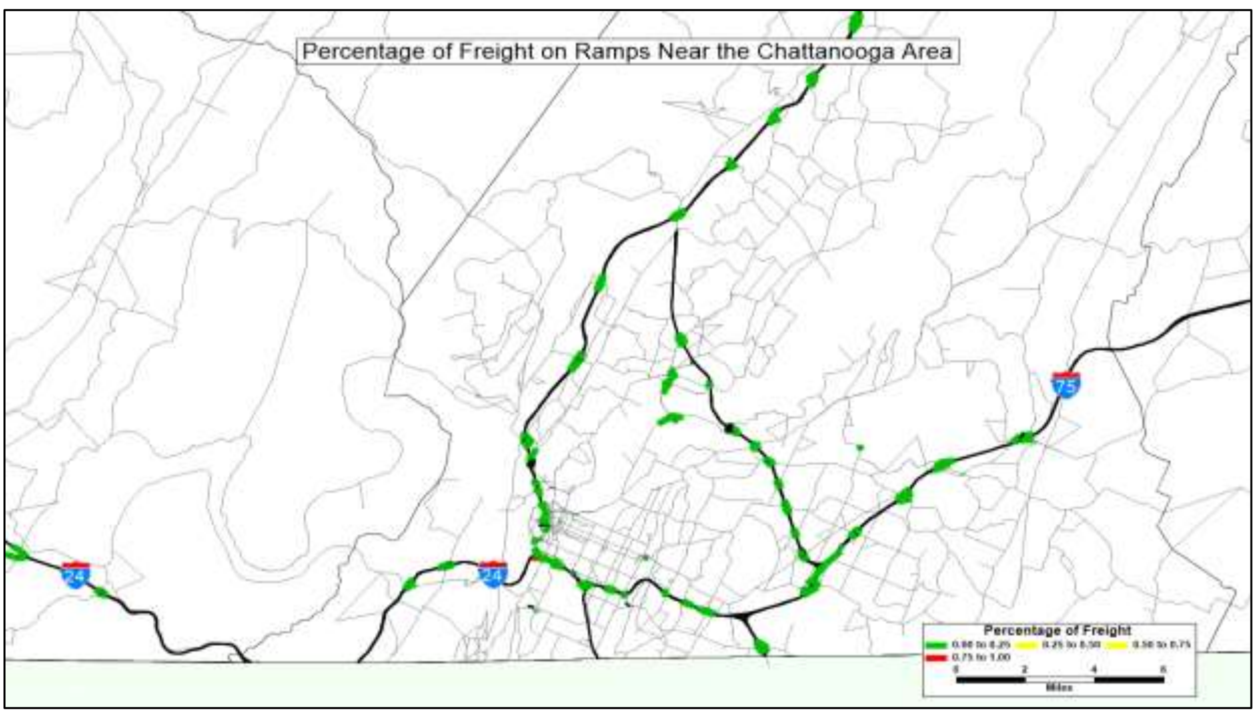


Figure 4.14. Percentage of Freight on Knoxville Ramps, 2010

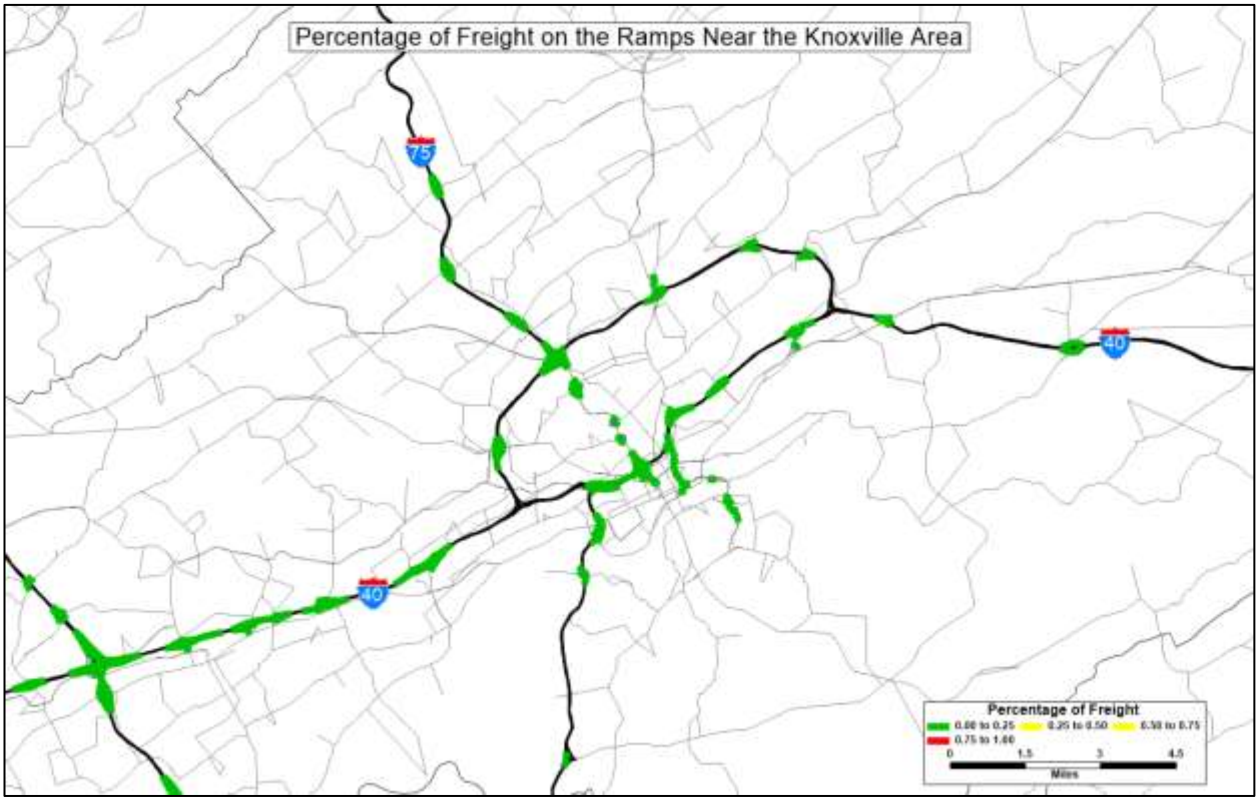


Figure 4.15. Percentage of Freight on Tennessee Ramps, 2040

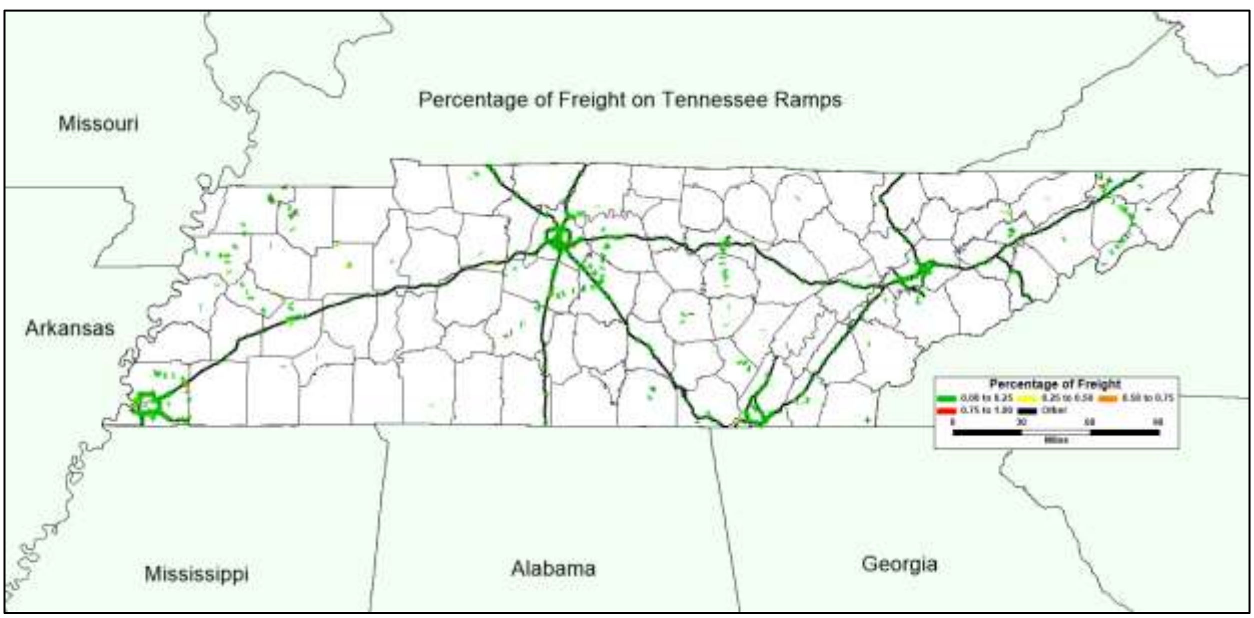


Figure 4.16. Percentage of Freight on Memphis Ramps, 2040

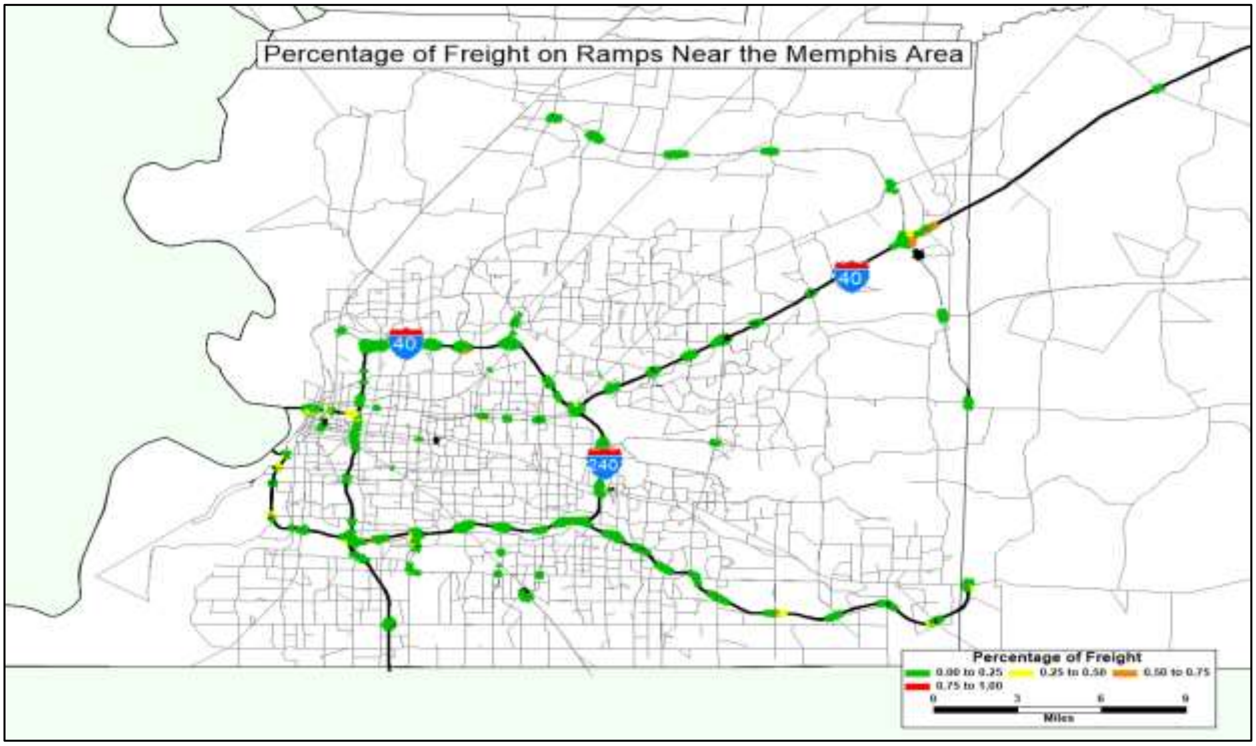


Figure 4.17. Percentage of Freight on Nashville Ramps, 2040

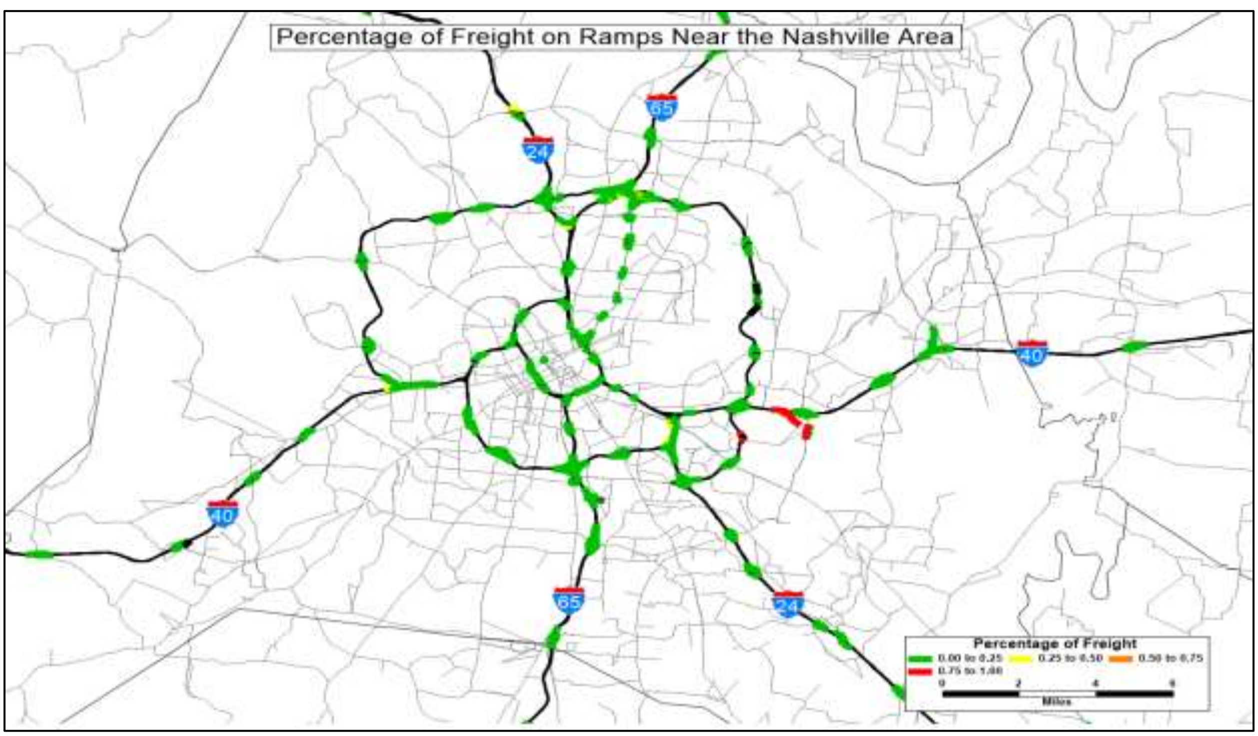


Figure 4.18. Percentage of Freight on Chattanooga Ramps, 2040

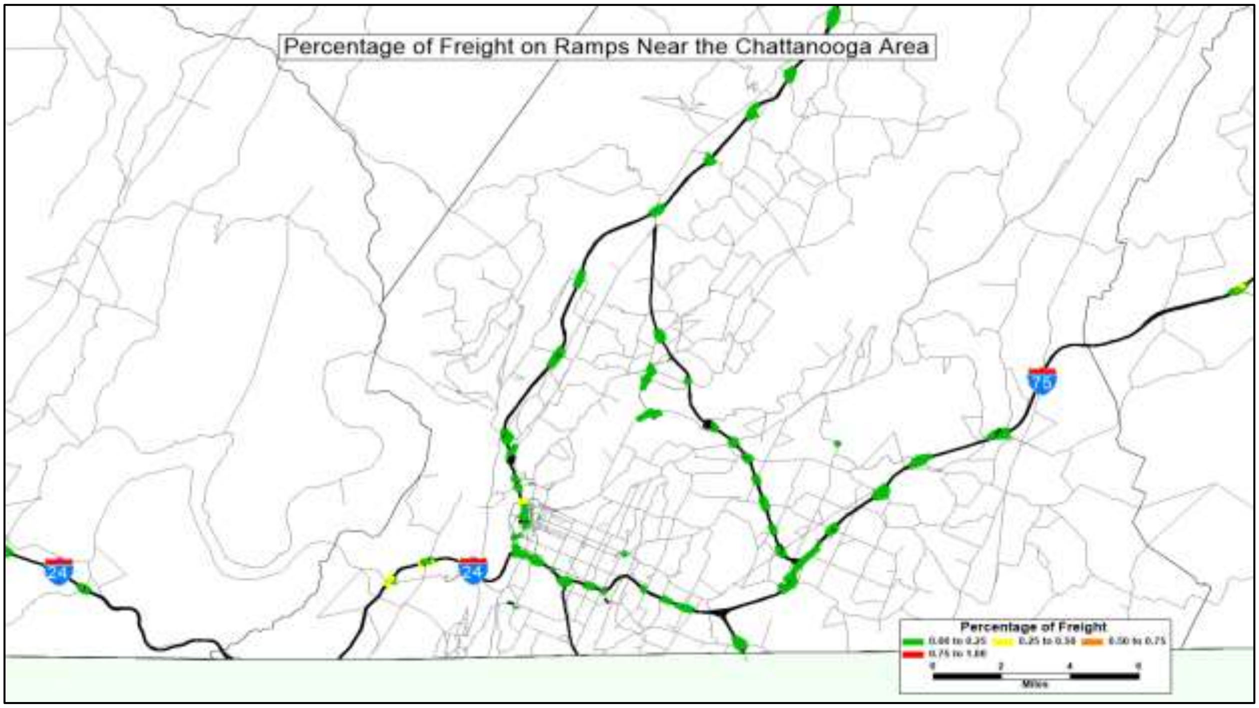
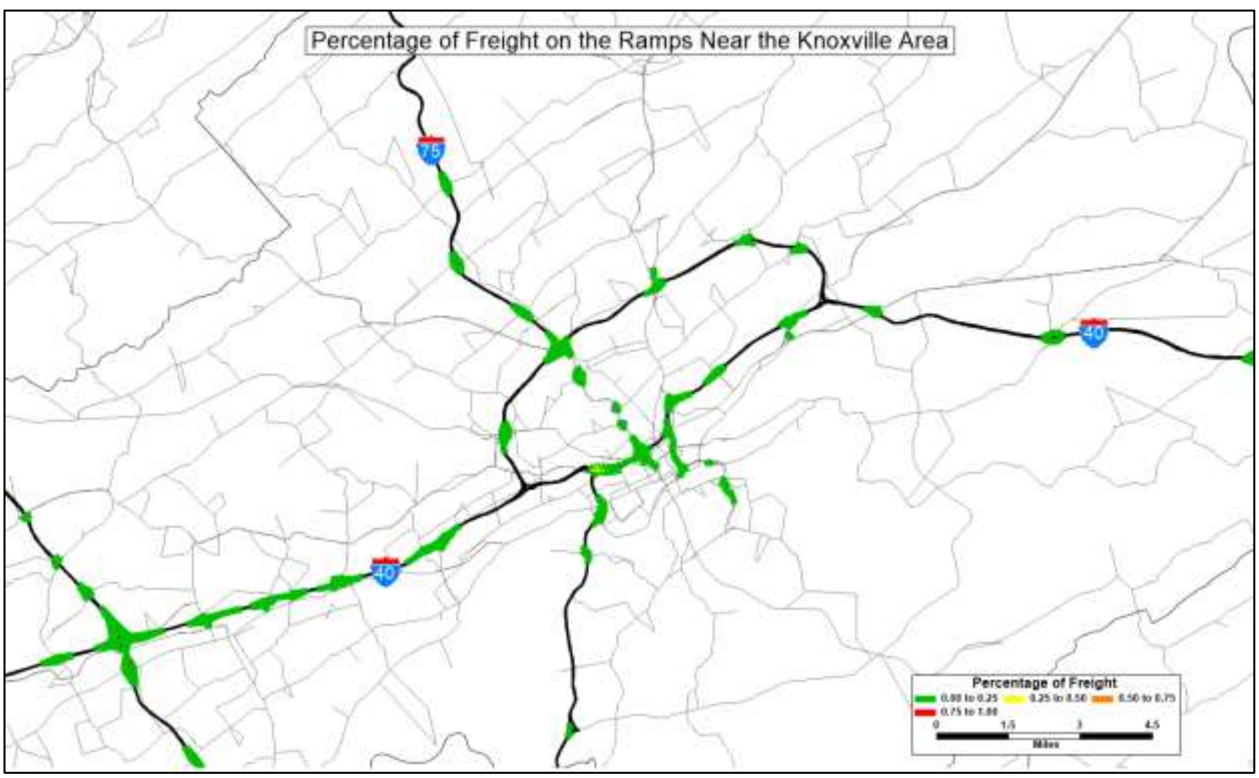


Figure 4.19. Percentage of Freight on Knoxville Ramps, 2040



In conclusion to the ramps and interstates for the percentage of freight movement on them, it is clear that the closer to the urban regions, the more personal vehicles start to appear. This could either be a positive thing for freight or a negative thing. The positive will be that since the percentage of freight decreases with closer distance to an urban area that there will be fewer delays for freight because they have already made there stops. On the negative side an increase in vehicles means that roads are becoming overcrowded and cause traffic to move slower which is delaying the movement of freight. An analysis of where the major freight distribution centers are in the urban areas will help will provide a better explanation for where freight is going in the urban areas and help to determine if there is a negative of positive impact with the decrease of freight percentage in the urban areas.

Chapter 5. Identification of Potential Bottlenecks

With the general idea of where the freight bottleneck indicators are at through the interstates of Tennessee, the next major step is to identify the areas that could potential be a bottleneck based on the identified indicators. This process will not be systematically ranking location, but rather just identifying hot spots based on the number of indicators in that area. Hot spots will be identified as an location on the interstate that contains 4 or more bottleneck indicators within a 2 mile radius. These hot spot will later be compared to NPMRDS data, which will provide the peak and non-peak travel speeds. It would be anticipated based on the graph in **figure 5.0** that the majority of the potential freight bottleneck locations will be found in the urban environments. **Figure 5.1** through **figure 5.6** will provide map visuals of the hot spots that could potentially be a freight bottleneck based on the indicators.

Figure 5.0. Congestion Contributors and Their Percentage. *Federal Highway Administration*

