

**IMPACT OF FREEWAY-ARTERIAL INTERCHANGE CLOSURES:
AN ALTERNATE ROUTE ASSESSMENT
USING TRAVEL DEMAND MODELING
FOR THE STATE OF DELAWARE**

by

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A thesis submitted to the Faculty of the University of Delaware in partial
fulfillment of the requirements for the degree of Master of Civil Engineering

Spring 2013

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ACKNOWLEDGMENTS

To the department faculty and staff,

Who have helped me succeed over the past six years of my education at this distinguished institution. Exceptional gratitude towards my advisor, Dr. Rusty Lee, for his support, much appreciation to Dzung Ngo for his patience and continual assistance, and lastly, extremely grateful for the direction provide by Mike DuRoss.

To my weekly coffee date,

Graduate school would have been impossible without you.

To my family, especially my mother and father,

I would not have succeeded in this achievement, and all leading up to it, without you as my guide in life and my foundation for love and support.

To my love,

Words cannot express how blessed I feel having your love and support during the up's and down's of this great accomplishment.

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ABSTRACT

Although the National Highway System provides an efficient network to move people and goods across the country, disruptions in the system can quickly bring the flow to a halt. The freeway-arterial corridors of the highway system are crucial nodes allowing users to enter and exit yet are vulnerable to considerable disruptions in the flow of traffic due to the frequency of closely spaced grade separated roadways and high traffic volumes surrounding interchanges. By analyzing the closure of the interchanges and assessing the subsequent traffic conditions throughout the network using travel demand modeling software, it is possible to determine the effects, adverse or not, of major closures. Such an assessment is purposeful, ensuring the resiliency of the freeway by understanding the resulting congestion to relieving or preventing its occurrence. Through a detailed understanding of the effects, transportation authorizes may be better able to maintain an efficient flow of people and goods. This research analyzes the prevailing traffic conditions along the I-95 corridor in New Castle County, DE due to the closure of three separately analyzed freeway-arterial interchanges along I-95: SR 896, SR 1, and US 202. It examines the change in volume, change in speed, and change in volume to capacity ratio on the network from before to after conditions. Each interchange closure produced distinctive network traffic conditions. While SR 896 primarily induces local effects SR 1 and US 202 results in a wider expanse of effects along the I-95 corridor. Significant disruptions in the flow of the network were contained to a few major arterials particularly during morning and afternoon peak periods.

Chapter 1

INTRODUCTION

The major eastern seaboard north-south interstate of I-95 traverses Delaware for a total length of twenty-four miles. The interstate system in Delaware also consists of two by-pass interstate roadways; I-495 serves as a by-pass around the City of Wilmington re-joining I-95 south of the city and also I-295 which connects northern Delaware to the state of New Jersey via The Delaware Memorial Bridge. There are twelve interchanges along I-95's path through Delaware. The roadway highlighted in green in Fig. 1 represents I-95 and the red circles highlight each interchange. There are four interchanges located in the City of Wilmington represented by the larger red circle.

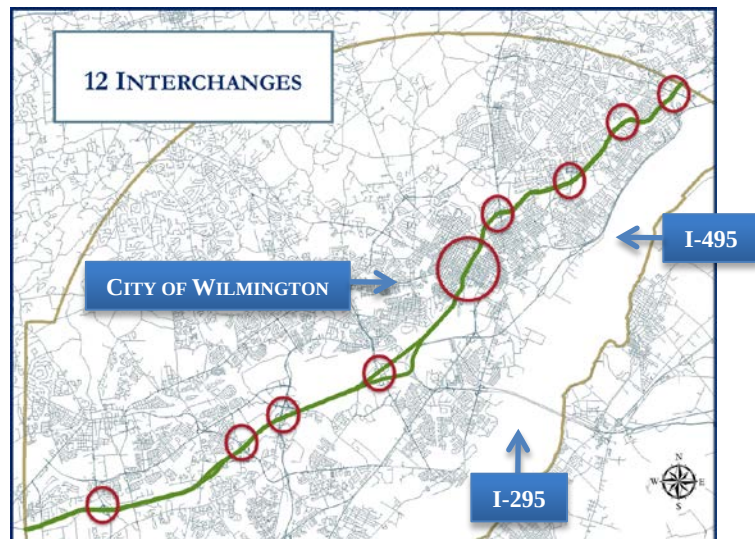


Figure 1 Map of Interstate Interchanges in New Castle County, DE

The interchanges serve as entry and exit points for the limited access highway. What if one of these interchanges was closed to traffic including the major and minor routes involved in the interchange? How would it affect the local versus through traffic? How would it affect the surrounding networking in comparison to the interstate? While most incidents only result in the closure of all travel lanes in one direction, an incident affecting two separate roadways is neither unprecedented nor out of the question. Closures like this can be caused by construction, accidents, and the possibility of sinks holes or bridge collapses or other failures. The following are two examples of major interstate closures, one due to an incident and the other needed for construction purposes.

In January of 2004, not too long before the start of the afternoon rush hour, a severe accident on located on the interstate just south of Baltimore, MD resulted in the shutdown of I-95 in both directions as well as the southbound overpass ramp of I-895 and all lanes did not completely re-open until a little over twelve hours later. This was the result of a fuel tanker traveling on the I-895 southbound overpass falling over the Jersey barrier landing on the northbound lanes of I-95 directly below and burst into flames upon impact. While catastrophic incidents such as this one rarely occur, then are possible.

In additions to incidents, construction, whether it is new construction or rehabilitation of existing structures, can cause significant impacts on interchange closures. While these closures are normally planned well in advanced and occur during off peak-times, a major closure could still affect the network in unknown ways. Emergency repairs may also be necessary limiting the amount of time for advanced planning and warning. In the fall of 2002, the Delaware Department of Transportation

(DelDOT) closed the majority of links supporting the I-95 and US 202 interchange for the construction of new over passes. Four ramps as well as I-95 in both north and southbound directions were scheduled for closure beginning at 8:00 PM on Friday and reopening at 5:00 AM the following Monday. All non-local traffic was advised to utilize I-495 in lieu of I-95 during this closure essentially inferring the diversion of a significant volume of traffic. Closures for construction such as this one are common but it is usually unknown the impact on the network wide traffic conditions it will have.

This research addresses these issues by analyzing and assessing the closure of three interchanges along I-95 in Delaware, SR 896, SR 1, and US 202 (Fig. 2), to better inform local and state decision makers. Each interchange is analyzed for changes in volume, speed, and volume to capacity ratio during four peak periods of AM, PM, MID-DAY, and OFF peak. A map highlighting the distribution of the change of each performance measure for each interchange's peak period is shown in Chapter 5, Results & Analysis. Enlarged maps can be found in the appendices.