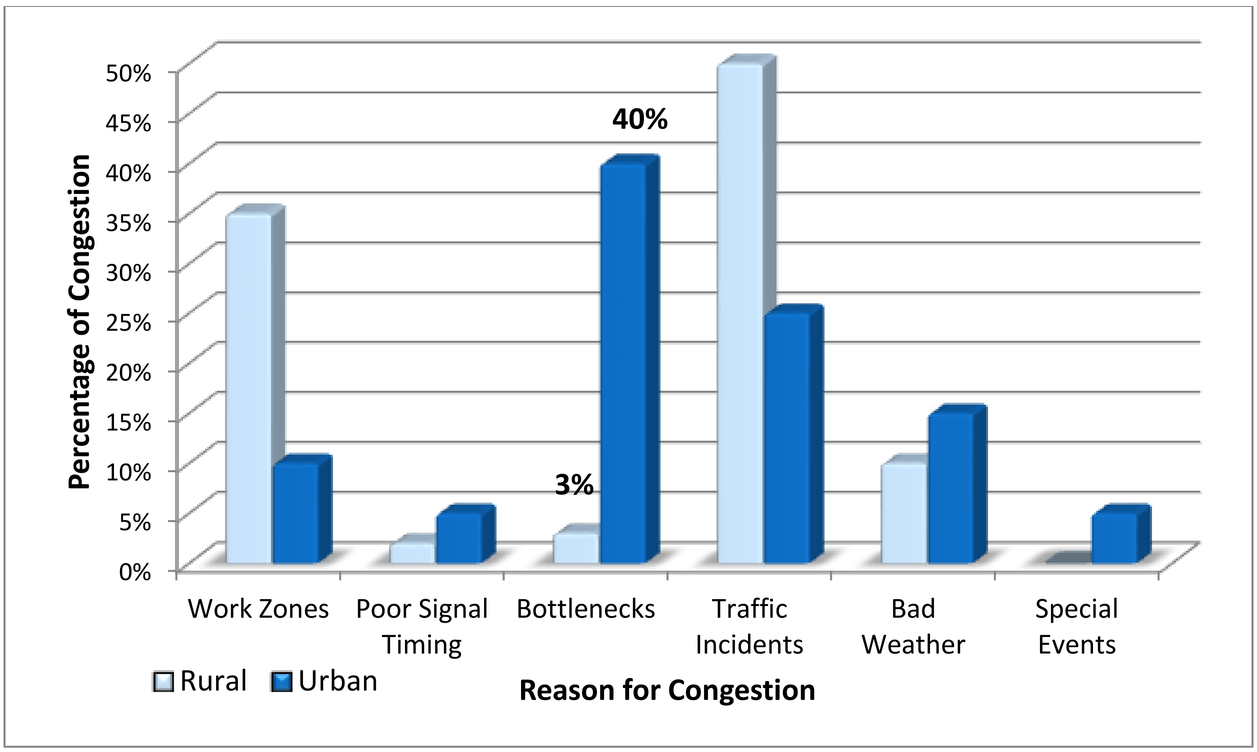


Figure 5.1 Potential Bottleneck Locations in Tennessee Based on Indicators

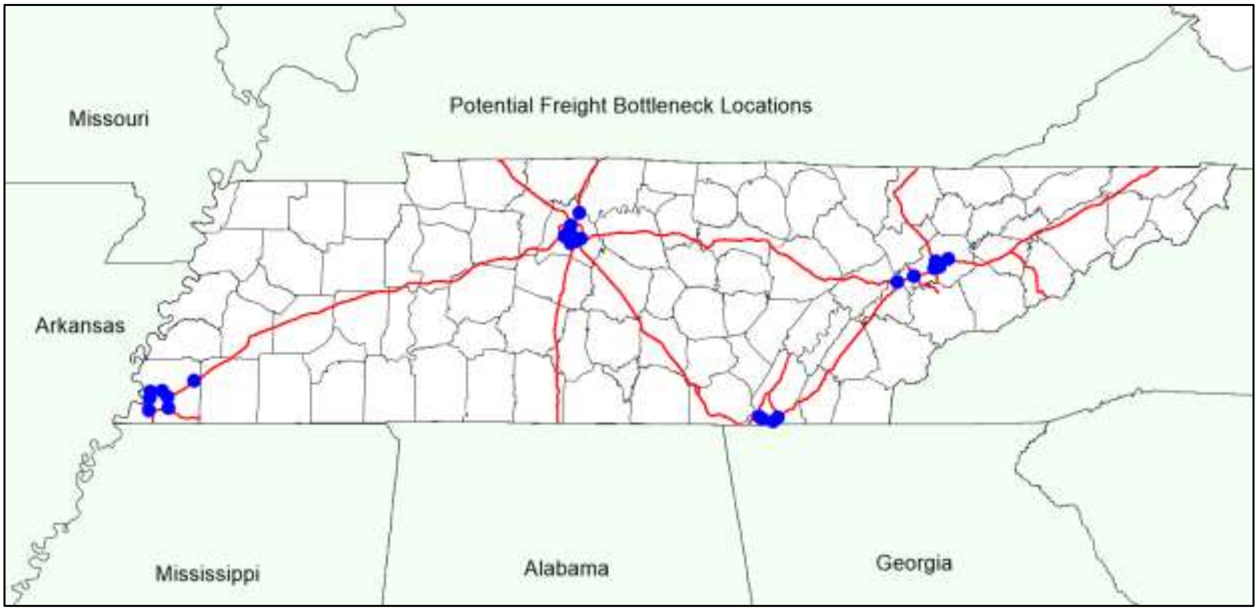


Figure 5.2 Potential Bottleneck Locations Based on Indicators near Memphis

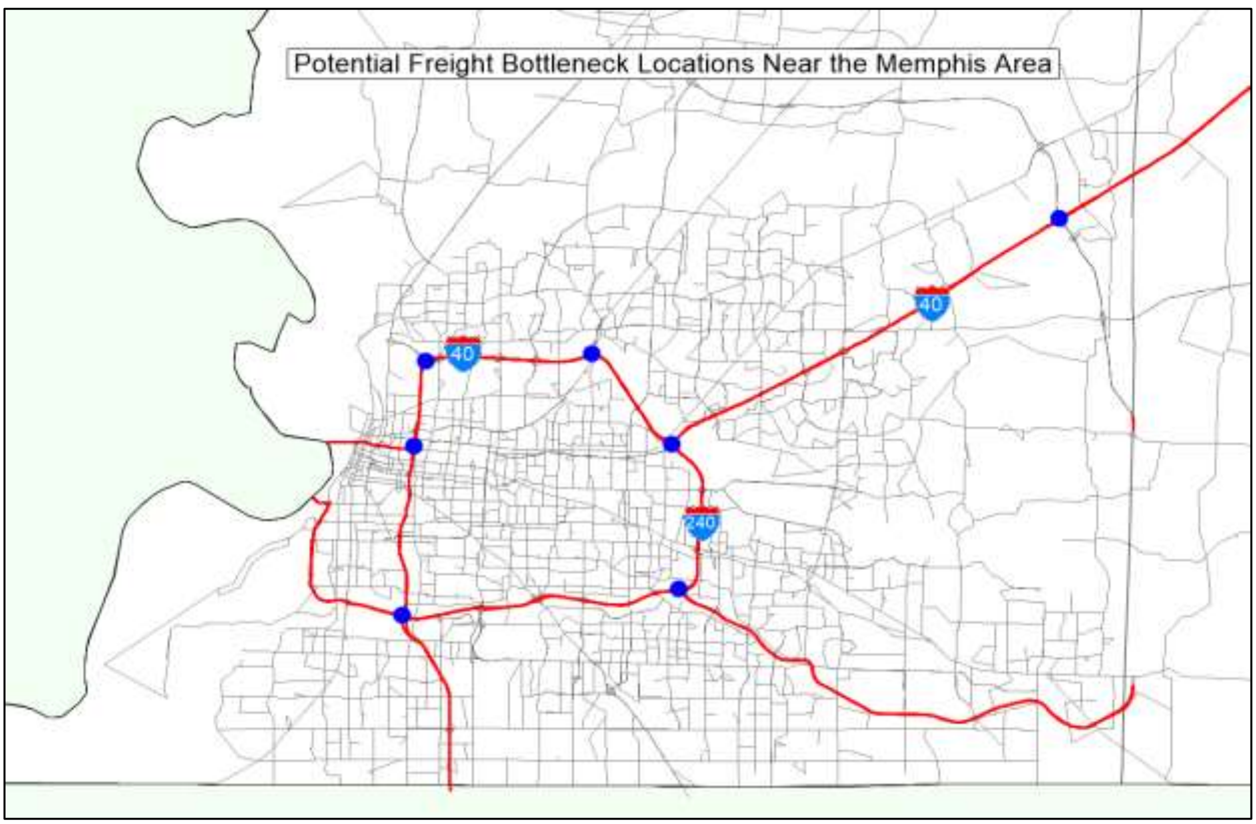


Figure 5.3. Potential Bottleneck Locations Based on Indicators near Nashville

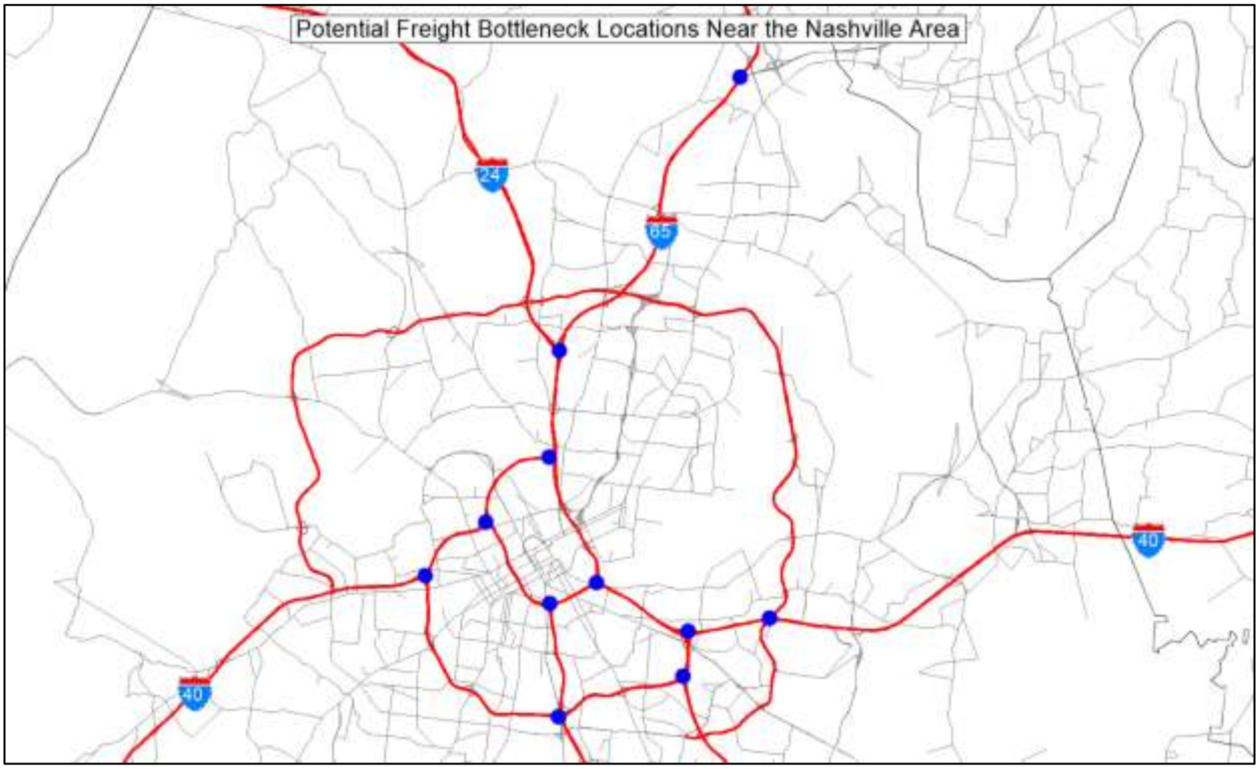


Figure 5.4. Potential Bottleneck Locations Based on Indicators near Chattanooga

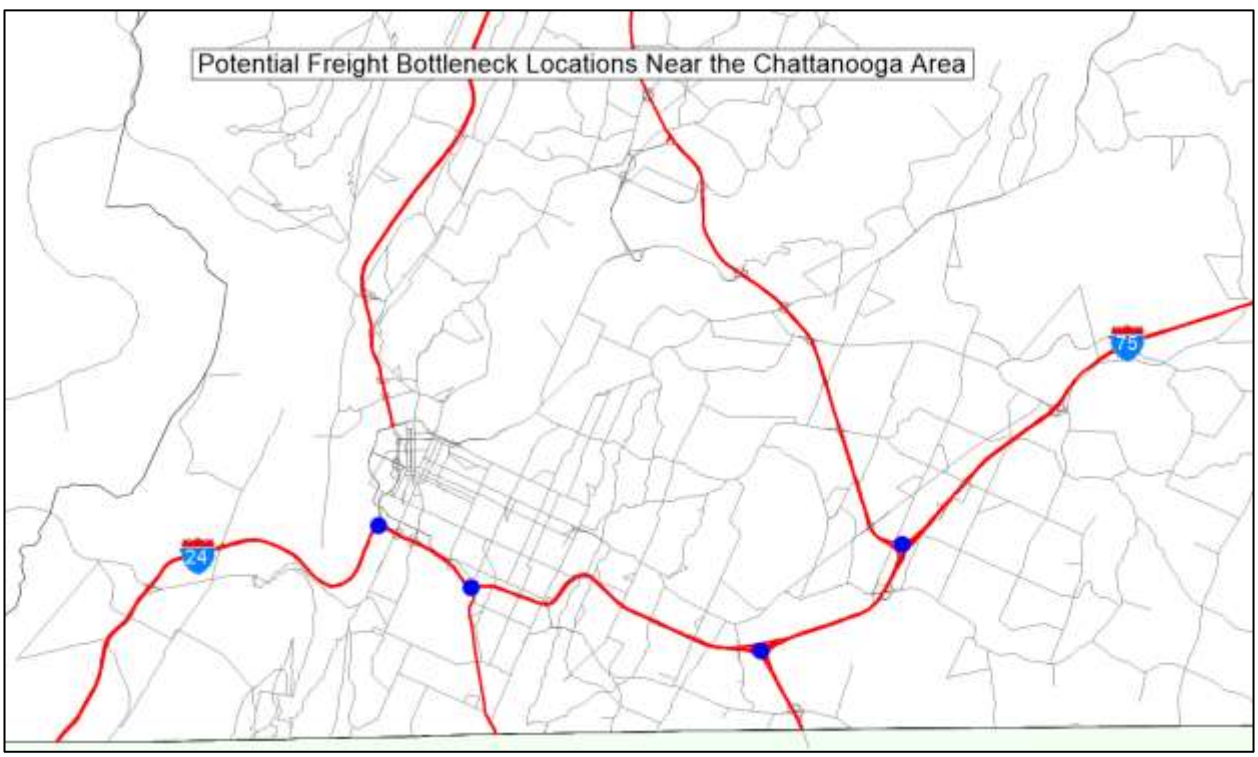
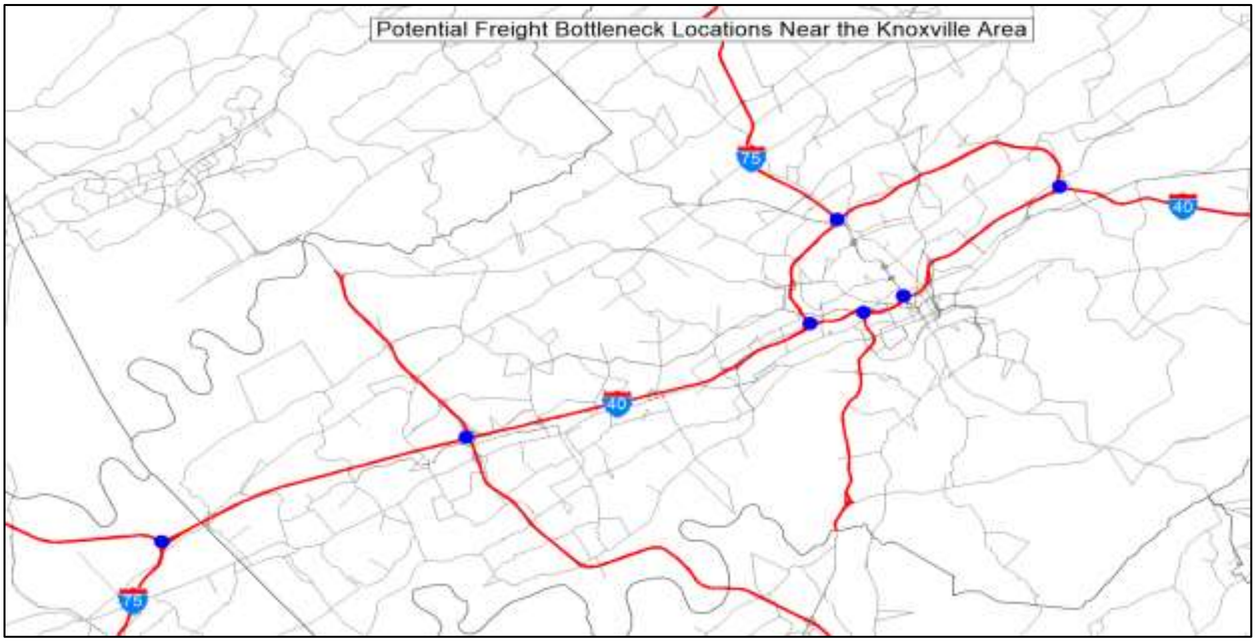
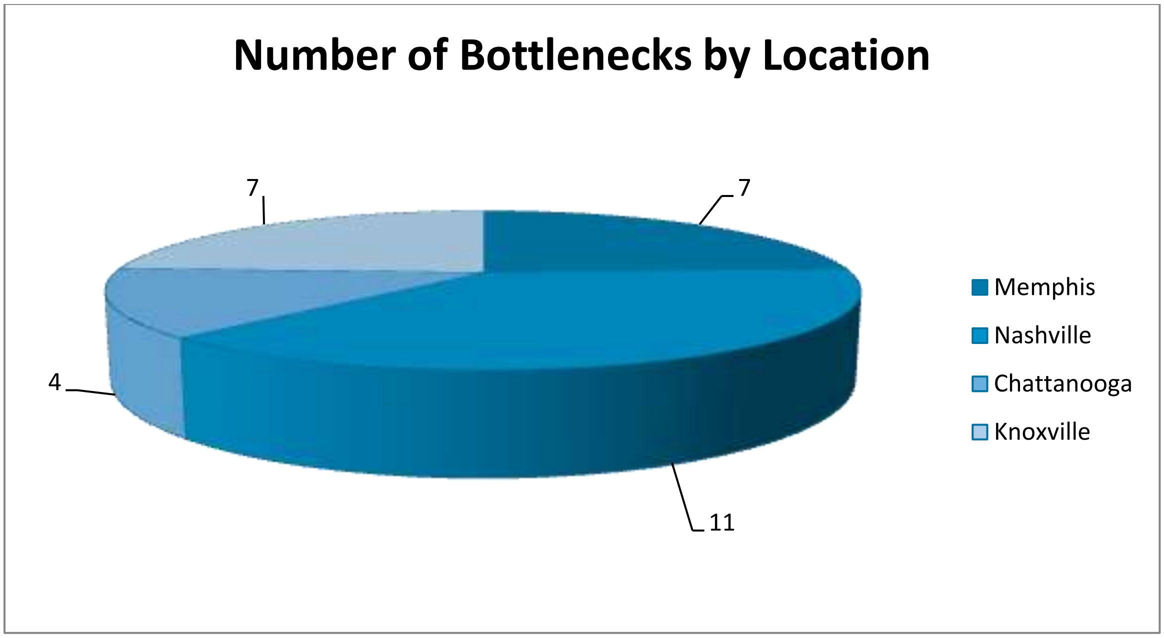


Figure 5.5. Potential Bottleneck Locations Based on Indicators near Knoxville



Based on the data collected from the indicators that have an influence on freight bottlenecks, there is a clear visual that when it comes to potential freight bottlenecks in Tennessee, there is a higher chance that they will be found in the urban areas, as supported in **figure 5.0**. **Figure 5.6** illustrates how many potential bottlenecks, bases on there being 4 or more indicators, which are near each of the major urban environments in Tennessee.

Figure 5.6. Number of Potential Bottlenecks by Location



The next step with this report is to determine which one of these potential freight bottleneck locations are actual bottlenecks based on the average peak hour and non-peak hour speeds, using NPMRDS data.

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Chapter 6. Freight Bottleneck Locations

6.0 American Transportation Research Institute Freight Bottlenecks

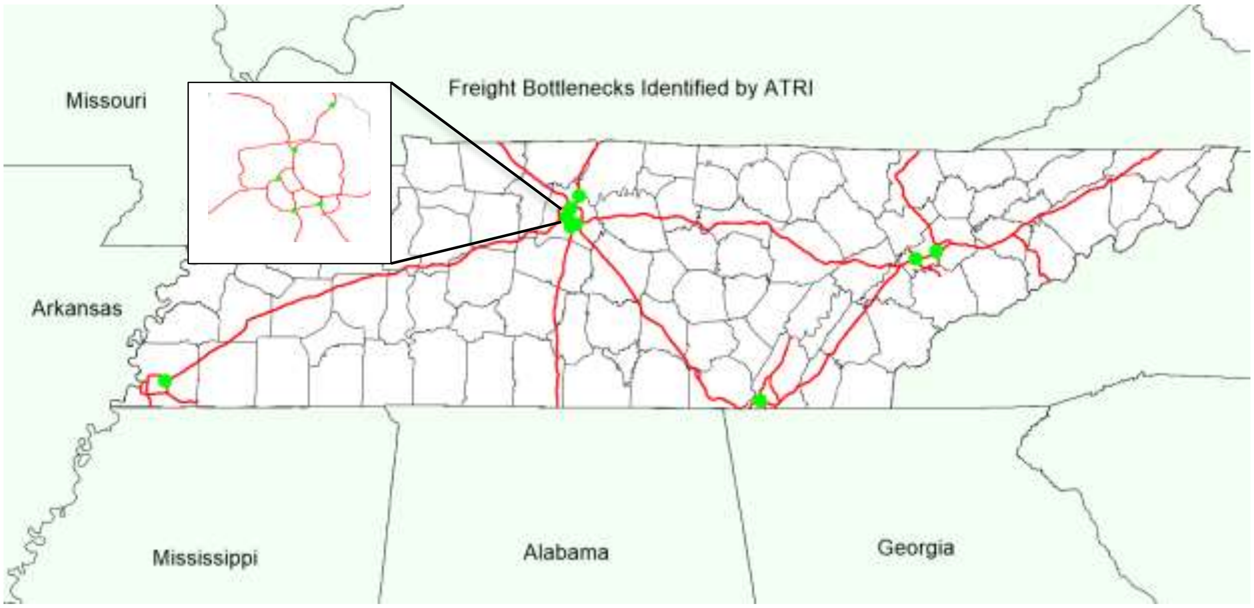
This analysis looks at the average non-peak hour speeds, as well as the average peak hour speeds at each of the 29 potential bottleneck locations previously identified. **Table 6.0** displays the characteristics of the nine freight bottlenecks in Tennessee that were identified by the American Transportation Research Institute.

Table 6.0. Tennessee Top Bottlenecks. ATRI 2018

Congestion Ranking	Location	State	Average Speed	Peak Average Speed	Non-Peak Average Speed