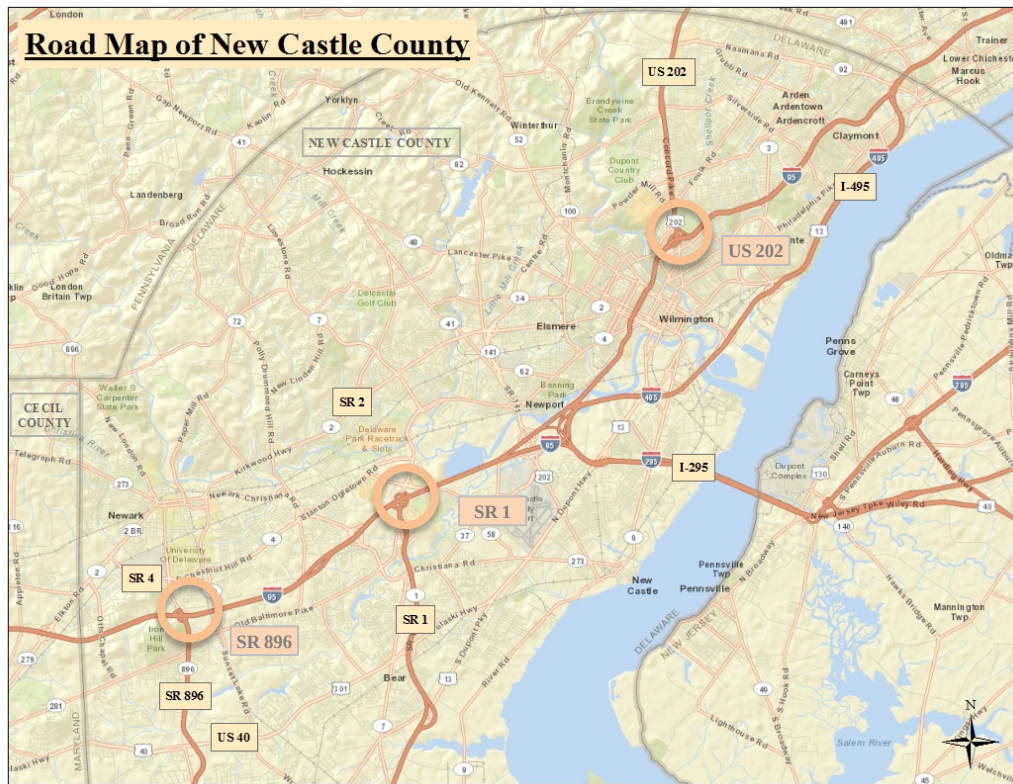


Figure 2 Road Map of New Castle County

Chapter 2

LITERATURE REVIEW

2.1 What is Alternate Route Planning?

Alternate route planning uses a variety of terms referring to the same general concept but each with a unique connotation. These include: (1) detour route, (2) freeway diversion (3) route diversion, and (4) alternate route. Of these terms, detour route is the most commonly used term as it is used to describe the action of guiding traffic around a construction area. However, the other three terms imply a more defined process of establishing a diversion route that was been proven to effectively handle a set amount of traffic while maintaining a reasonable level of congestion and delay. Freeway diversion refers solely to diverting traffic off of a freeway, not other road classification such as arterials where the term route diversion is more generic. The *Alternate Route Handbook* defines an alternate route as a devised route that “provides additional capacity to service primary route traffic” (Dunn 2006). Under alternate route and freeway diversion definitions, the alternate route begins at one point on the primary route, in this case on a freeway, and terminates at another point on the primary route. This implies that the diverted traffic returns to the primary route and that the terminal point must be downstream of the incident (Dunn 2006; Son et al. 2004).

Alternate routes also encompass an established methodology with specific goals in determining the diversion route. The first of which is choosing an alternate route that can handle the additional demand without causing the alternate route to fail.

Secondly, the alternate route should minimize the potential increase in congestion and travel time that results from incident as compared to not implementing an alternate route at all. Lastly, the alternate route should be established from an optimization analysis of roadway conditions (Dunn 2006; Huaguo 2008; Birst and Ayman 2000).

Route diversion, freeway diversion, and alternate route planning all share a common thread of referring to traffic diverted around an incident in an attempt to relieve roadway congestion. Alternate routes must accommodate daily traffic in addition to diverted traffic from another facility (Dunn 2006). This definition is in contrast to other types of re-directing large amounts of traffic such as evacuation routes. Alternate routes differ from evacuation routes in a variety of ways. Evacuation routes typically move a larger number of vehicles, specifically vehicles of a higher than normal occupancy levels, from a particular geographical region. The re-routed vehicles are not returned to a point downstream on the facility from which they were diverted (Dunn 2006). The analysis conducted for this paper accounts exclusively for alternate routes and not evacuation routes.

Alternate routes are a key component of incident management especially for and isolated incidents. Birst and Smadi defines incident management as a “coordinated and planned program that controls, guides, and warns the motorists of traffic problems in order to optimize the safe and efficient movement of people and goods” (2000). Incident management also involves the coordination of emergency response personnel with highway personnel and includes various warning devices such as variable message signs (Huaguo 2008). Incidents by nature are unpredictable, unplanned, and occur without warning. Usually evacuation routes are implemented in advance with time to warn motorist and set-up directional signs. Alternate routes are implemented

after an incident occurs and more conclusively, after congestion has built up. Incident management involves more than diverting the traffic off of a freeway to the surface streets transferring the congestion from one roadway to another but should instead direct traffic in an orderly fashion to facilities that are able to handle the additional capacity (Sawaya et al. 2005).

2.2 Congestion: What Alternate Routes Attempt to Alleviate

There are two established types of congestion: *recurrent* and *non-recurrent* congestion. Congestion is defined by an increase of travel time from normal operating conditions usually due to a volume on a roadway that is greater than its design capacity. This is normally evident by a reduction of free flow speeds. Recurrent congestion refers to congestion that occurs regularly, such as on daily basis or at a specific time periods. Bottlenecks are an example of this type of congestion. Recurrent congestion is usually caused by a demand volume greater than what the facility was designed to accommodate at a given speed. Non-recurrent congestion does not occur on a regular basis and is not due to the physical aspects of a roadway but rather due to the occurrence of external events such as incidents (Camsys 2004).

2.2.1 How Congestion is Measured

Accurately measuring congestion has been debated as well as how to present it to a technical and non-technical audience. Level of service (LOS) is a method to translate model and mathematical outputs into a uniform, easily comprehensible system. Under this system roadways can be classified as A, B, C, D, E, or F based on a calculated volume to capacity ratio or a density measured in passenger cars per mile per lane. While the ease of the LOS system is beneficial, there is much criticism of its

subjectivity and it does not take into account the unique differences in roadways that lead to congestion.

The FHWA report on *Traffic Congestion and Reliability* states that travel time is a direct measure of how congestion affects users. It has become a key principal of FHWA practices as users can immediately understand and relate to the level of congestion and how it affects their daily driving habits (Camsys 2004). On the other hand, the *Urban Mobility Report* measures congestion primarily on speed data collected by INRIX and compiled in their National Average Speed database (Schrank et al. 2011). Measuring the change in travel time as well as the change in speed are two of the performance measures used in this paper.

2.2.2 Commons Causes of Congestion

The chart (Fig. 3) shows major sources of congestion. The percentages will vary from urban to suburban to rural areas as urban areas are more prone to congestion than rural area. Four of the six categories listed, inclement weather, traffic incidents, bottle necks, and work zones, are classified as non-current congestion showing that non-recurrent congestion causes a significant portion of the congestion in the US. (Camsys 2004).

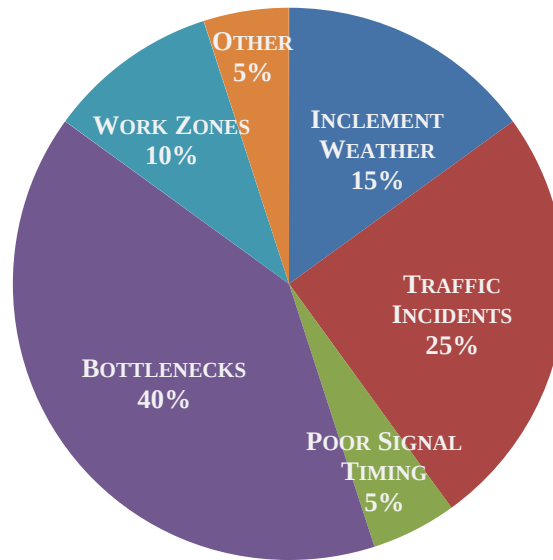


Figure 3 Sources of Congestion^a

As discussed previously in this section, the physical design of a roadway can lead to congestion. For freeways and highways, the following are primary causes of recurrent congestion especially on highways in or around urban area: (i) interchanges, usually freeway to freeway, or (ii) a series of closely spaced interchanges. When calculating free flow speed, total ramp density of a segment of a freeway is a factor defined by the number of ramps located between three miles upstream and three miles downstream of the midpoint of the freeway segment (TRB 2010). (iii) Lastly, the reduction in the number of lanes such as the merging of lanes (Camsys 2004).

^a Adapted from Fig. 2.1 (Camsys 2004)

2.2.3 Relieving Congestion: The Daily Double

As congestion levels rise, it becomes more important to develop solutions that relieve or prevent congestion. The traditional method to relieve congestion is to add capacity to roadways by adding more lanes and new highways. However, there is only a finite amount of land available to add lanes and roads. Recently, other methods have been developed to more efficiently use the roads already constructed.

The advancement of technology has spurred these methods. Son proposes various methods that involve late 20th century technology to guide users off of roadways due to non-recurrent congestion. This included various Intelligent Transportation Systems (ITS) and Advanced Traveler Information Systems (ATIS) to communicate with the drivers to divert traffic to arterials before they reach the incident. Son's research incorporates various ITS and ATIS systems such as variable message signs, highway advisory radio, and ramp metering for sharing information and managing an integrated arterial and freeway corridor (2004).

Computer modeling is another piece technology that has opened the door to developing congestion relieving solutions. Sawaya introduces an approach to compute time-dependent alternate routes around incidents that is based on inputs of prevailing traffic conditions. Reducing demand upstream of an incident is a key component to relieving congestion caused by incidents. Sawaya believes this is possible with its methodology that computes "alternate routes by interpreting the optimal flow patterns produced by the System Optimum Dynamic Traffic Assignment (SO-DTA) model". The authors intent for this methodology is to relieve congestion in real-time by serving as a decision-aid tool for traffic managers and also in planning process by evaluating the effectiveness of ATIS such as variable message signs (Sawaya et al. 2005).

In regards to relieving non-recurrent congestion, technology has proved to be a solution. Computer modeling in conjunction with real-time intelligent transportation systems installed on roadways work together to assess the congested traffic conditions to determine and communicate the diversion of traffic to an establish, more optimized, and less congested roadway system.

2.3 Established Theories

Much of the current state of practice of alternate route analysis is based on a concept developed in the 1970's which states that relieving non-recurrent congestion on freeways should involve an integrated approach between the freeway and adjacent arterials (Son et al. 2004). An integrated approach involves managing traffic on freeways and adjacent arterials jointly as a single corridor and not as individual facilities. This is accomplished through the implementation of policies and strategies that promote improving the mobility, safety, and environment of the entire freeway-arterial corridor (Urbanik et al. 2006). Every source for this research follows this concept and many of the sources take that theory a step further showing that the ability to divert more volume from a freeway to an arterial is significantly dependent upon the capacity of the intersections along the arterial. Much like how the spacing of interchanges and lane drops affect the operations of a freeway, how effectively and efficiently an intersection moves traffic through is directly related to congestion on arterials. A few papers base their analysis of alternate routes on various intersections modeling software to determine a more effective signal timing plan and coordination of signals as solution to relieving congestion caused by freeway incidents (Son et al. 2004, Huaguo 2008).

It is a basic and accepted concept that incidents will lead to queuing which in turn causes delay and increases motorists travel time (Son et al. 2004). Therefore, the objective in alternate route planning is to reduce the queue length or prevent it from building altogether. The *Alternate Route Planning* handbook states that “alternate route plans is a key strategy to minimize the effects of non-recurring congestion by reducing the demand upstream of an event” (Dunn 2006). In essence, alternate route planning research works towards re-routing traffic before users reach the location of an incident in order to prevent the buildup of a queue and maintain an acceptable travel time.

Creating alternate routes and using diversion strategies are not the only accepted method of preventing queues. Strategies that physically improve pre-existing bottlenecks will also lessen the impacts of roadway events such as incidents, inclement weather, and work zones. While adding capacity through lane additions has become a best management practice and an effective method for relieving congestion, eliminating congestion on freeways due to the physical constraints outline in section 2.2.2 can still help reduce the build up of queues due to incidents. Preliminary research conducted by sources for this paper first identify pre-existing bottlenecks in order to determine if physical aspects of the roadway will exasperate traffic conditions if additional traffic was diverted to that area (Sispoiku 2007). Although alternate route planning can alleviate congestion, it cannot fix pre-existing capacity issues that should also be considered during the planning process.

2.4 Background on Modeling for Alternate Routes

Three types of modeling were identified as common modeling applications used for alternation route planning. Background on travel demand modeling is discussed in this section.

1. Travel Demand Modeling
2. Signal Optimization
3. Incident Modeling

2.4.1 Travel Demand Modeling

Travel demand modeling is the process by which the modeler makes assumption and uses collected data to describe and/or explain the decisions made by hundreds or thousands of trip makers deciding when, where, and how to make a trip. This method is based on several assumptions. (i) The trips generated by the model are not for the purpose of just traveling (i.e. a Sunday drive) but are made with a destination in mind. Common destination includes work, home, school, shopping, and recreation. (ii) The land use incorporated into the model is very influential to the travel patterns generated. Certain land uses attract more or less users/trips than others. For example, compare the observed number of trips made to a mall to the number of trips made to a school. (iii) Finally, the decision process through which individual users go through in deciding when and where to make trips is not based on a pre-determined set of rules but rather a decision process that can be subconscious, changed at any point during the trip, and maybe quite rational or solely out of habit. The last point can makes travel demand modeling a prediction or estimation, not a true fact (Fricker and Whitford 2004). From these stated assumptions, a four step modeling process was developed and is the most commonly used model for travel demand modeling and

used for the model for this research. Table 1 below outlines for the four steps as well as states the question each step is designed to answer (Fricker and Whitford 2004).

Table 1 Transportation Planning: Four Step Process^b

STEP		QUESTION ANSWERING
1	Trip Generation	<i>Should I make the trip?</i>
2	Trip Distribution	<i>What should be my destination?</i>
3	Mode Choice	<i>What mode of transportation should I use?</i>
4	Trip Assignment	<i>What route or path should I take?</i>

2.5 A Continuation of Previous Work

The research for this paper grew out of the future work of a previous research project also conducted at the University of Delaware. *The Impacts of I-95 Closures on Traffic and Air Quality* evaluated detour route plans established by the Delaware Department of Transportation (DelDOT) for one-directional closures along segments of I-95. In the research, eight scenarios were model using the same model used for this paper. The eight scenarios consist of the northbound and southbound segments between four exits. The detour plans were evaluated and improvements were suggested if necessary. The research primarily assessed where the majority of diverted traffic off of I-95 was assigned by looking at changes in volumes on specific links but also included induced delay (changes in travel time), an increased trip length, and

^b Based on (Fricker and Whitford 2004)

changes in vehicle emissions due to reduced speeds by employing the MOBILE model.

A summary of the paper's conclusions are as follows: (i) Computer models can aid system managers and provide insights. (ii) DelDOT's detour plans were consistent with the model's output. However no more than 45% of the traffic on I-95 diverted. A limitation of the work was that although the outputs agreed with the detour plans, the results did not take into account if all or at least a majority of the traffic on I-95 diverted onto the local arterials (Ngo 2010).

From the conclusion of this research project, it was asked, what if an entire node (interchange) along I-95 became inoperable? This provided the start for the research conducted for this paper.

Chapter 3

PURPOSE & APPLICABILITY

The reliability and resiliency of transportation corridors has become a significant concern not only for the burden it places on users but also for maintaining an efficient movement of goods and its connection to the US economy. As congestion on the roadways increases, their reliability and resiliency becomes increasingly unknown. Interstate 95, the primary highway for the eastern seaboard reaching from Maine to Florida for a total length of 1,917 miles, serves as the backbone of the movement of goods as well as people for one of the Nation's most densely populated areas. The 2011 AADT along the stretch of I-95 in Delaware is 92,200 making it the most traveled road in Delaware and important to a variety of users (DelDOT 2011).

Although only twenty-four miles of I-95 travel through Delaware, it remains an important piece of I-95's resiliency. In the WILMAPCO^c region, 53% of the total truck tonnage in the region is classified as through truck tonnage and is projected to grow to 88% in the near future (Camsys 2007). The region is also declared as "a major thoroughfare for goods moving along the northeast corridor on I-95..." (Camsys 2007). Half of the tonnage traveling in Delaware originates out of the state and is destined for a location out of the state showing that the reliability of I-95 is important to not only users living in the state but those traveling through the state.

^c WILMAPCO stands for the Wilmington Area Planning Council which consists of New Castle County, Delaware and Cecil County, Maryland; see Fig. 4.

Reliability refers to a roadway's level of consistency in transportation service (Camsys 2006). Level of service is linked to the importance to the economy since congestion on US highways has a larger influence on the efficiency of international trade referring to the movement of goods across the US borders. Another benefit of improving reliability is the significant cost savings of time and fuel as well as decreased vehicle emissions (Camsys 2006). Alternate route planning can help a roadway's resiliency and reliability through reducing high levels of congestions making its resiliency and reliability more known. Table 2 shows more specific and direct impacts of alternate route planning. The purpose of this research is to improve the resiliency of I-95 in Delaware due to its status as an important link in the movement of goods and people as well as to reduce congestion.

Table 2 Benefits of Alternate Route Planning^d

Congestion causes <i>Increased Costs</i> of...	Alternate Route Planning causes <i>Reduction</i> of...
Wasted gallons of fuel	Secondary incidents
Wasted hours of productivity	Vehicle fuel consumptions & emissions
Shipping for businesses & trucking companies	Response time to incidents/events
	Motorists stress levels
	Aggressive driving behavior
	Impact on movement of freight regionally

^d Based on (Dunn 2006)

Chapter 4

METHODOLOGY

4.1 Principals of the Methodology

The methodology incorporates the following principals gathered from the literature review:

- Evaluating the freeway and the arterial simultaneously
- Focusing on network wide congestion
- Employing accepted travel demand modeling methods

4.2 The Peninsula Model

The model used for this analysis is called the Peninsula Model, referring to the DelMarVa peninsula it simulates, consisting of Delaware and portions of Maryland and Virginia. It was developed in the Citilabs program, CUBE Voyager, by the consulting firm Whitman, Requardt, and Associates in conjunction with the Delaware Department of Transportation in 2008. The model encompasses the three counties of Delaware and nine counties in Maryland (Fig. 4) summing to an area of 5,000 mi². Over 2,000 TAZ's (traffic analysis zones) are incorporated in the model covering a population greater than 1.2 million.