11	Chattanooga: I-24 at Hwy 27	TN	49.4	42.2	52.8
15	Nashville: I-24 at I-440 (north)	TN	43.1	31.8	49.2
22	Memphis: I-40 at I-240 (east)	TN	37.7	30.8	40.7
32	Nashville: I-65 at I-440	TN	49.4	39.8	53.9
60	Nashville: I-40 at I-65 (east)	TN	43.5	33.3	48.3
68	Nashville: I-65 at RT 386	TN	52.7	47.2	55
77	Nashville: I-65 at I-24	TN	49.2	41	52.7
84	Knoxville: I-40/I-75 at I-140	TN	53.4	49.5	55
85	Knoxville: I-40 at I-640 (west)	TN	53.5	50.2	54.9

The National Performance Management Research Data Set (NPMRDS) speeds were collected on an hourly basis, from January 1, 2017 – December 31, 2017. The objective of this analysis is to compare the peak hour speeds against non-peak hour speeds, to identify any possible significant discrepancies between the two. The findings are then compared to Tennessee's nine bottlenecks, as identified by American Transportation Research Institute (ATRI). **Figure 6.0** shows the nine freight bottleneck locations that were identified by American Transportation Research Institute *(ATRI).*

Figure 6.0. Tennessee Bottleneck Locations Source: ATRI



The first section of this analysis looks at the freight bottlenecks that were identified by ATRI, their locations within Tennessee, and the travel speed trends within these particular road segments. The American Transportation Research Institute is a research arm for the American Trucking Association and has collected and processed truck GPS data in support of the Federal Highway Administration's Freight Performance Measures (FPM) initiative, a program that maintains and monitors a series of performance measures related to the nation's truck-based freight transportation system.

The images below summarize the peak hour travel speed averages and the non-peak hour travel speed averages in these locations. Additionally, the Average Daily Travel Speed Chart indicates the yearly averages are during each time of the day. **Figures 6.1** through **figure 6.18** illustrate the daily travel speeds for each of the bottleneck locations identified by ATRI.