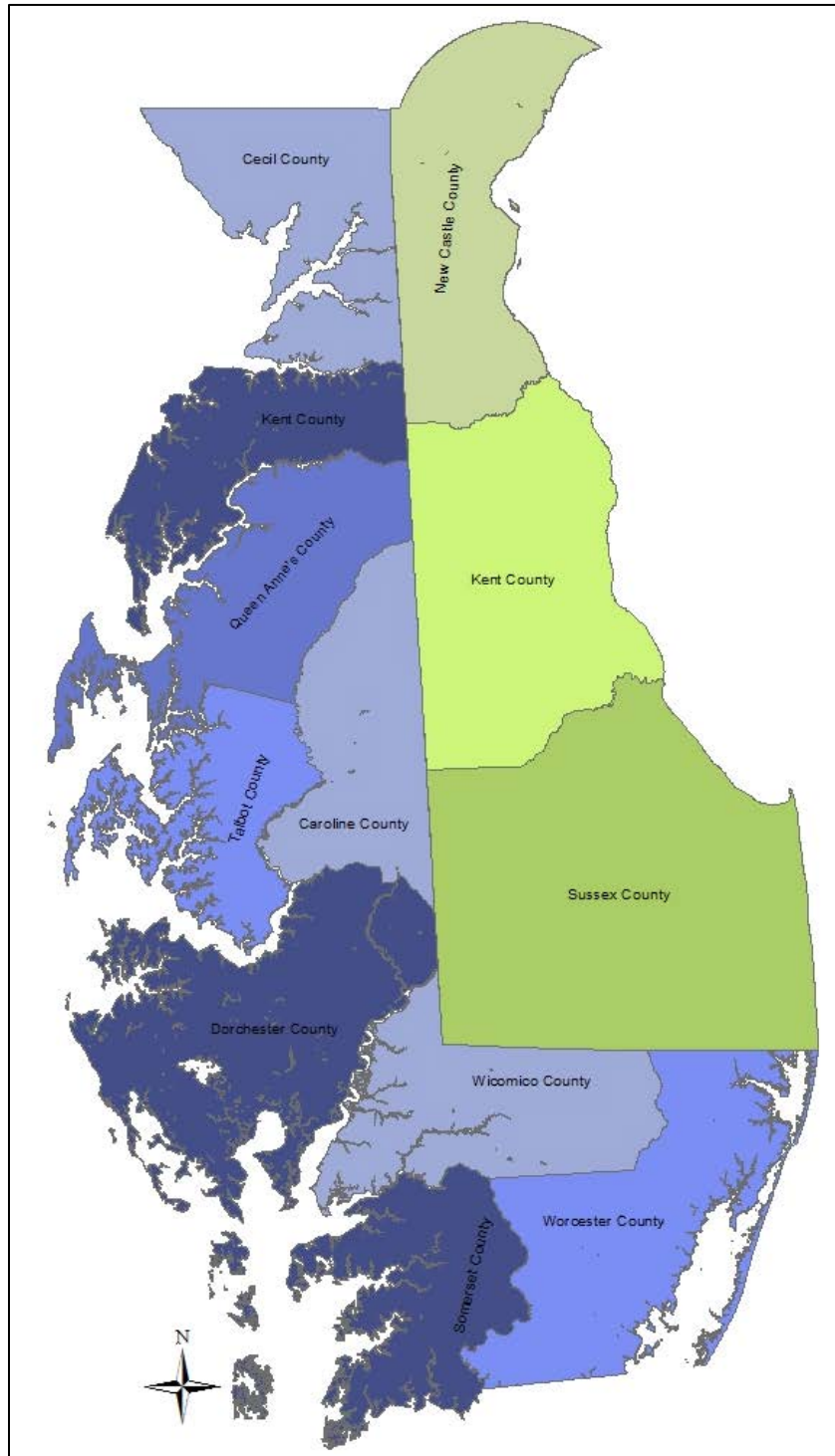


Figure 4 Peninsula Model Map

The model is a travel demand model built with eight fully integrated models and four post processor models (Fig. 5). The fully integrated models run with a base model run while the post processor models are intended for after a base model run and are utilized as needed. This research primary employed the build/no-build post processor for the analysis.

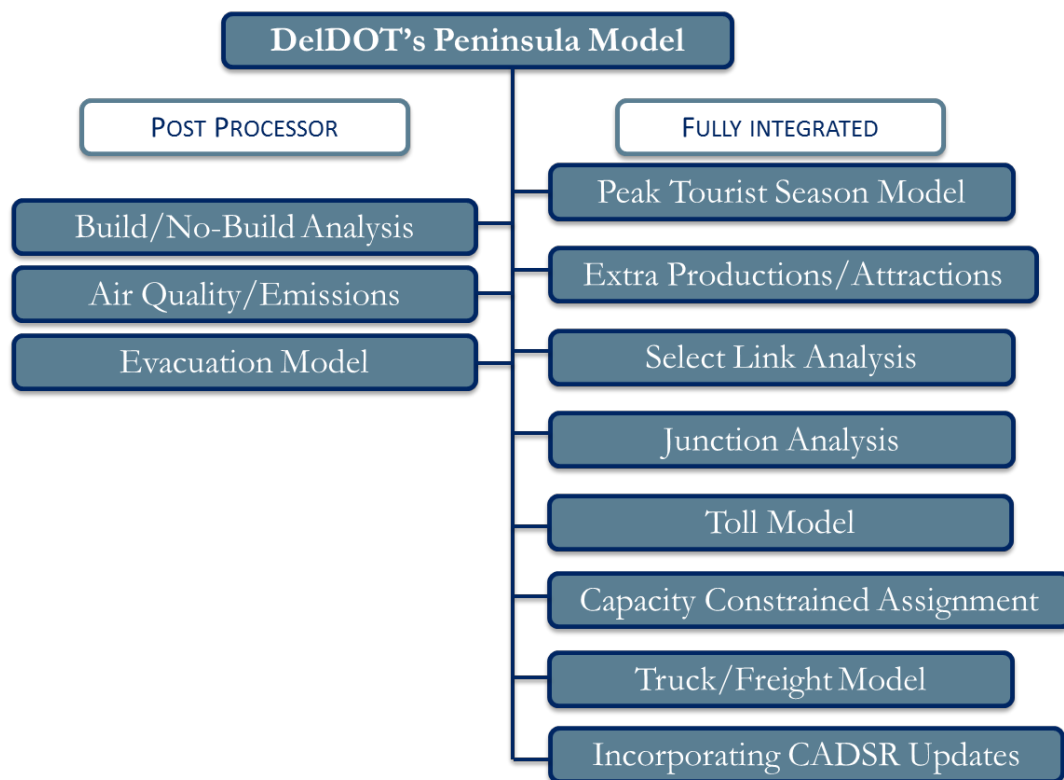


Figure 5 Peninsula Model Chart

The model is based on the four-step planning model discussed in section 2.4.1. It conducts analysis for four peak periods (AM, PM, MIDDAY, and OFF PEAK), includes twenty volume delay curves, uses a nested logit mode choice model, and a

feedback loop between the traffic assignment and trip distribution step to create an optimized distribution of the vehicles across the network.

Two primary analysis years, 2005 and 2030, are incorporated into the model each of which can be run using the AADT or the SADT input tables. The SADT (Seasonal Average Daily Traffic) is used to analyze traffic conditions in Delaware specifically during the summer months when the roadways experience an increase in traffic by users traveling to and from the Delaware beaches.

4.2.1 Model Use in this Research

The AADT 2005 model was used for this research. A more current analysis year is superfluous due to the empirical nature of the analysis comparing the change before and after scenarios. True numbers are not as important as the magnitude of the change. Below is an outline of the basic procedure employed.

- 1) Desired links to be closed were determined and the base road network was modify by coding the links to be closed with a unique scenario name. For example, a link that would be closed for modeling the interchange at SR 896 would be coded with 'I_A_896' under a catalog key (i.e. an attribute of the link). All closed links under this scenario were given this name. A different scenario would use a different coded name.
- 2) A base model was run in order to generate the trip tables and load the network with trips.
- 3) After the base model was run, each scenario outlined in section 4.3 was run separately using the build/no-build post processor.

- 4) The resulting loaded roadway networks were exported as shapes files and the results were analyzed in ESRI's ArcGIS software in conjunction with Microsoft Excel.

4.2.2 Build/No Build Model

When analyzing the results of this model, it is necessary to understand that this model is an optimization of the travel patterns. An equal number of trips were generated by the model for the build (before/open) and no build (after/closed) scenarios and trips were assigned to the network to achieve an equilibrium based on the coded capacity of each link. It is expected that the results of this model run represent a snap shot of the traffic conditions not immediately following an incident that would cause a closure of an entire interchange but more likely an interval of time after a closure. The results depict a network where knowledge of the closure is known to a majority of the users and a when a certain level of balance has been achieved over time. It is reasonable to assume that some trips made under normal conditions may not be made at all if a an interchange closure occurs. Section 5.5 discusses the a brief analysis on assessing if the number of trips would change due to a closure.

It is also important to explain why the OFF peak period resulted in the greatest magnitude of change over other peak periods even though it is the period that generates the least number of trips. Due to the nature of optimization, the model loads links with 'more space' before links with 'less available space'. Since less trips are generated, links are not as filled to capacity as during other peak periods leaving links with more empty spaced to be filled. This results in a greater change between the before and after scenarios. Impacts of using the build/no build analysis are further discussed in Chapter 6, Limitations & Future Work.

4.3 Existing Conditions of the Interchanges

While eight interchange were modeled, three interchanges were chosen (Table 3) for an in depth analysis due to their significance in the travel patterns of New Castle County and the characteristics of each interchange are discussed the following sub-sections.

Table 3 Scenarios & Interchanges Modeled

Scenario 1	<i>Interhcnage A</i>	SR 896
Scenario 2	<i>Interhchange C</i>	SR 1
Scenario 3	<i>Interchange E</i>	US 202

4.3.1 Scenario 1 - Interchange A - SR 896

Interchange A, SR 896, is the first I-95 interchange northbound traffic reaches as they travel from Maryland to Delaware, and the last interchange the southbound traffic reaches before exiting Delaware. SR 896 is major north-south arterial in the western part of Delaware connecting northern New Castle County to larger towns in southern Delaware. The interchange is located immediately south of the City of Newark, the second largest city in New Castle County and a densely residential area of the county (Fig. 6). The 21 mile long roadway has an AADT of 42,000 in proximity to the interchange (DelDOT 2011).



Figure 6 Aerial Photograph SR 896

4.3.2 Scenario 2 - Interchange C - SR 1

Interchange C, SR 1, located centrally along I-95 in reference to the county, is the major north-south arterial for the eastern part of the state that becomes a toll road south of its crossing with I-95 interchange. A major function of SR 1 is to provide an efficient and direct connection to the Delaware Beaches, a major tourism attraction for in state and out of state travelers. The interchange, however, is not only significant for its connection to the beaches but also for trips attracted to Christiana Mall located adjacent to the interchange which is a premier shopping mall for the region. Many office parks, sit-down restaurant pads, and stand-alone retail establishments are located in the vicinity of the interchange (Fig. 7). The 100 mile long roadway has an AADT of 66,000 in proximity to the interchange (DelDOT 2011). New Castle County

experiences the highest amount of traffic on SR 1 and Sussex County experiences the lowest (DelDOT 2011).



Figure 7 Aerial Photograph SR 1

4.3.3 Scenario 3 - Interchange E - US 202

Interchange E, US 202, is another north-south arterial primarily serving as a connection from Delaware north into Pennsylvania to the rural areas at the outskirts of the Philadelphia suburbs. The route officially designated as US 202 begins just south of the I-95/I-495 interchange and is co-designated with I-95 as it traverses through the City of Wilmington. The focus of this research is US 202 is from its interchange with I-95 located at the north of the city limits of Wilmington to the Pennsylvania state line. The Concord River bisects the northern part of the City of Wilmington limiting access

along the northern edge of the city and increasing the significance of US 202 as a major route for local travelers commuting in and out of the city (Fig. 8). The five miles of US 202 from the interchange to the Pennsylvania line has an AADT of 30,000 in proximity to the interchange (DeIDOT 2011).

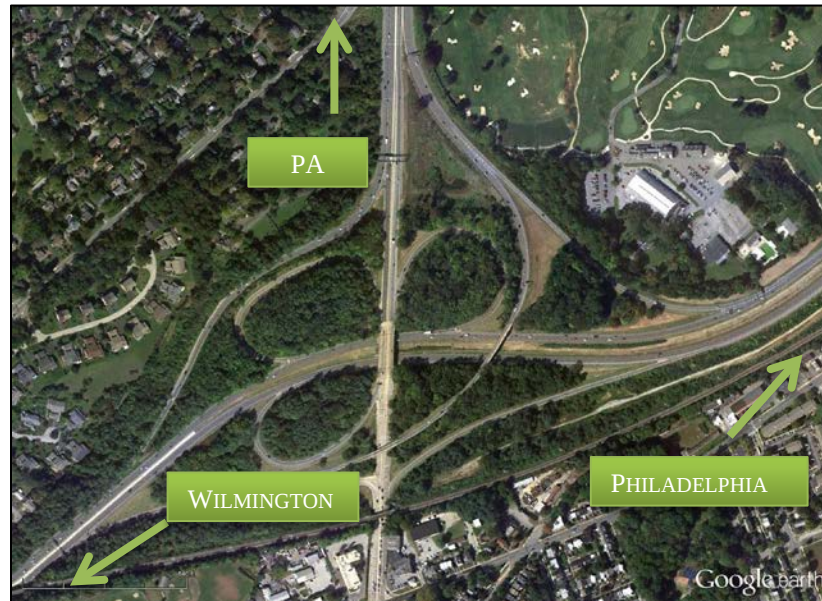


Figure 8 Aerial Photograph US 202

4.3.4 Comparing and Contrasting the Interchanges

Figure 9 contrasts the traffic volume in context of AADT of the three selected interchanges as well as the difference in volume between the interstate and the arterial at each interchange. The magnitude of the AADT represents the amount of traffic entering each interchange on the arterial and interstate not accounting for whether the vehicles are passing through the interchange or using the interchange to change routes. The SR 1 interchange serves the greatest volume of the three with over twice the

volume as the US 202 interchange. It is also evident that the interstates serve a greater volume at all three interchanges than the arterials.

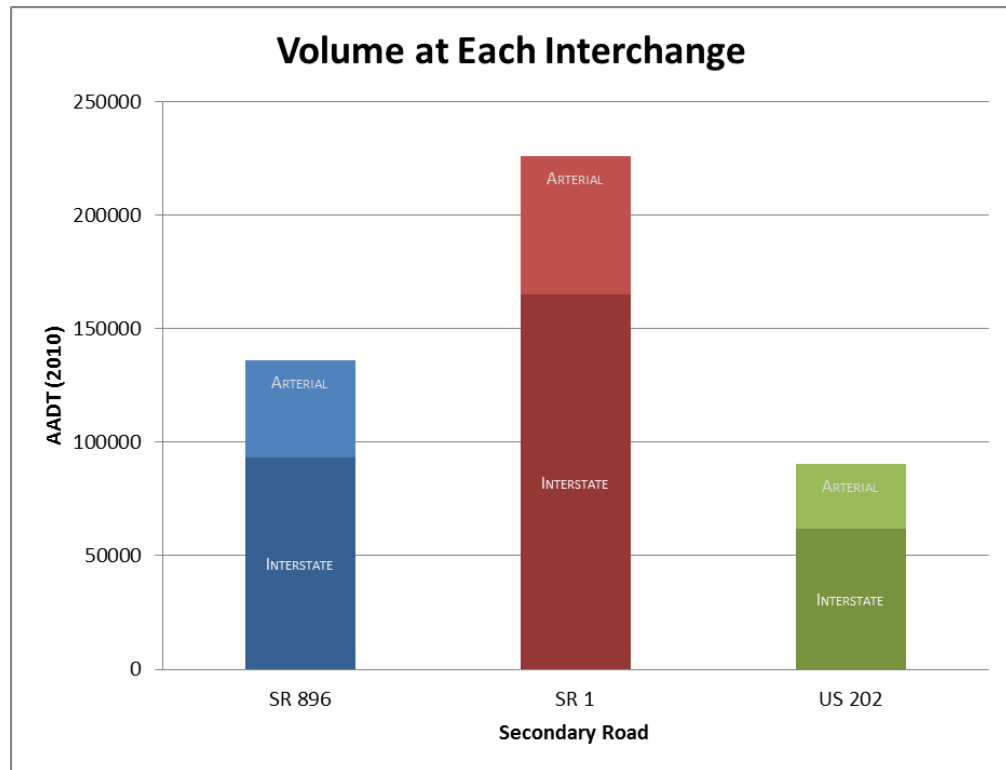


Figure 9 Interchange AADT^e

4.4 Performance Measures Background

The analysis only incorporates the major route types of the roadway network. The classification of the roadways are pre-coded into the network of the model and are

^e Based on AADT values from (DelDOT 2011)

differentiated by default speed and capacity. The coded attributes of the links analyzed are shown in Table 4.