Figure 6.1. Chattanooga Freight Bottleneck Location Source: ATRI, 2018

Figure 6.2. Average Speed by Time of Day. Chattanooga Source: ATRI, 2018

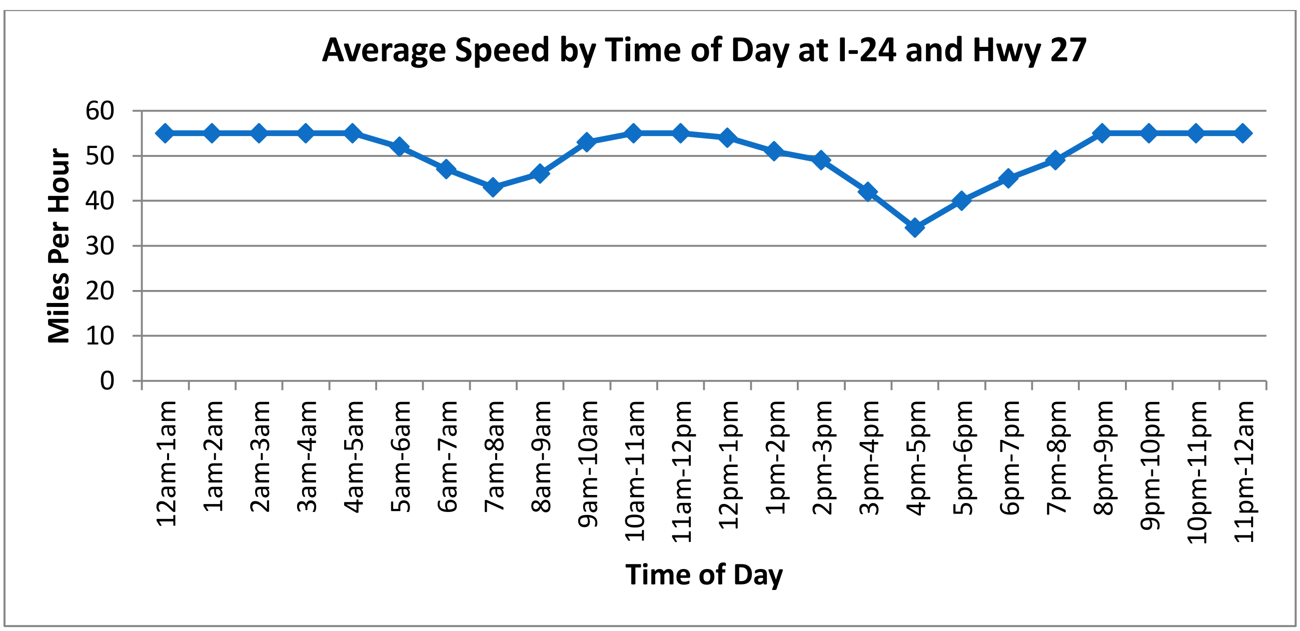


Figure 6.3. Nashville Freight Bottleneck Location Source: ATRI, 2018

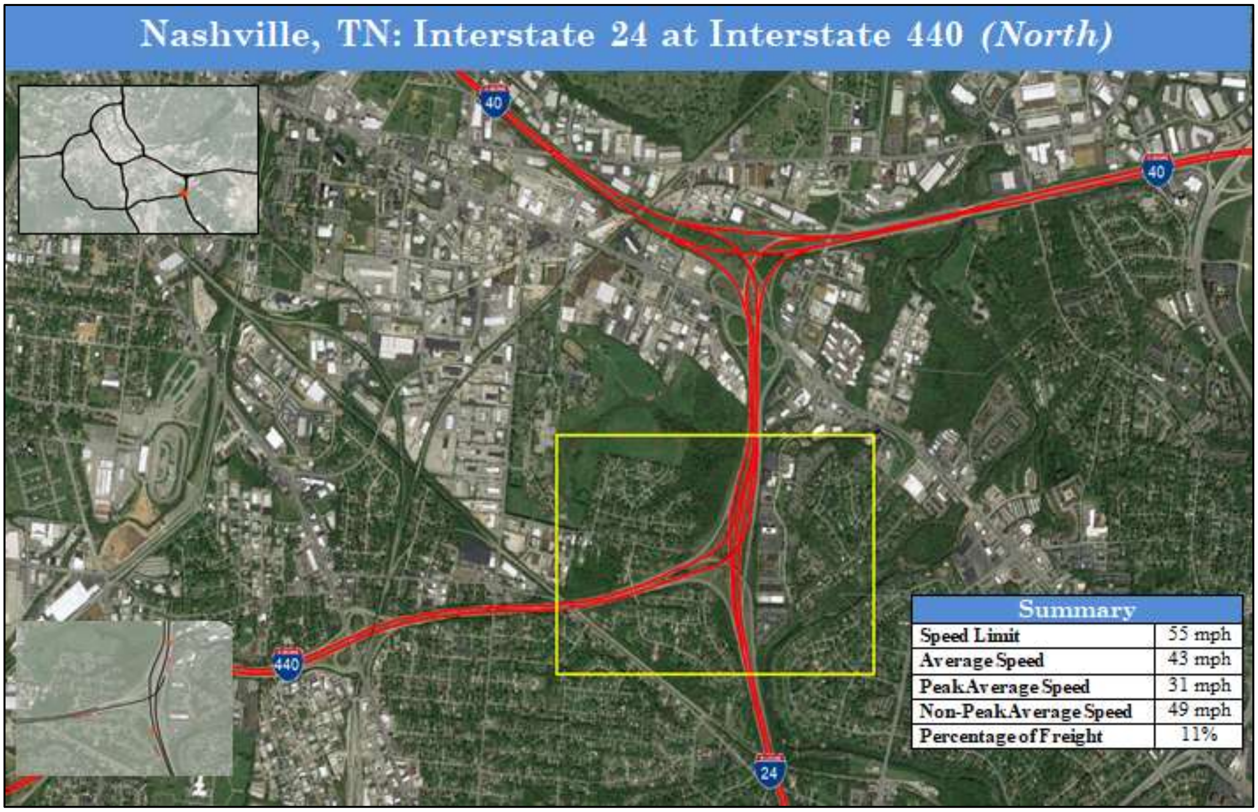


Figure 6.4. Average Speed by Time of Day. Nashville Source: ATRI, 2018

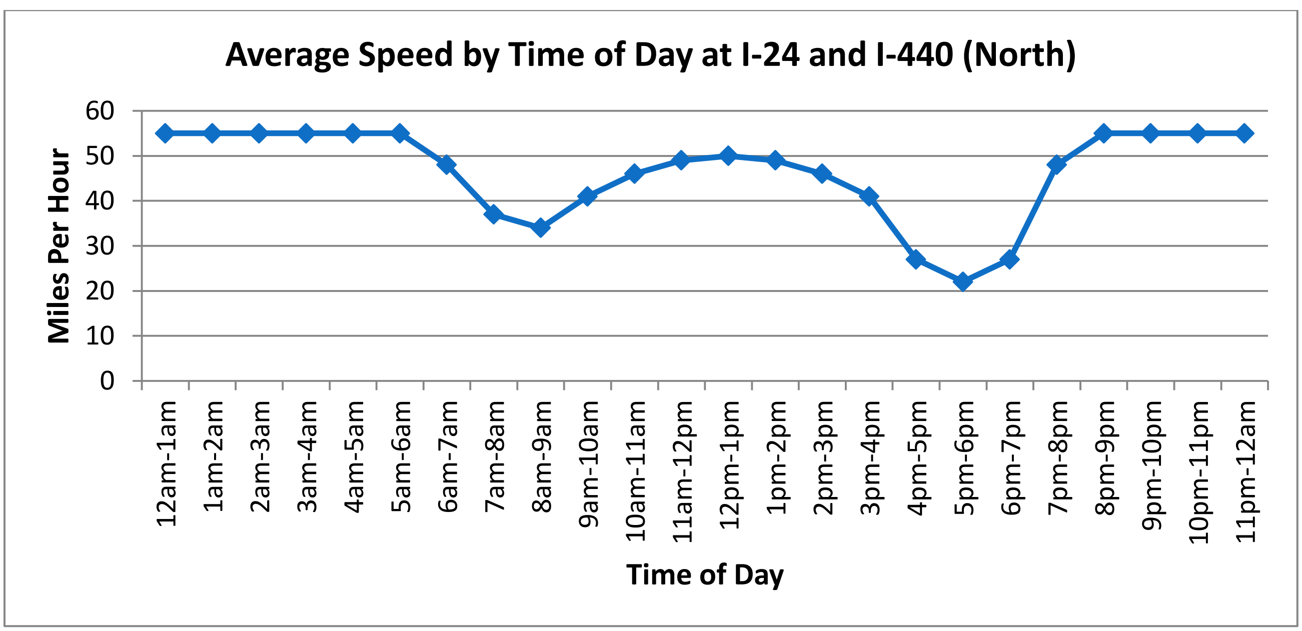


Figure 6.5. Nashville Freight Bottleneck Location Source: ATRI, 2018

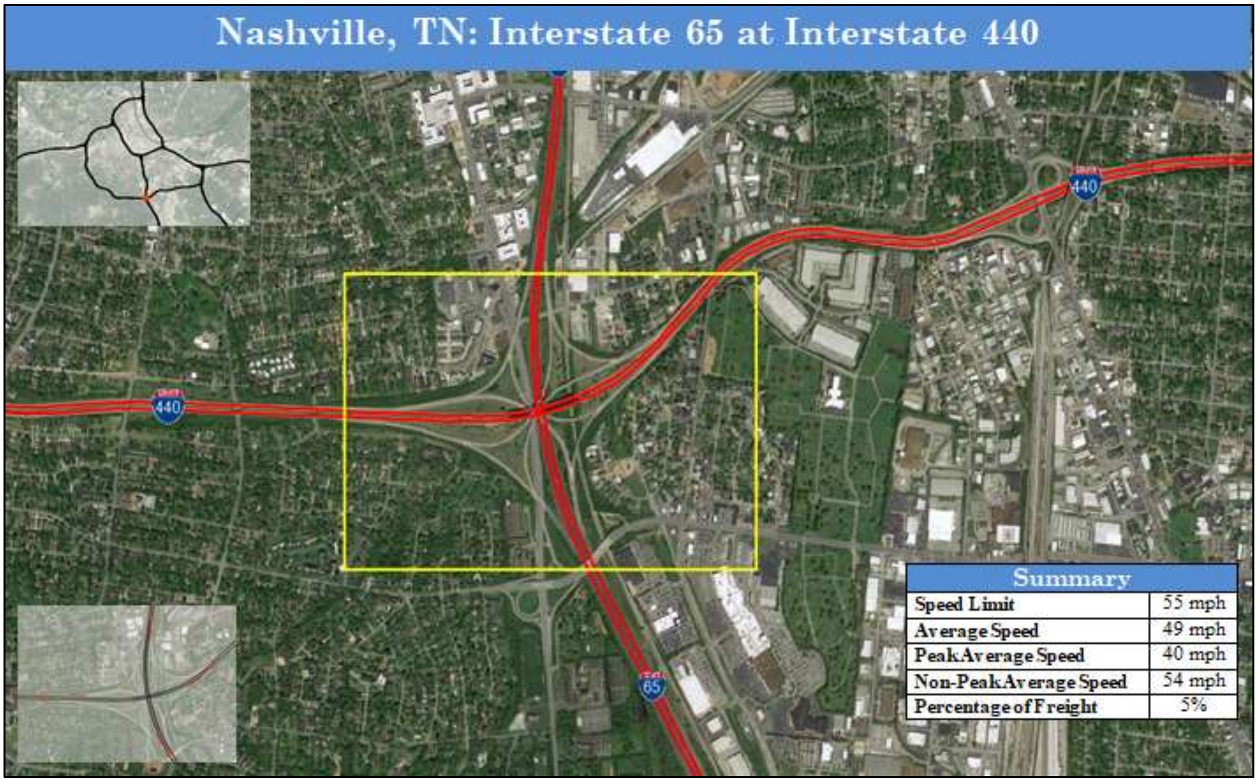


Figure 6.6. Average Speed by Time of Day. Nashville Source: ATRI, 2018

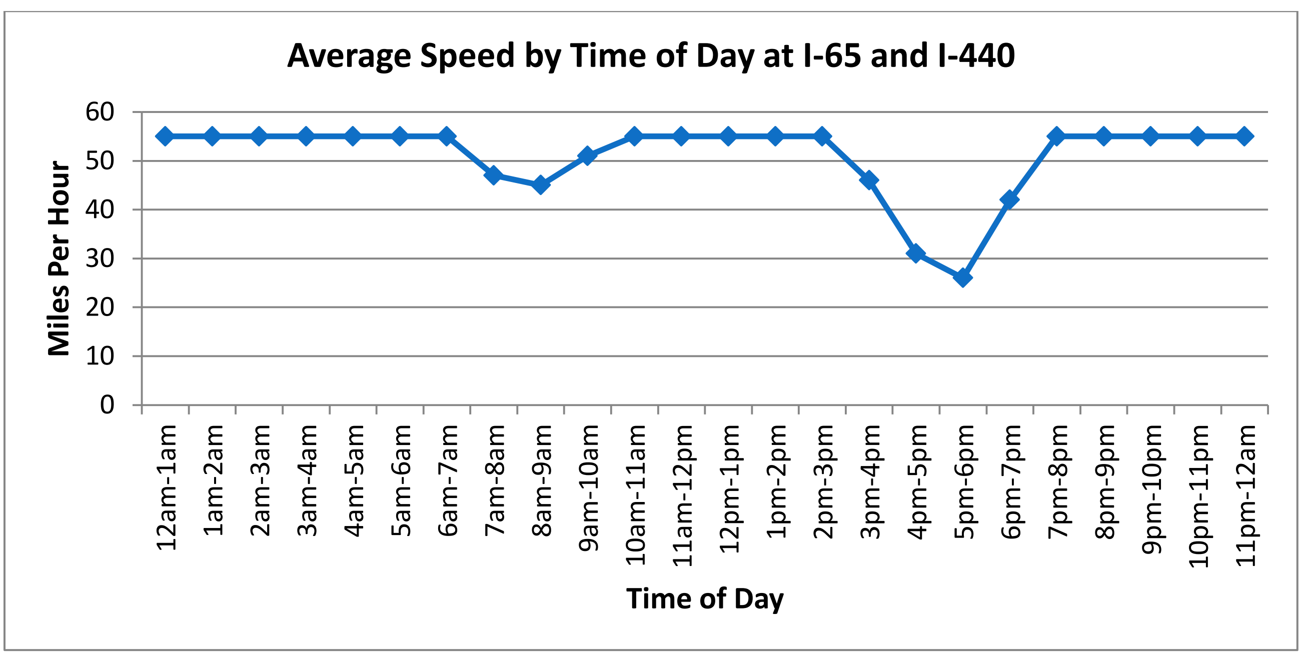


Figure 6.7. Nashville Freight Bottleneck Location Source: ATRI, 2018

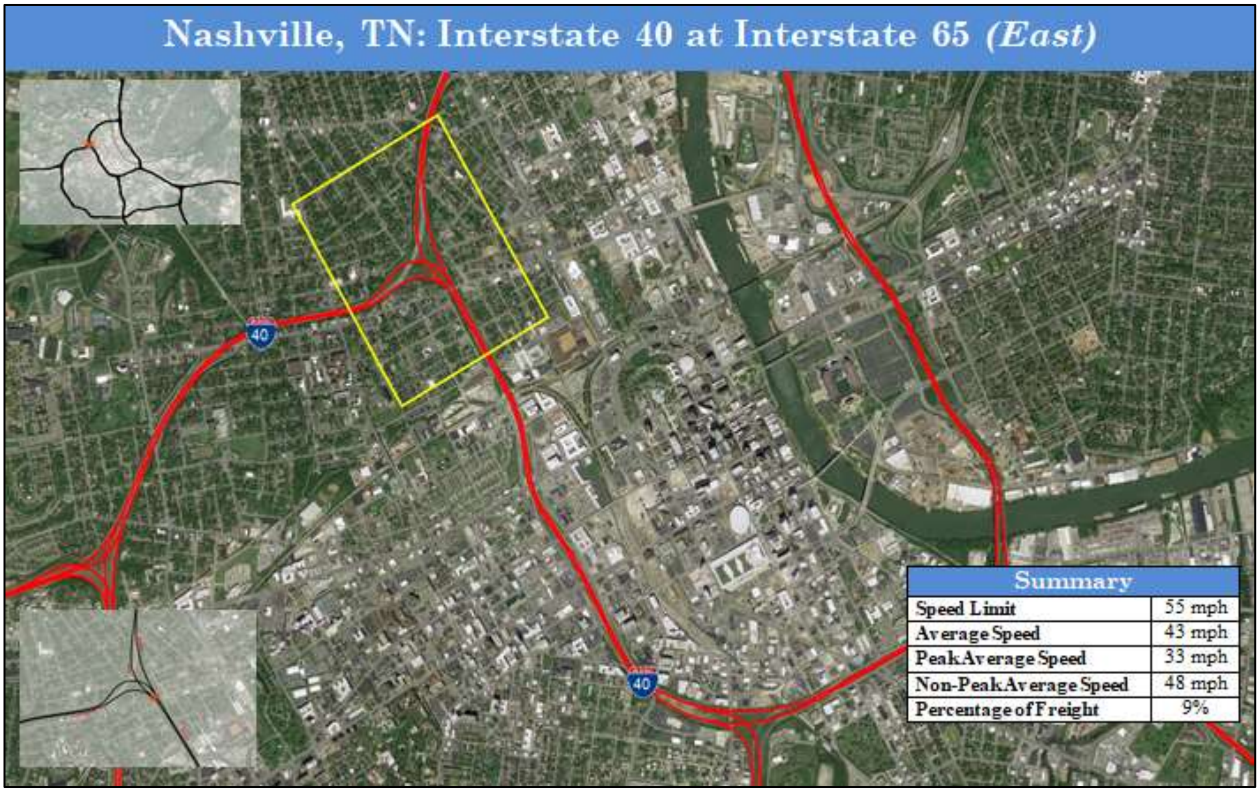


Figure 6.8. Average Speed by Time of Day. Nashville Source: ATRI, 2018

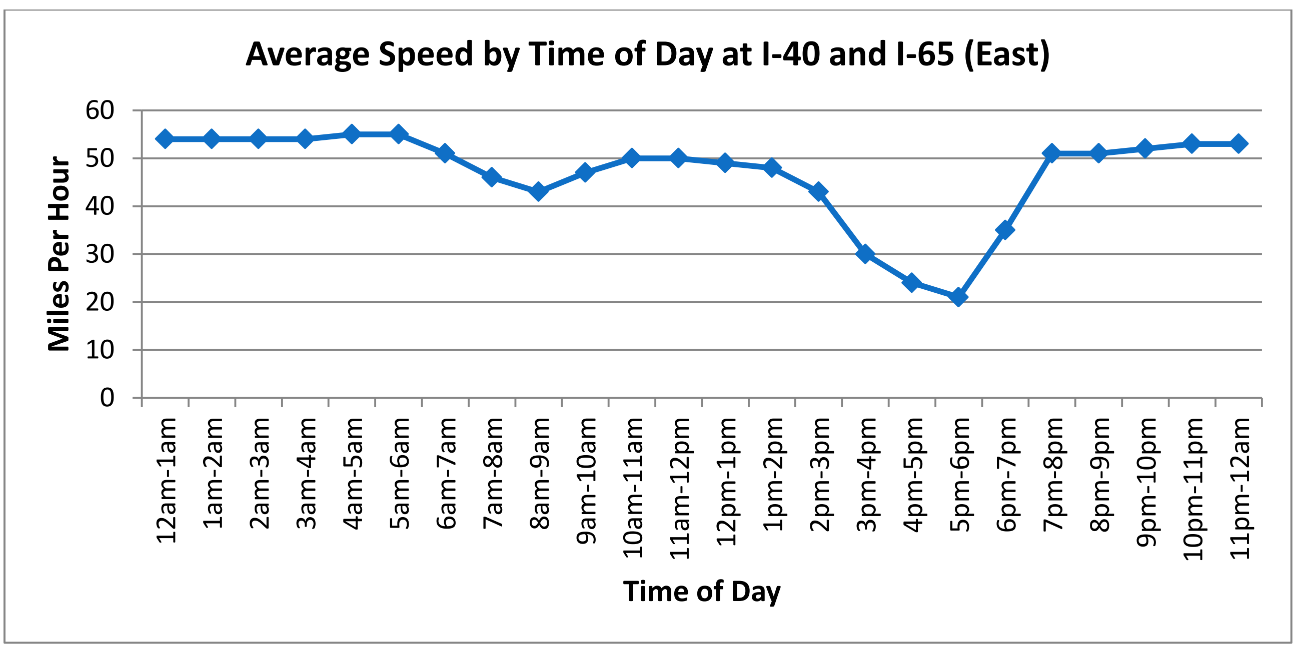


Figure 6.9. Nashville Freight Bottleneck Location Source: ATRI, 2018

Figure 6.10. Average Speed by Time of Day. Nashville Source: ATRI, 2018

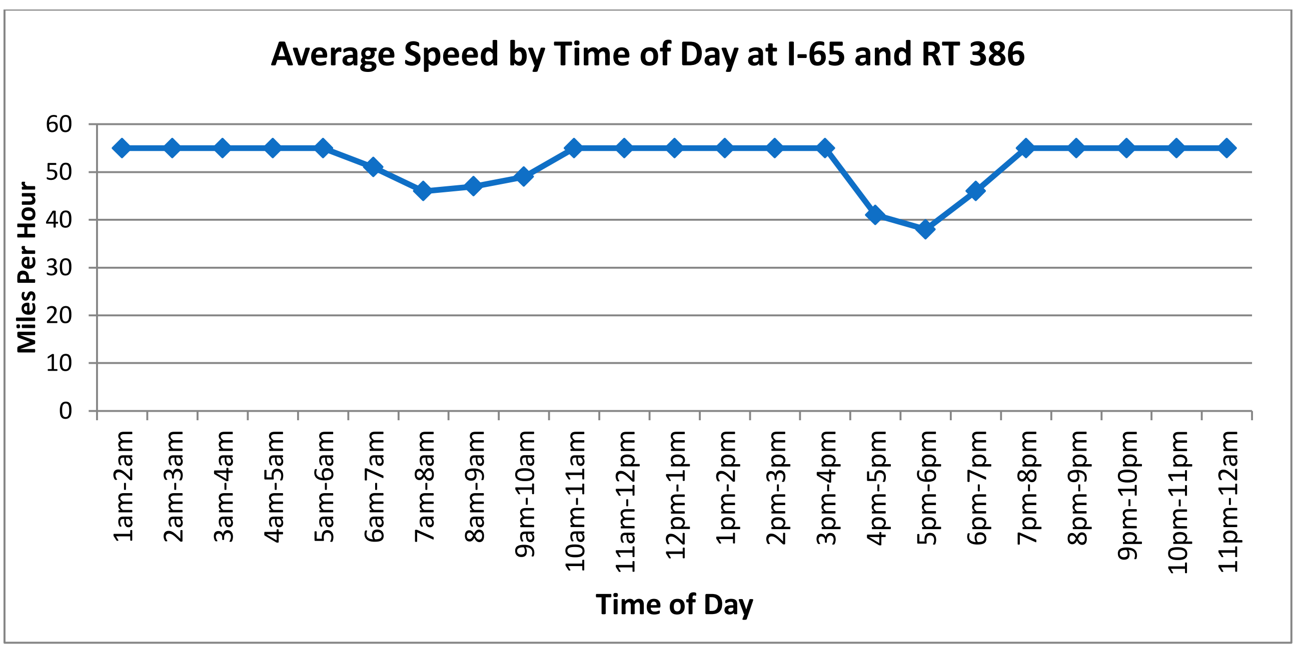