Table 4 Analyzed Route Type Coded Attributes^f

Route Code	Facility Type	Speed - <i>Default</i> (Rural/Urban)	Capacity - <i>Default</i>
1	Freeway	70/70 mph	2000 veh
2	Expressway	65/60 mph	15000 veh
3	Major Arterial High Functioning	60/55 mph	900 veh
11	Major Arterial Low Functioning	50/45 mph	800 veh
4	Minor Arterial High Functioning	50/45 mph	700 veh

4.4.1 Volume

The volume attribute is calculated and reported by the model for each of the four peak periods and refers to the number of trips on a specific link.

4.4.2 Congested Speed

The congested speed attribute, measured in miles per hour, is calculated and reported by the model for each of the four peak periods.

4.4.3 V/C Ratio

The variables in the v/c ration stand for volume *v* and capacity *c* and is calculated and reported by the model for each of the four peak periods. This value normalizes the performance of a roadway by dividing the number of vehicles on a

^f Based on Table II-B-4 from (WRA 2008)

given section of roadway by the roadway's capacity. The volume variable is usually observed through traffic counts however the capacity is dependent on the roadway's characteristics. Capacity defined by the Highway Capacity Manual is the "maximum hourly rate at which persons or vehicles can reasonably be expected to traverse a point or uniform section of a lane or roadway during a given time period under prevailing roadway, traffic, and control conditions" (TRB 2010). Some characteristics that influence a roadway's capacity are the number of lanes, number of entry/exit points, number of trucks compared to the number of vehicles, and the roadway's terrain. Both variables are flow rates and measured with the same units of vehicles per hour resulting in a unit-less ratio that indicates whether the given roadway is performing well, adequately, poorly, or failing. A v/c of 1.00 or greater, where the volume exceeds the capacity, indicates a failing roadway. Ratios less than 1.00 are non-failing roadways but the thresholds of performing adequately versus poorly are usually dependent upon the type of road and even the jurisdiction responsible for the roadway's operations.

Chapter 5

RESULTS & ANALYSIS

5.1 Organization of Results

This chapter analyzes and discusses the impact on traffic conditions for each of the three interchanges. The following performance measures are displayed cartographically for each interchange's four peak periods and are presented in the order listed: change in volume, change in congested speed, and change in v/c ratio. The section begins with SR 896, proceeds to SR 1, and concludes with US 202. Observations are discussed under the volume and speed sections to provide an overview and background where as conclusions are discussed under the v/c sections. In the final section of the chapter, a brief analysis on induced trips due the closures is also discussed.

Each map discussed represents a performance measure's change from before to after the closures and not specific conditions prevalent during an open interchange or a closed interchange. The difference is calculated as after minus before in order for the signage to be logical with expected increases and decrease. For example, if the speed on a link before a closure is 55 mph and after a closure reduces to 35 mph then the calculated change would be $35(\text{after}) - 55(\text{before}) = -20$ showing a decrease or reduction in speed. The symbology for each performance measure is consistent across the peak period for each interchange but varies slightly among the interchanges to account for unique distributions as well as minimums and maximums. Only major routes in the network were symbolized for each map and I-95 is emphasized in each

map by a dark outline. The sections following explain each performance measure in more detail and specific observations are discussed for each interchange in its respective section. The chapter concludes with a comparison between all three interchanges.

Volume – The range of change in volume was the largest of the performance measures and therefore is symbolized by the greatest number of breaks to account for the spread of the distribution. Links symbolized by red hues represent an increase in volume with the deeper reds meaning a greater increase and the light red meaning a smaller increase. Links symbolized in blue hues represent a decrease in volume with a deeper blue meaning a greater decrease than the light blues. Links that did not change (after – before = 0) were excluded from the symbolization.

Congested Speed – Most peak periods resulted in a maximum/minimum change of +/- 40 mph. A reduction in speed is symbolized in reds or purples and an increase in speed is represented in blues or greens. For every peak period, expect the off-peak, changes in speed between -4 mph and +4 mph were excluded from the map as variation in speeds this low are neither abnormal nor significant.

Change in v/c Ratio – See section 4.4.3 for information on the v/c ratio. While the previous performance measures provide a background on how the closure affects the network, this measure normalized each peak period for a direct comparison. A v/c ratio of 0.85 was chosen as the threshold between ‘poor’ and ‘adequate’ performing links. Links with a v/c less than 0.85 are considered adequately performing and links with a v/c greater than 0.85 are considered poor performing links. The maps intend to highlight which links were most affected by the closure and symbolized into four following categories: (i) Links that are less than or equal to 0.85 before and after the

closure are highlighting in a light grey. (ii) Links that have a v/c of greater than 0.85 before and after the closure are shown in a coral color. These categories indicate little significant influence on the network. (iii) Links that decrease in v/c from a value greater than 0.85 before the closure (links that perform poorly under normal conditions) to a value less than 0.85 after the closure (links that experience the least congestion after the closure) are highlighted in navy. (iv) Lastly, links that increase from a v/c value of less than 0.85 before (links that perform adequately under normal conditions) and a value greater than 0.85 after the closure (links that experience the most congestion after the closure) are symbolized in red.

5.2 Interchange SR 896

The effects of the SR 896 closure extend into Cecil County more so than the other interchange closures. A single peak period does not stand out as significantly more altered, however the MID-DAY peak period is less affected than the AM and PM peak periods. The closure did not cause other parts of I-95 throughout the county to perform poorly and has the most influence on SR 2, SR 4, and US 40 from points in Cecil County to points around the I-95, I-495, & I-295 convergence.

5.2.1 Change in Volume

The change in volume does not significantly differ between the four peak periods. I-95 as well as I-495 decreases in volume throughout the county except for parts of I-95 north of the City of Wilmington (Fig. 10 – Fig. 14). While links in the northern part of the county see an increase in volume (less than 1,700 trips), the arterials adjacent to I-95 near the interchange experience a greater increase ranging from 1,700 to 5,500 trips. The vehicles appear to divert using two alternate routes: 1)

The vehicles exit/enter I-95 at the interchange preceding SR 896 to the south and return/leave to the highway at the interchange following SR 896 to the north using arterials that travel through the center of the City of Newark. Or 2) The vehicles divert to US 40 to the south of I-95 to travel from origins/destinations in Cecil County to origins/destinations in the northern part of the county.