Figure 6.11. Nashville Freight Bottleneck Location Source: ATRI, 2018

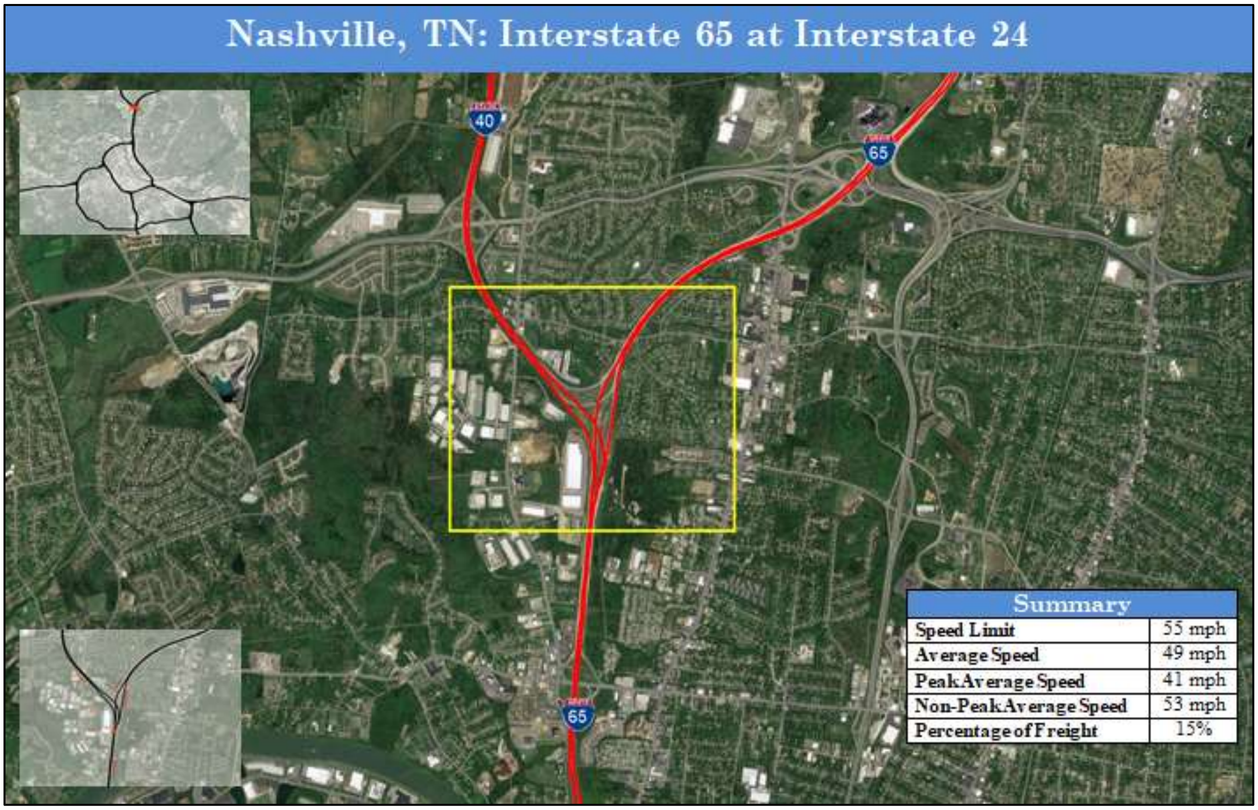


Figure 6.12. Average Speed by Time of Day. Nashville Source: ATRI, 2018

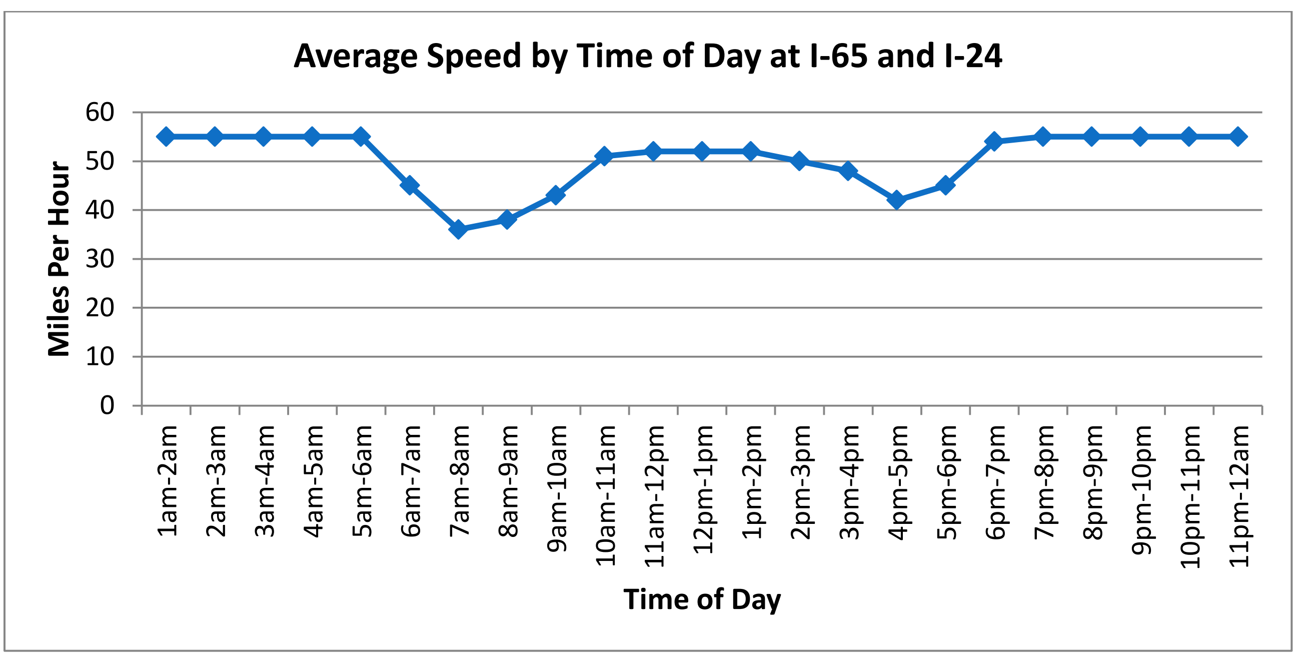


Figure 6.13. Knoxville Freight Bottleneck Location Source: ATRI, 2018

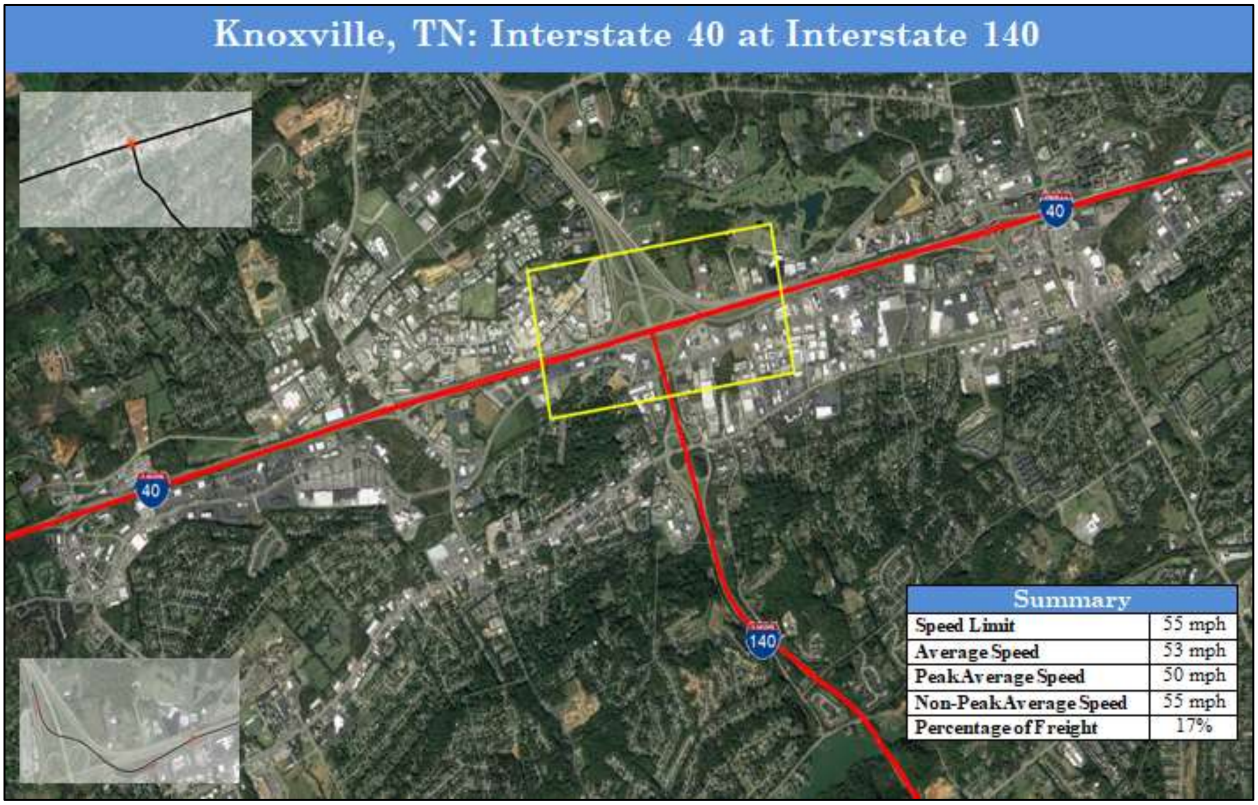


Figure 6.14. Average Speed by Time of Day. Knoxville Source: ATRI, 2018

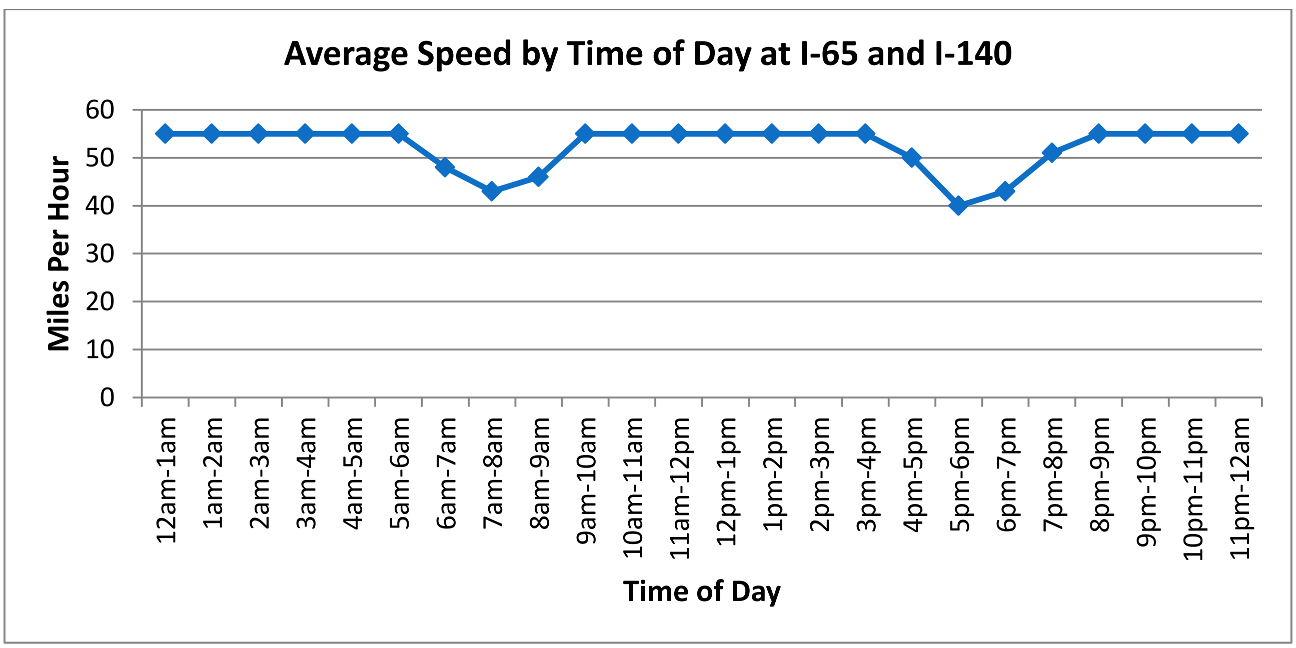


Figure 6.15. Knoxville Freight Bottleneck Location Source: ATRI, 2018

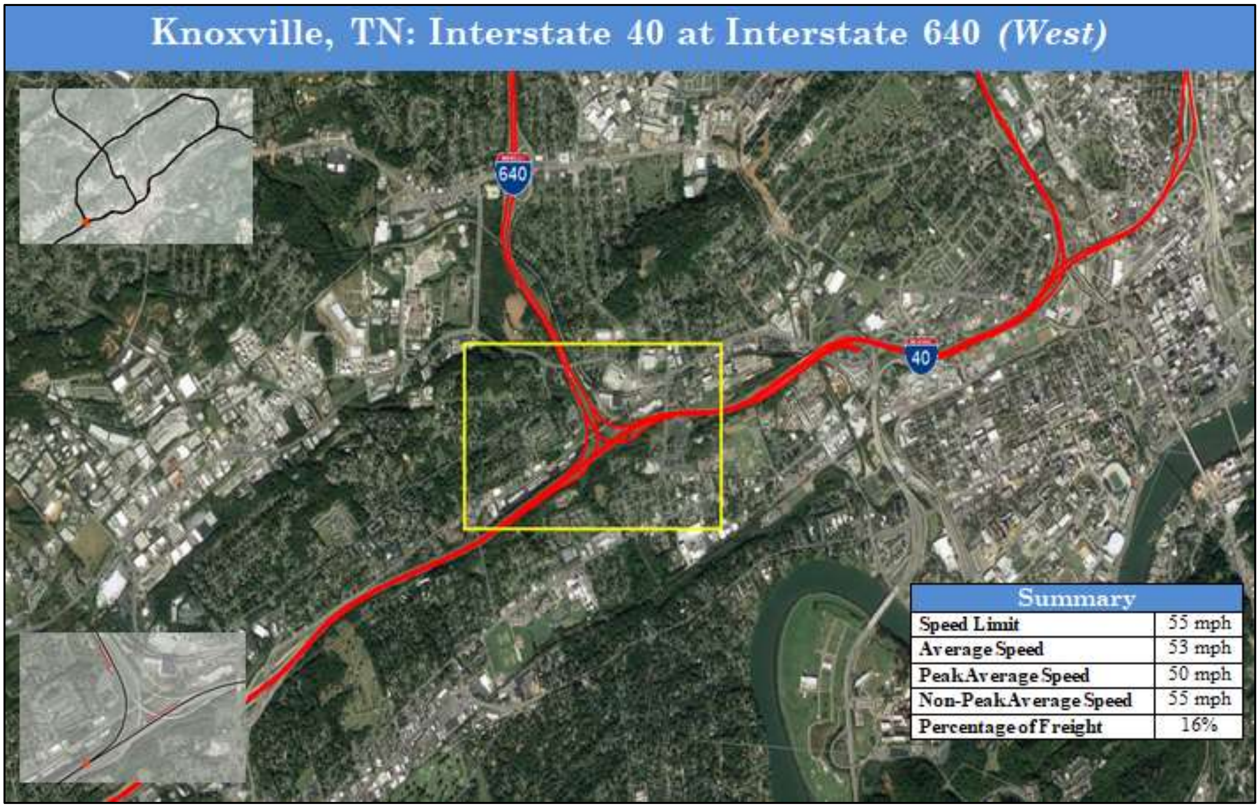


Figure 6.16. Average Speed by Time of Day. Knoxville Source: ATRI, 2018

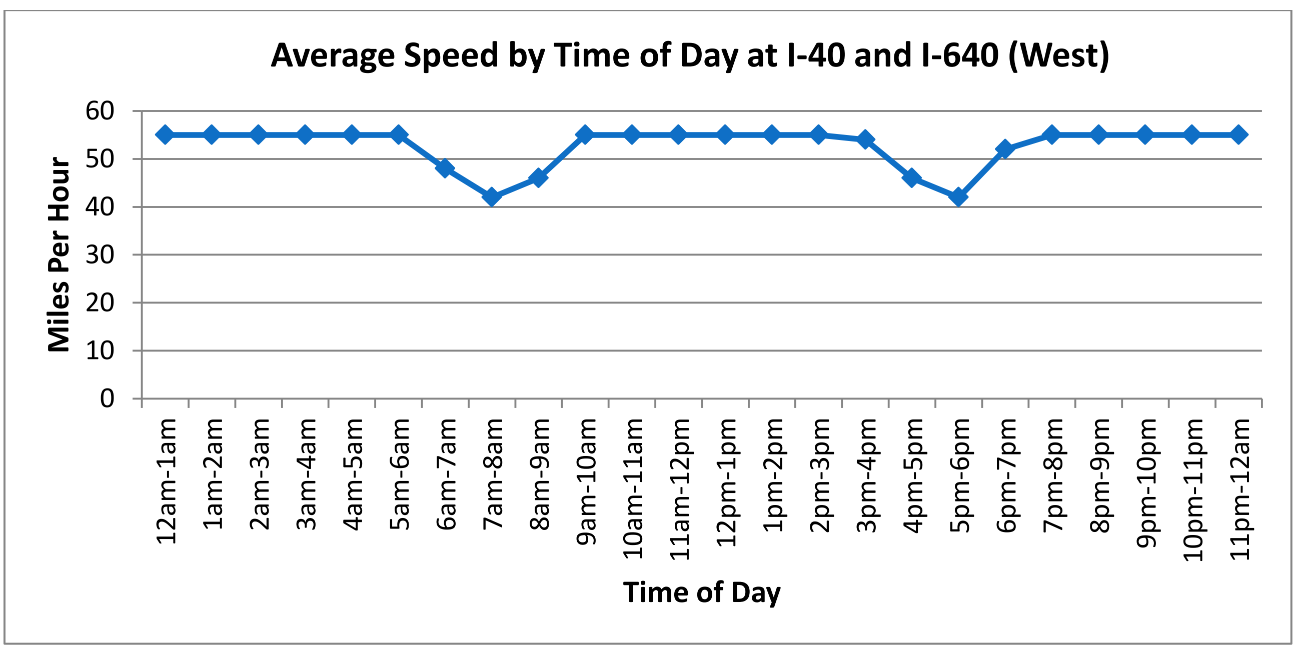


Figure 6.17. Memphis Freight Bottleneck Location Source: ATRI, 2018

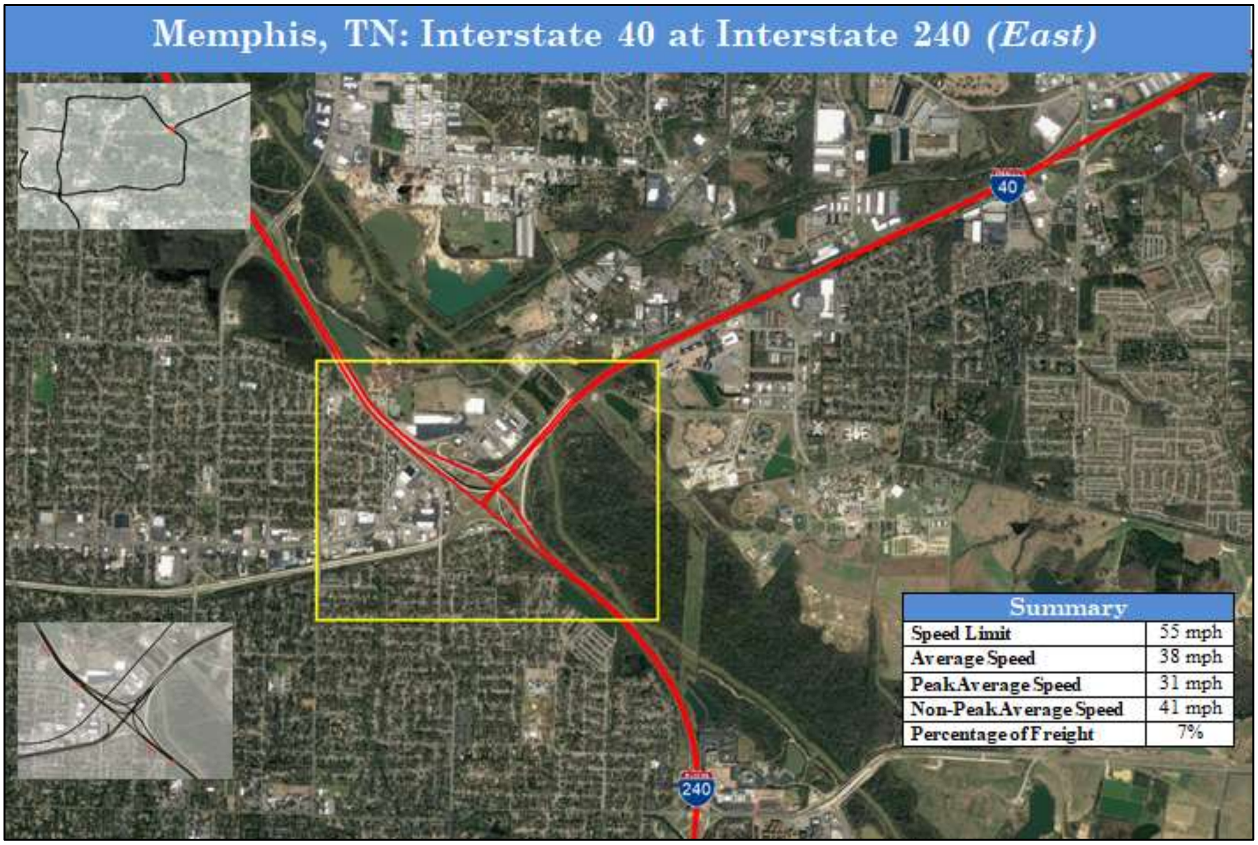
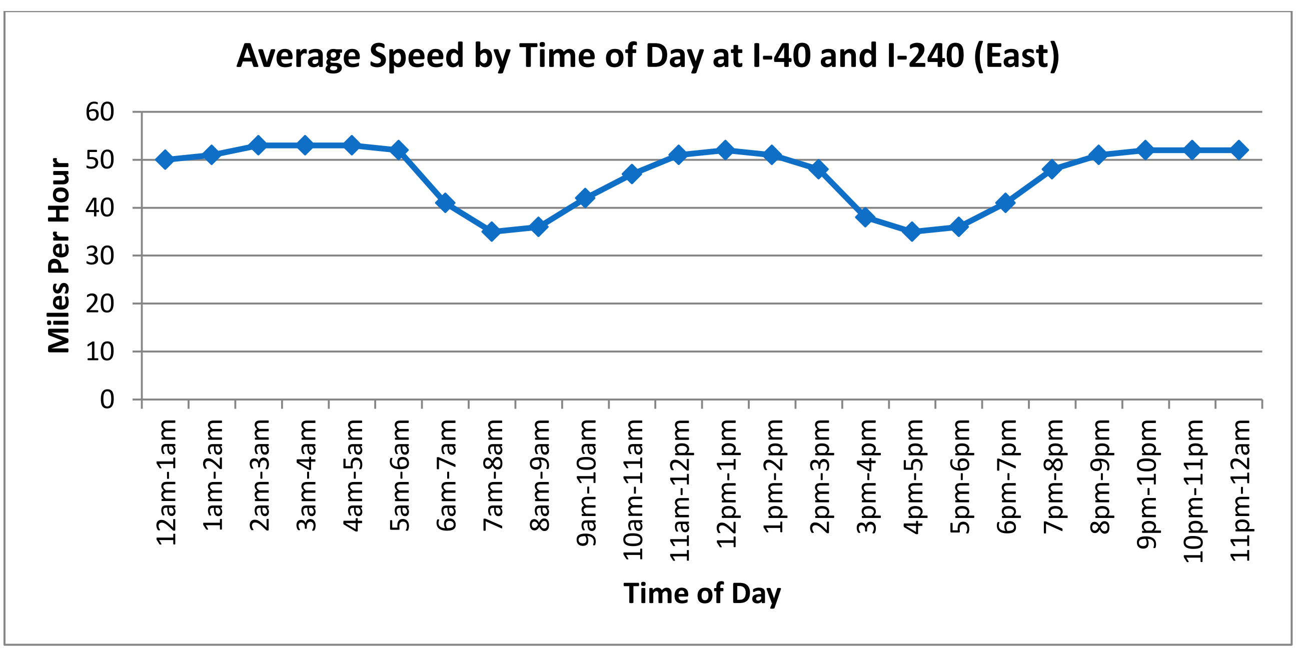


Figure 6.18. Average Speed by Time of Day. Memphis Source: ATRI, 2018



6.1 Bottlenecks Not Identified by ATRI

The following subsection identifies additional freight bottleneck locations in Tennessee that were not identified in American Transportation Research Institute *(ATRI)* Top 100 Bottlenecks. The 84 locations that were previously identified as potential bottleneck locations are now evaluated by travel speeds. There are three critical travel speeds for identifying bottleneck locations; these are: Average Daily Travel Speed, Average Peak Hour Travel Speed, and Average Non-Peak Hour Travel Speed. This speed data is collected on an annual basis, and broken into hourly averages. For the purposes of this analysis, a bottleneck is defined as any location in which the Peak Hour Travel Speed is at least 9 miles per hour (mph) greater than the Average Non-Peak Hour Travel Speed. In this analysis, the Peak Hours of Travel are defined as 6am-9am, and 3pm-7pm. 9 miles per hour was selected for the difference in travel speed to compare to the similar results in the ATRI bottleneck analysis. **Figures 6.19** through **figure 6.25** illustrate the additional bottleneck locations identified based upon travel speed data. **Table 6.1** illustrates the location and characteristics of the 12 freight bottlenecks that were identified throughout Tennessee.

Figure 6.19. Freight Bottlenecks Not Identified by ATRI

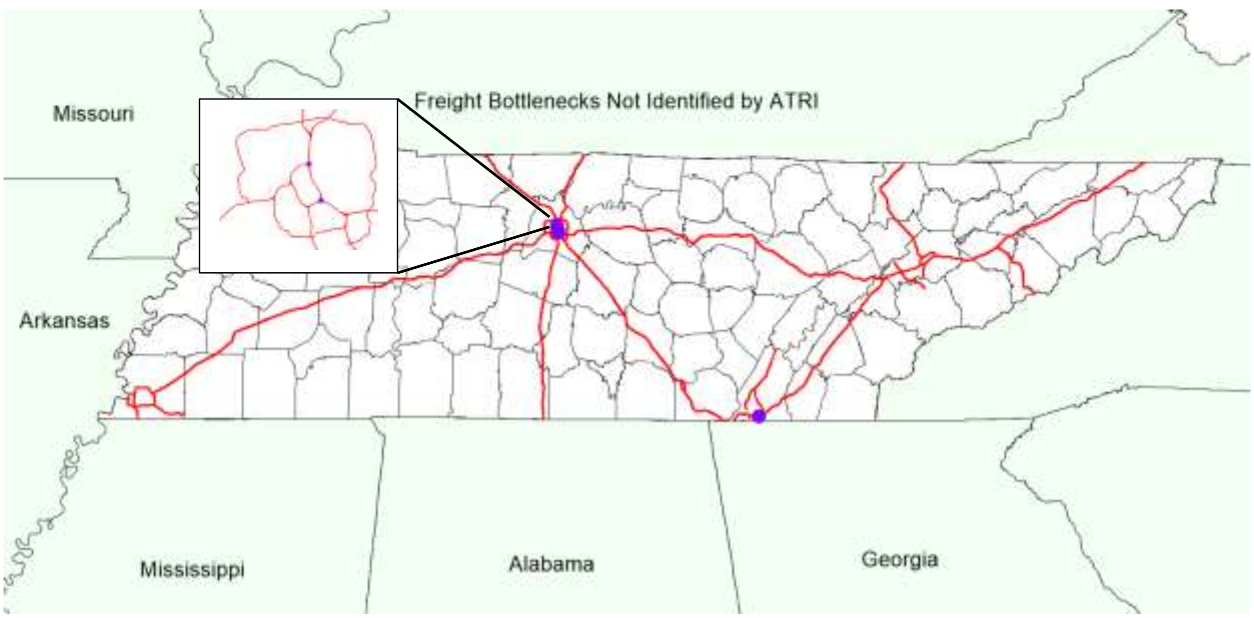


Figure 6.20. Additional Nashville Freight Bottleneck Location

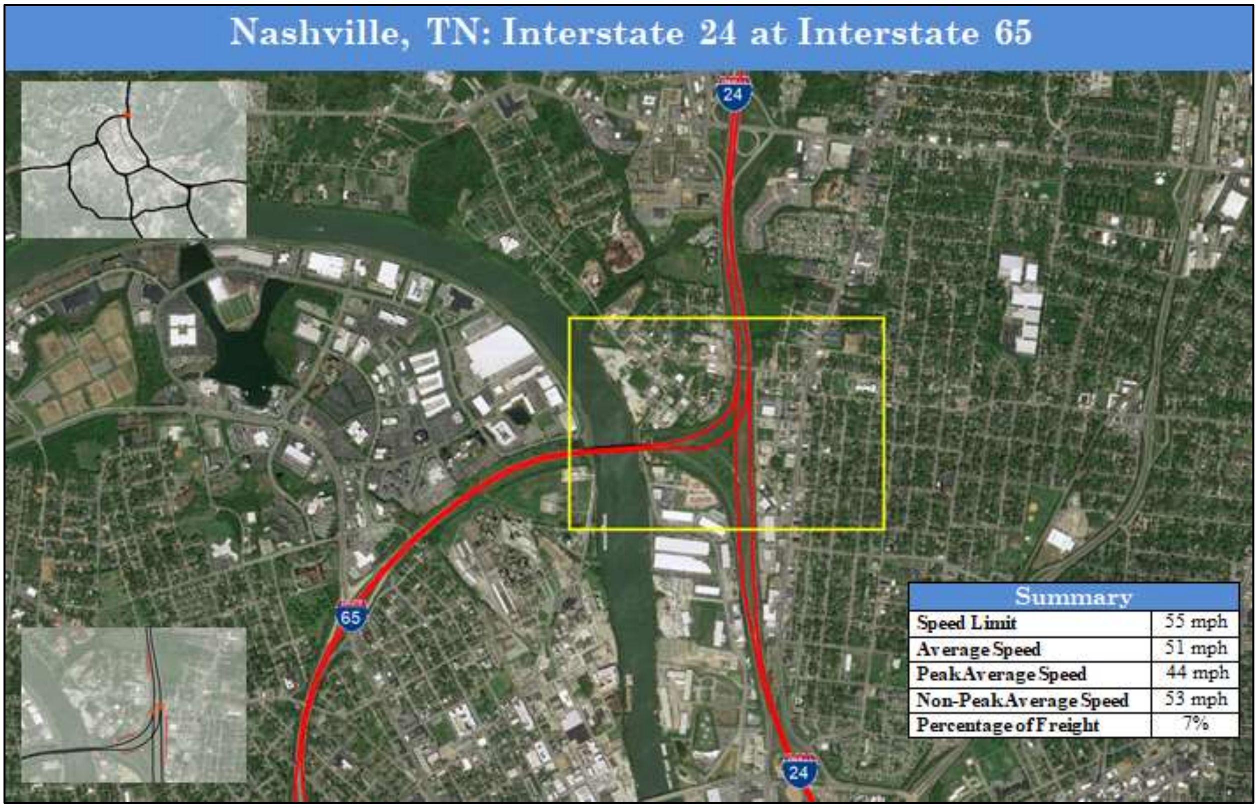


Figure 6.21. Average Speed by Time of Day: I-24 at I-65, Nashville

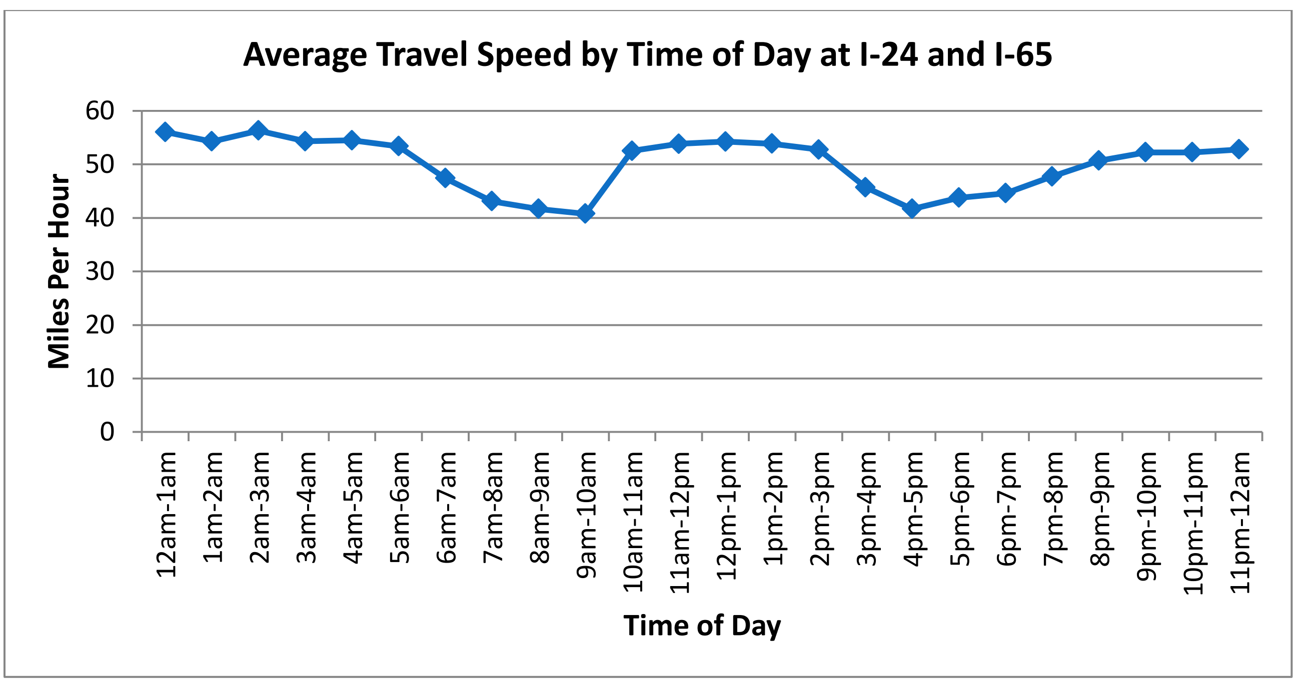


Figure 6.22. Additional Nashville Freight Bottleneck Location

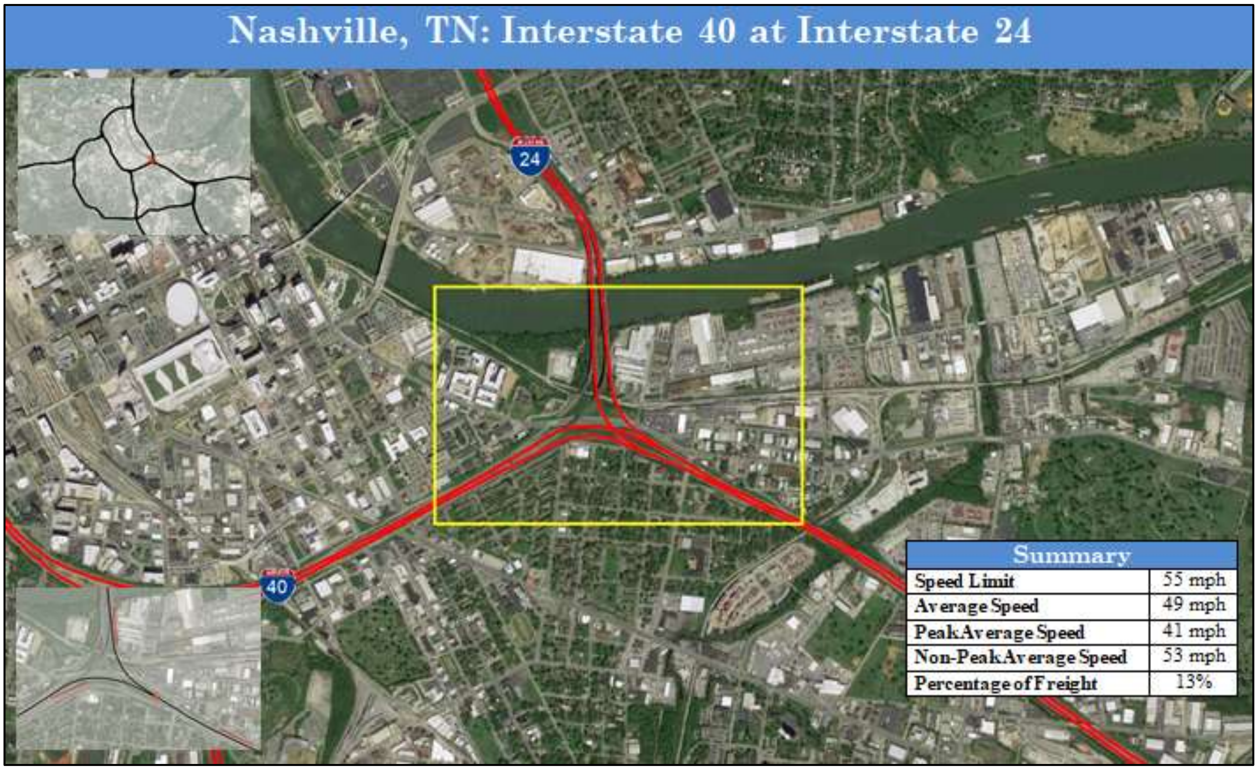


Figure 6.23. Average Speed by Time of Day: I-40 at I-24, Nashville

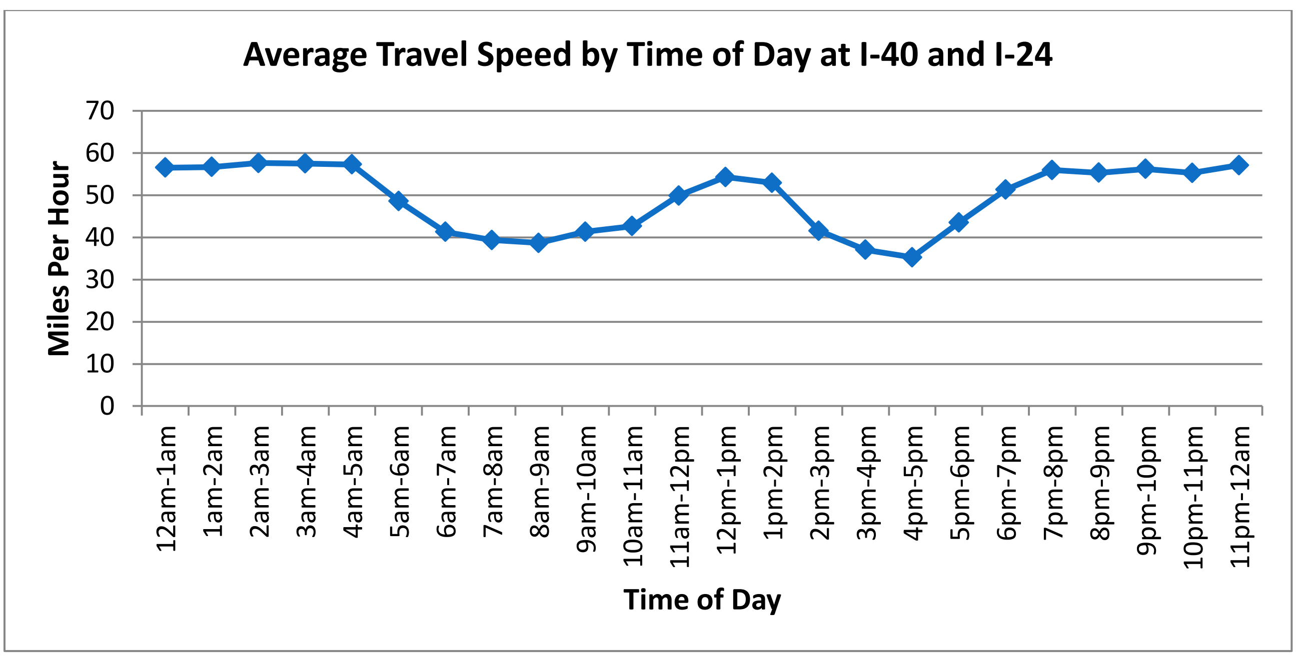


Figure 6.24. Additional Chattanooga Freight Bottleneck Location

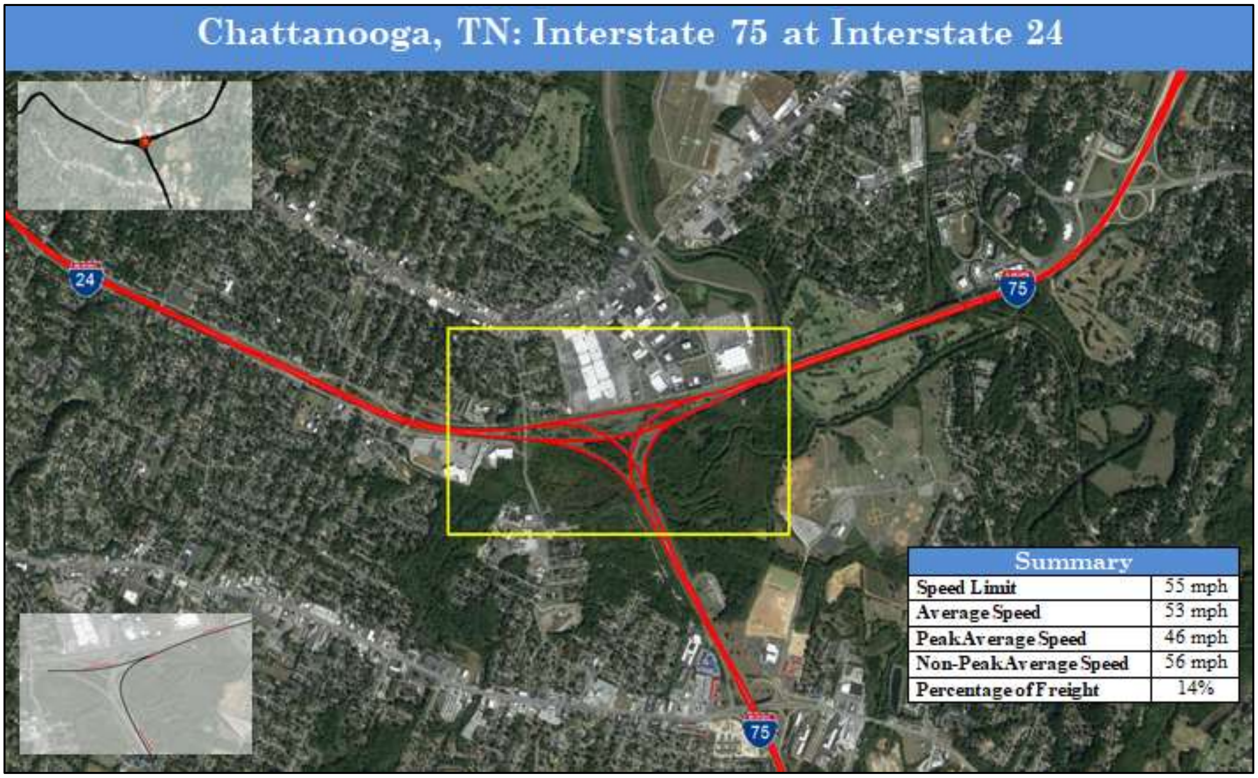


Figure 6.25. Average Speed by Time of Day: I-75 at I-24, Chattanooga

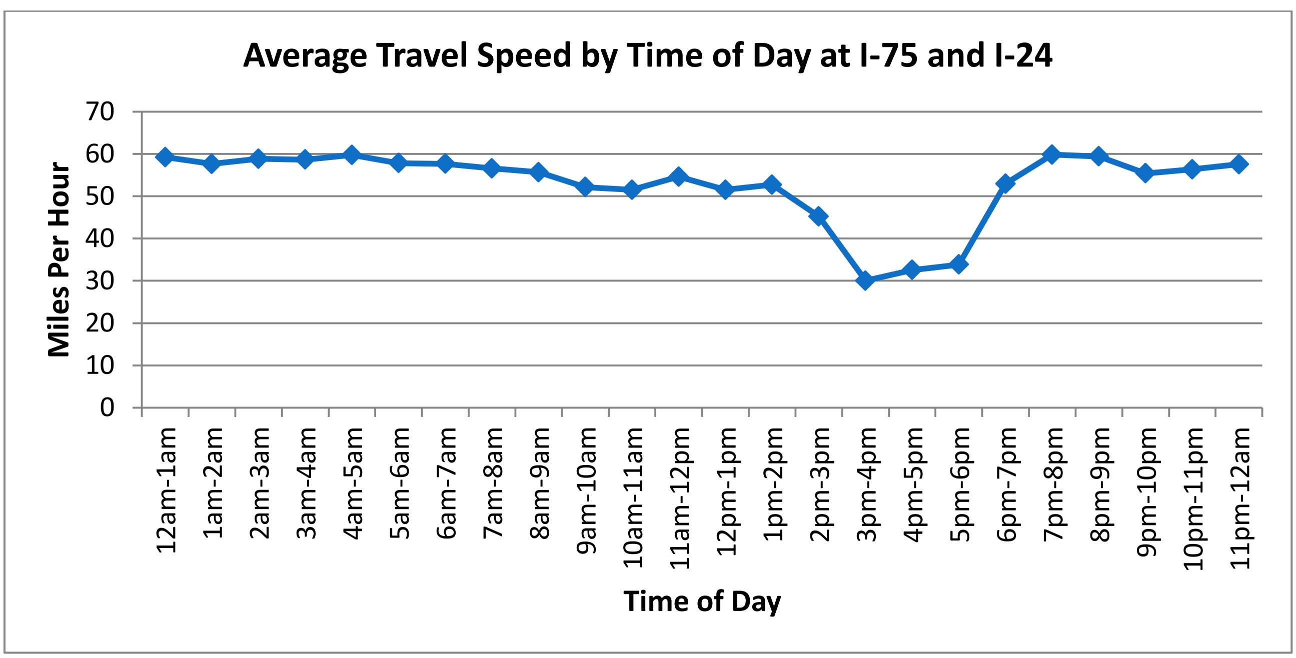


Table 6.1. Freight Bottleneck Travel Speed Statistics

	Location	State	Average Speed	Peak Average Speed	Non-Peak Average Speed
1	Chattanooga: I-24 at Hwy 27	TN	49.4	42.2	52.8
2	Nashville: I-24 at I-440 (north)	TN	43.1	31.8	49.2
3	Memphis: I-40 at I-240 (east)	TN	37.7	30.8	40.7
4	Nashville: I-65 at I-440	TN	49.4	39.8	53.9
5	Nashville: I-40 at I-65 (east)	TN	43.5	33.3	48.3
6	Nashville: I-65 at RT 386	TN	52.7	47.2	55
7	Nashville: I-65 at I-24	TN	49.2	41	52.7
8	Knoxville: I-40/I-75 at I-140	TN	53.4	49.5	55
9	Knoxville: I-40 at I-640 (west)	TN	53.5	50.2	54.9
10	Nashville: I-24 at I-65	TN	51.1	44.2	53.6
11	Nashville: I-40 at I-24	TN	49.3	41.2	53
12	Chattanooga: I-75 at I-24	TN	53.7	46	56.4