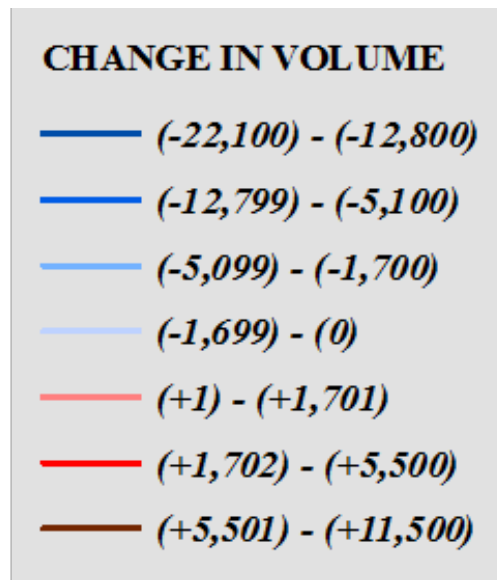


Figure 10 Legend SR 896 Volume

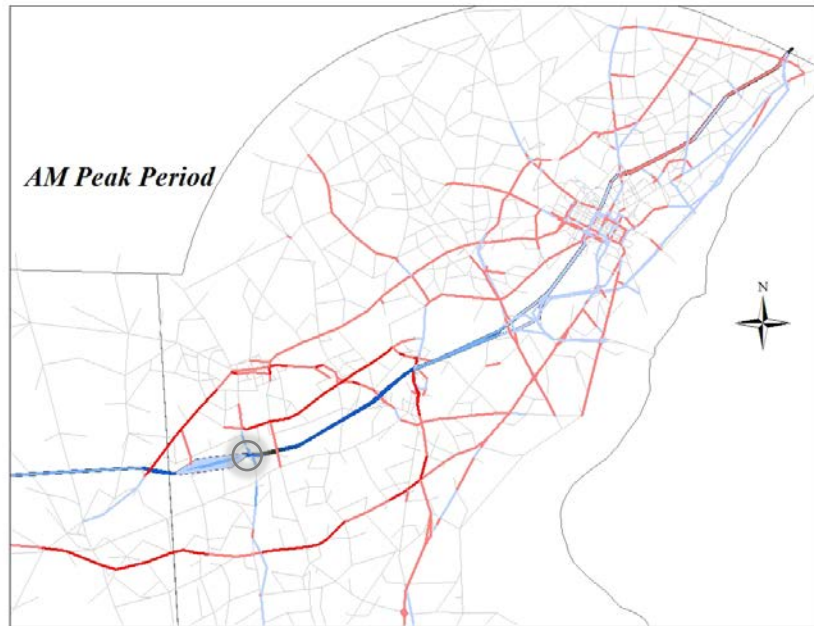


Figure 11 SR 896 AM Change in Volume

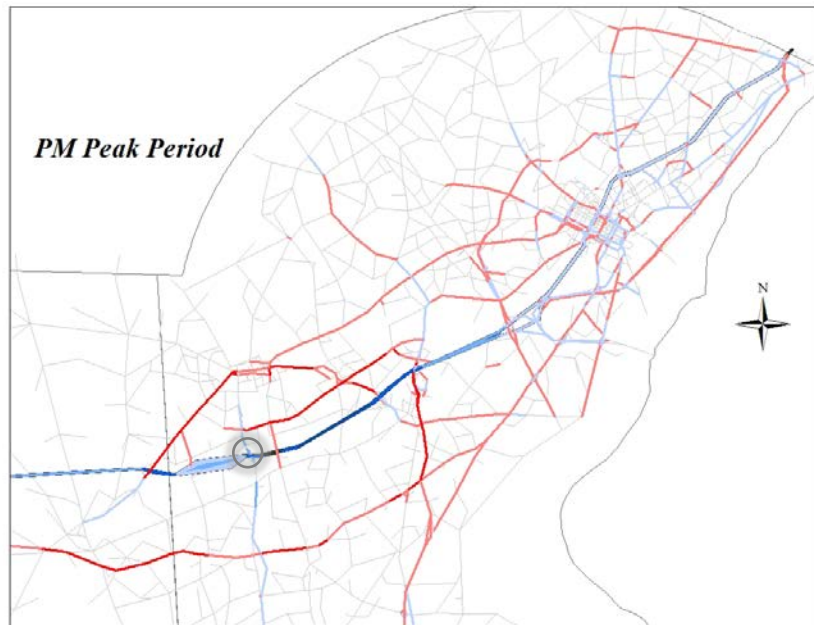


Figure 12 SR 896 PM Change in Volume

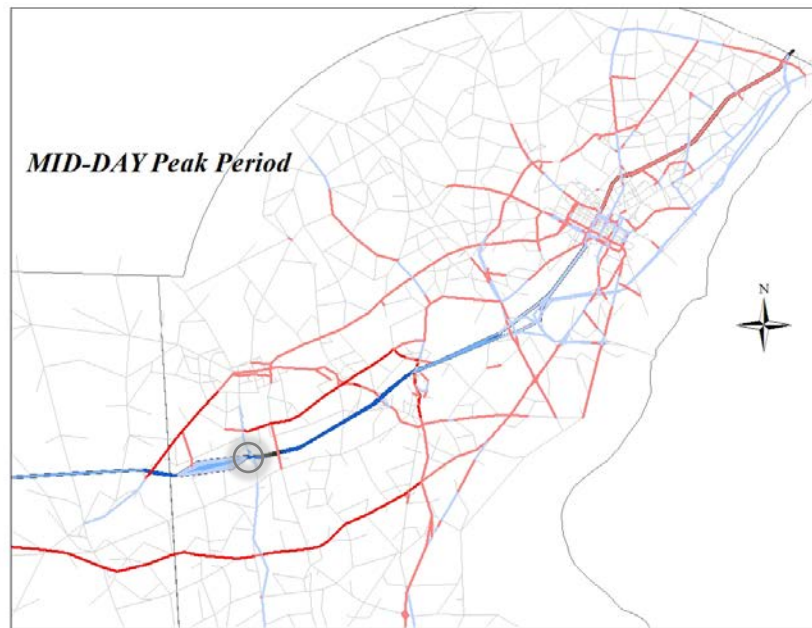


Figure 13 SR 896 MID-DAY Change in Volume

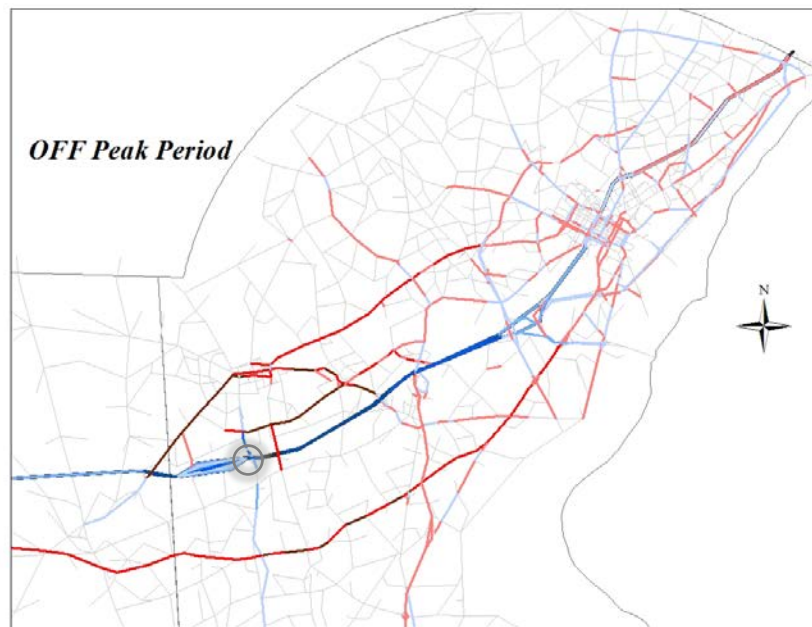


Figure 14 SR 896 OFF Change in Volume

5.2.2 Change in Congested Speed

Significant changes in speed occur in the western part of the county with speeds reducing up to 45 mph (Fig. 15 - Fig. 19). Links that experience an increase in volume also experience a reduction in speed as evident on the roadways adjacent to I-95 near the SR 896 interchange. Again, US 40 and various arterials through the City of Newark experience the greatest change with speeds which reduce primarily by 15 mph to 25 mph. Speeds on I-95 increase as a result of the closure. Despite a greater change in volume during the off-peak hours, the closure does not affect traveling speeds during this peak period. Here, the tan colored links represents links that experienced a change between -4 mph and +4 mph.