The number of freight bottlenecks in Tennessee is increasing each year; For example, in 2017 the ATRI identified 4 Tennessee bottleneck locations within their Top 100 List. However, in 2018, which number jumped to 9; this does not include the additional 3 bottlenecks identified in this Freight Bottleneck Analysis. **Figure 6.26** shows the location of the 12 freight bottlenecks that have been identified and the remaining potential locations.

Figure 6.26. Freight Bottleneck Location and Potential Locations

Figure 6.27. Freight Bottleneck Location and Potential Locations near Memphis

Figure 6.28. Freight Bottleneck Location and Potential Locations near Nashville

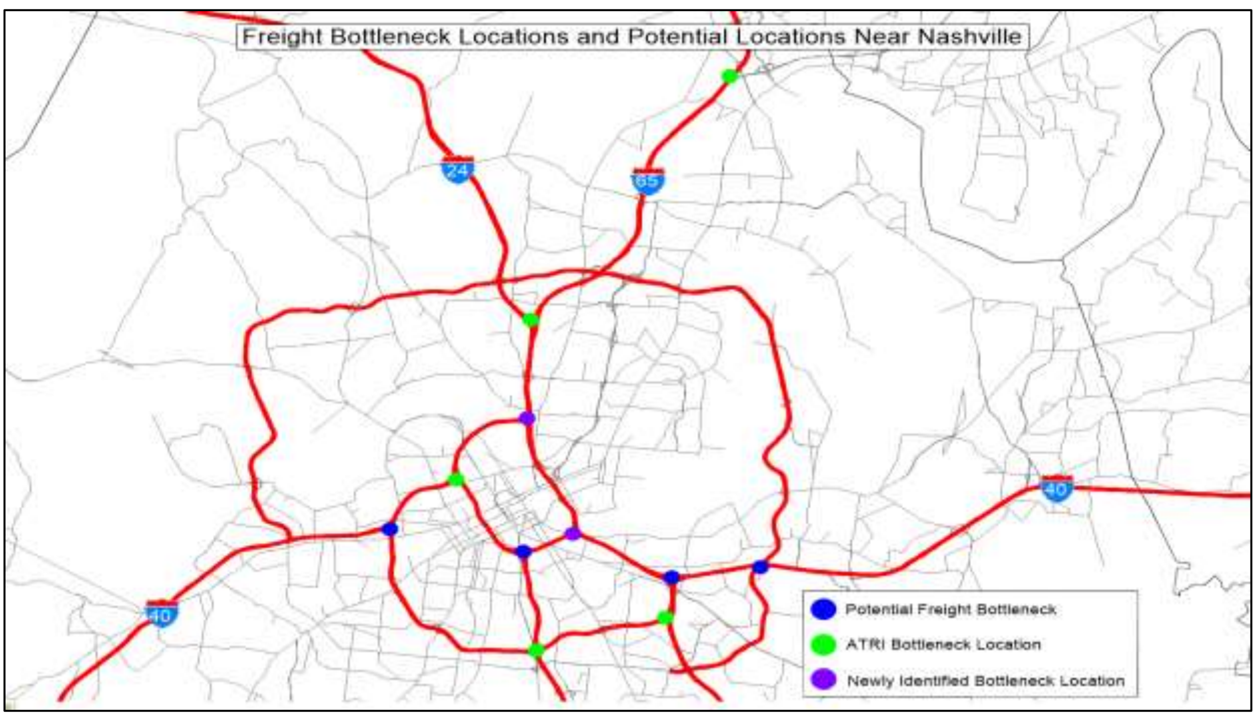


Figure 6.29. Freight Bottleneck Location and Potential Locations near Chattanooga

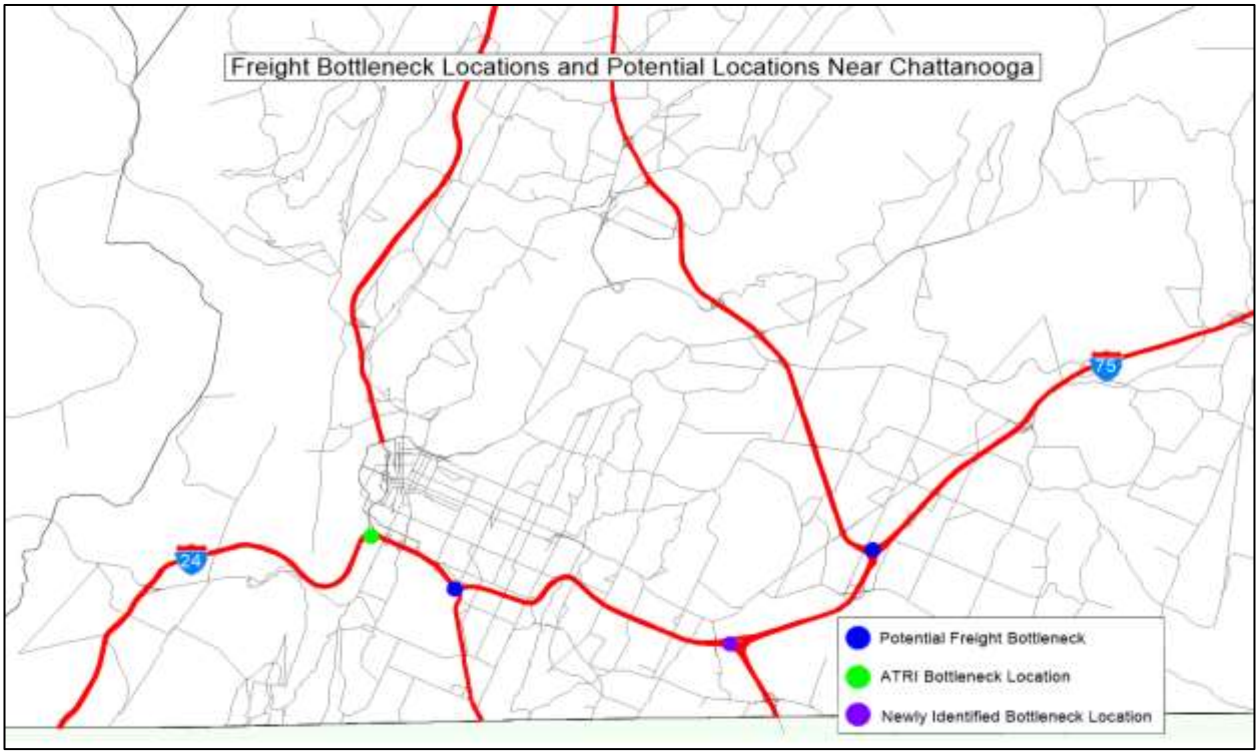
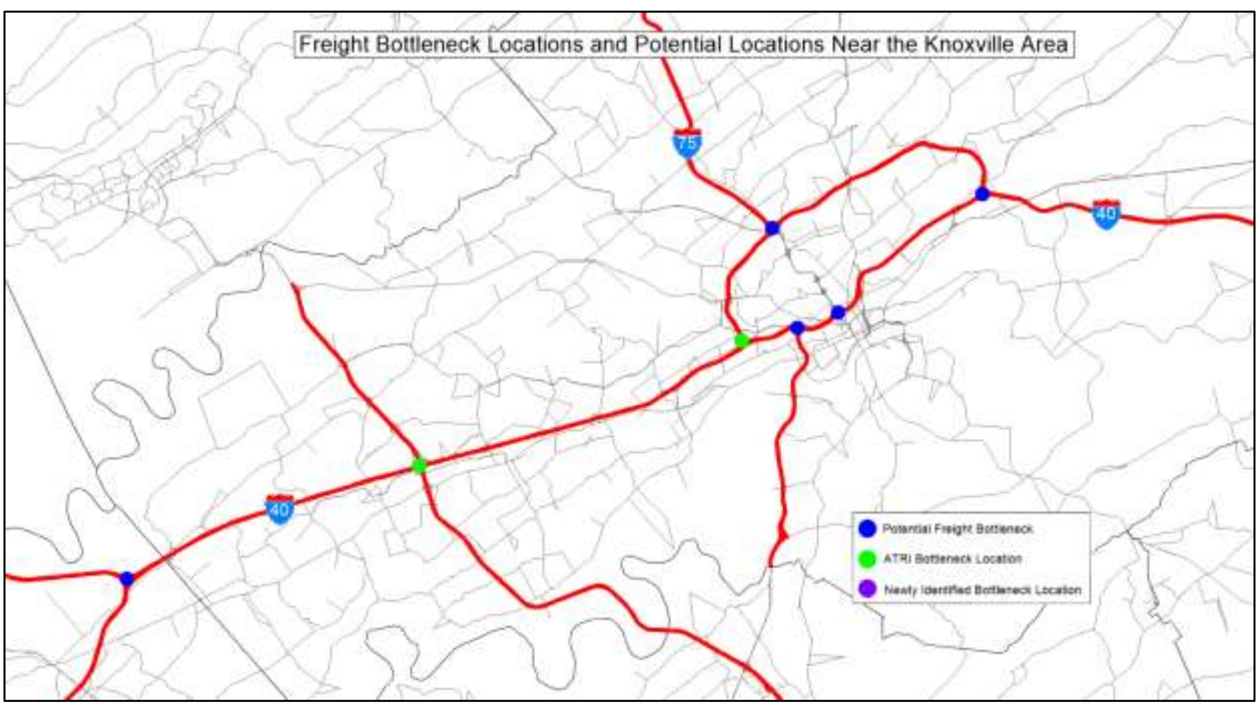


Figure 6.30. Freight Bottleneck Location and Potential Locations near Knoxville



Chapter 7. Strategies for Defusing Bottlenecks

The purpose of this section is to look at the different indicators of a freight bottleneck and come up with innovative solutions which can be implemented in order to help reduce the risk of a bottleneck thus easing congestion and potential delays. Some of the bottlenecks are going to be more complex to solve because they are difficult to predict and control, such as accidents which can occur at any given time, date and location.

Number of Freight on the Road

The first indicator to influence a freight bottleneck is the volume of freight vehicles that are on the road. Future projections of freight growth are going to increase in Tennessee, especially as the population continues to increase.

Recommendation #1

- One recommendation to help with the movement of freight on the highway system is to look for opportunities for modal shifts from the highways to pipelines, water, rail or even air opportunities. As the demand for goods and services increases, modal shift could reduce the congestion and also be a cheaper alternative for freight movement within Tennessee.

Freeway Ramps Entering and Exiting

Recommendation #1

- One recommendation to improve the situations with the ramps is to look into extending both the entrance and exit ramp lanes from and to the interstate. Currently entrance ramps are not sufficient enough to provide enough space for a vehicle to achieve a high enough speed to be integrated with traffic. When a freight vehicle enters the interstate from the ramp, they come in at a slower speed which will cause the vehicles on the road to either slow down or move into other lanes to le the vehicle enter on the highway. There are a few reasons why this could be an issue:
    1. When a vehicle currently on the interstate switches lanes to pass the entering freight vehicle, they take the chance of cutting another vehicle off, which could result in an accident if not done carefully.
    2. Freight vehicles are typically ‘governed’ with speed restrictors and it takes a longer time to build up to the merging speed of the traffic flow on the interstate.

3. When a slower moving vehicle merges into traffic, the faster moving vehicles are forced to slow down which if not careful, could result in a vehicle rear-ending another or a quick reduction of speed and braking .
4. With a short ramp to gain speed before entering the interstate, vehicles are forced to enter the ramp at an unsafe speed compared to the rest of traffic. With the extended lane, vehicles will be able to increase speeds before they merge onto the interstate. This will also allow for vehicles to have more time on the ramp to look for a wider gap to merge into, so they are not forcing vehicles over or slowing down speed.

Recommendation #2

- Another recommendation for reducing the bottleneck near a ramp is is to control the number of vehicles from the ramp on to the interstate one at a time. A ramp meter, ramp signal, or metering light is a device, usually a basic traffic light or a two-section signal (red and green only, no yellow) light together with a signal controller that regulates the flow of traffic entering freeways according to current traffic conditions. It is the use of traffic signals at freeway on-ramps to manage the rate of automobiles entering the freeway. Ramp metering systems have proved to be successful in decreasing traffic congestion and improving driver safety. When ramp metering efforts are applied they could be extremely beneficial at or near downtown areas where there is a heavy volumes of mixed traffic. These can be extremely beneficial to the freight industry as they can accelerate safely to the proper merging speed when there is less congestions on the entrance ramp.

Width of Road Lanes

- Lane width is not an issue in Tennessee on the interstate system as all highways are set at a minimum of 11 feet wide. This standard width is critical for the safe and efficient movement of freight and vehicles in the state so they can safely navigate traffic conditions.

Change in the Speed Limit

- The change in speed limit is a very important factor in helping to reduce the number of accidents since not every location is built or designed to travel at high speeds. However, managing the speed limit zones (specifically when the speeds limit decreases) can be a major influence in helping freight move through the state. This is not an issue for every location in Tennessee, but when getting closer to the downtown metropolitan areas. There are some locations in which the speed limit decreases from 70 miles per hour to 55 mph within one mile. This could be an issue when the sudden change is not observed by every driver on the interstate. There could be someone who thinks the speed is s65 mph and traveling at a higher speed than everyone else, which could be a hazard for everyone on the road. This is especially important for freight because of the additional distance required when coming to a complete stop. When there are gradual decrease in speed limits, freight vehicles will have a less chance of 'hard' braking and the potential for rear-end crashes (which are normally more severe than passenger vehicle accidents) The change in speed over a longer mileage span will allow for the drivers to adjust to the decrease in speed and flow of traffic which will result in a smoother and safer flow of traffic for all vehicles to adjust together, improving travel time reliability.

Frequent Crash Locations

The change in decreasing accidents is a difficult concept, but with the safe implementation of the previous recommendations, accidents could be reduced on the roads, which would be a good thing not only for the movement of freight but for the movement of everyone.

Conclusion

Based on the current freight project list and the freight bottleneck locations, there is a clear visual that shows there are actions that are being taken in trying to improve the bottleneck locations so that the movement of freight can be more efficient. Most of these pushes are coming from the widening of interstate lanes to provide more space for the flow of traffic *(the adding of additional lane. Ex. From 6 lanes to 8 lanes),* which as stated before could be a good thing and it could be a bad thing depending on whether or not motorist who currently are not driving decide to make the mode switch or not. These bottleneck locations should be continuously monitored for improvements because eventually the widening of roads is not going to be an option and there will need to be technological advances needed in order to continue to move freight through congested corridors effectively. Moving forward from the freight bottleneck analysis, the next goal will be to use these 12 locations and identify freight projects that need to be addressed first.