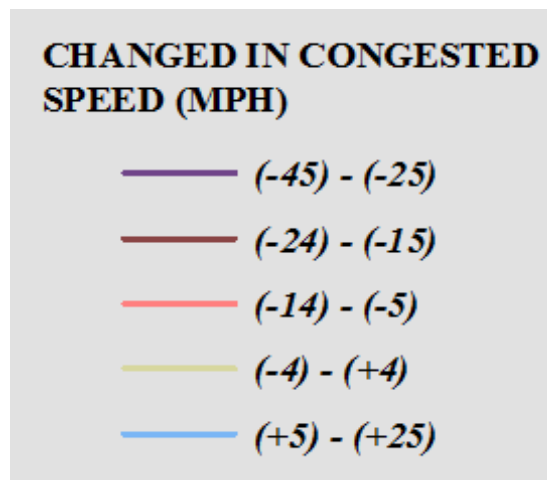


Figure 15 Legend SR 1 Speed

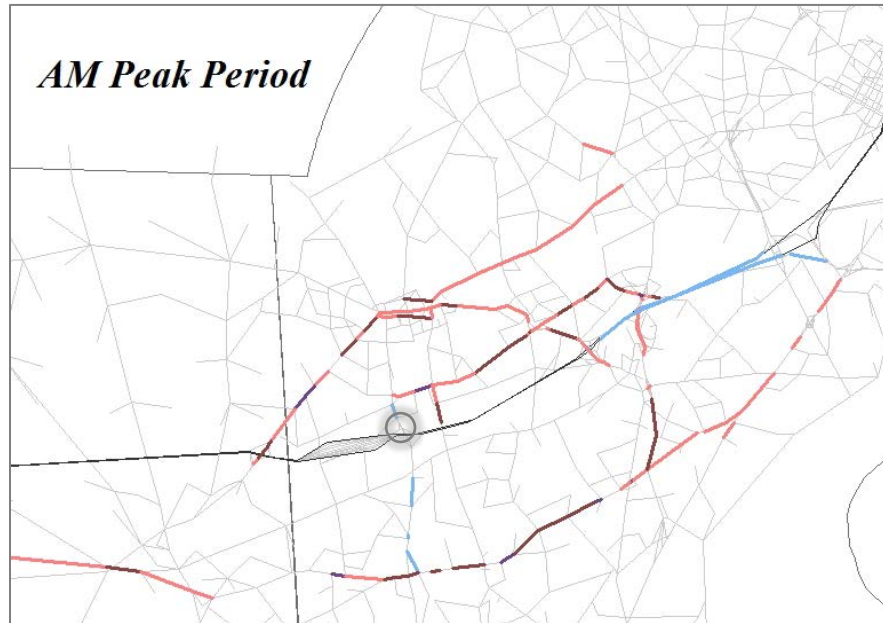


Figure 16 SR 896 AM Change in Congested Speed

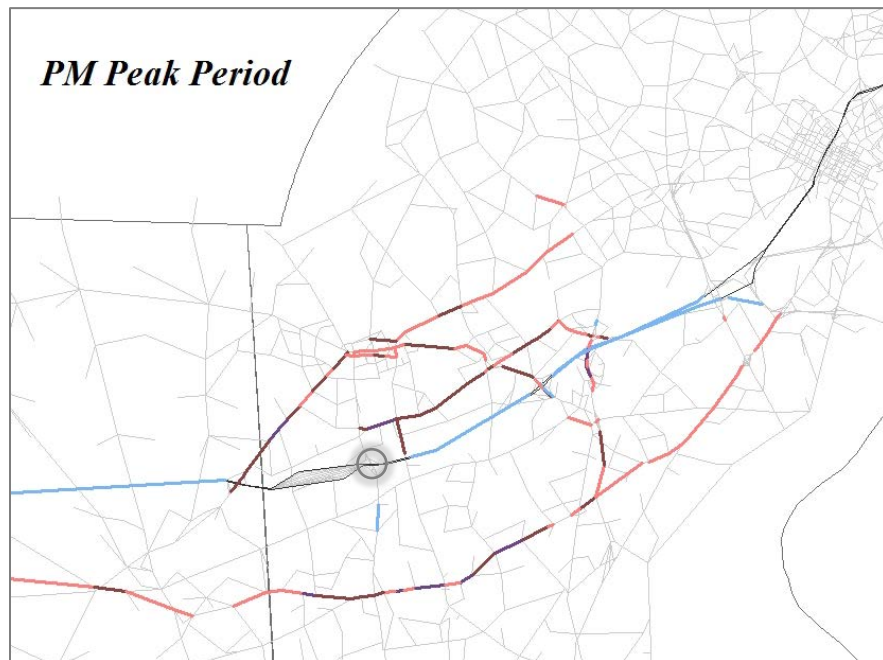


Figure 17 SR 896 PM Change in Congested Speed

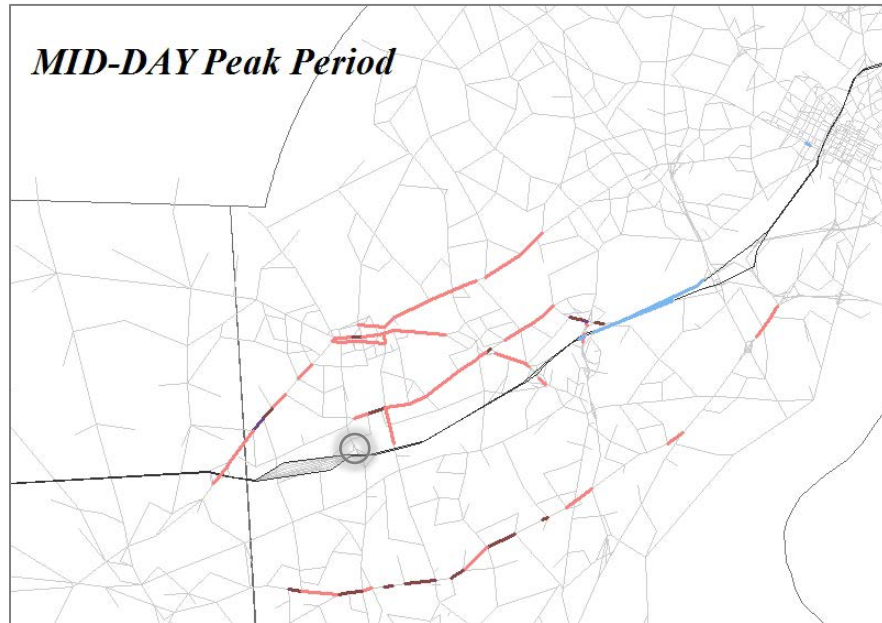


Figure 18 SR 896 MID-DAY Change in Congested Speed

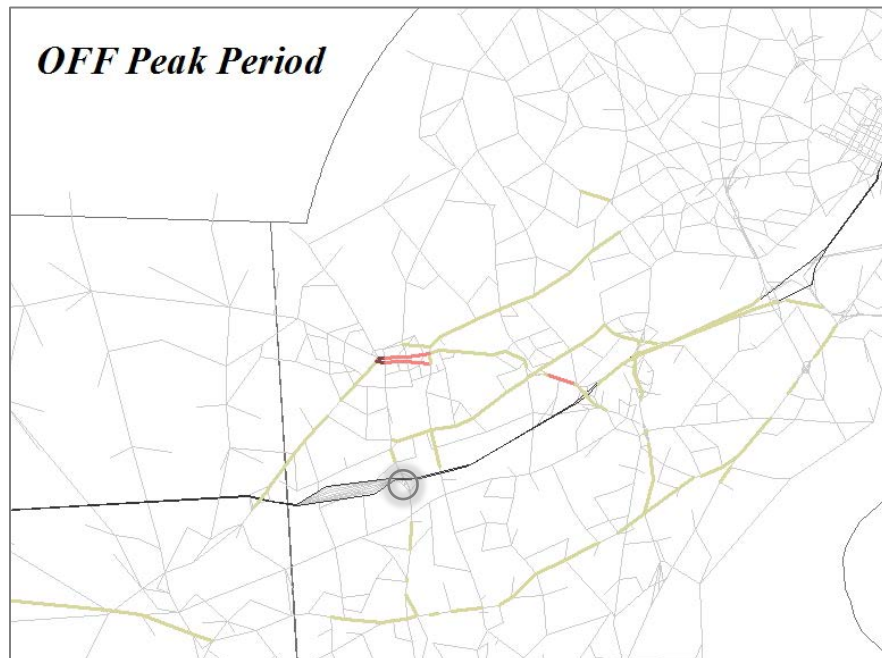


Figure 19 SR 896 OFF Change in Congested Speed

5.2.3 Change in V/C Ratio

The links that experience an increase in v/c ratio are again in the western part of the county and long the same alternate routes that experience a change in volume and a reduction in speed (Fig. 20 - Fig. 24). The v/c of the primary alternate routes increases to greater than 0.85. These routes will be the most adversely affected by a closure. Although the off-peak period experiences the greatest change in volume, the increase in traffic does not adversely affect the conditions because the change in speed is virtually non-existent and the v/c remains below 0.85. If the SR 896 interchange were to close, the congestion causing effects would be centered in the western part of the county.

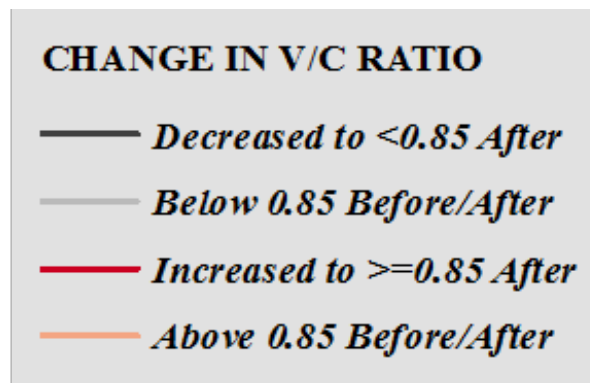


Figure 20 Legend SR 896 V/C

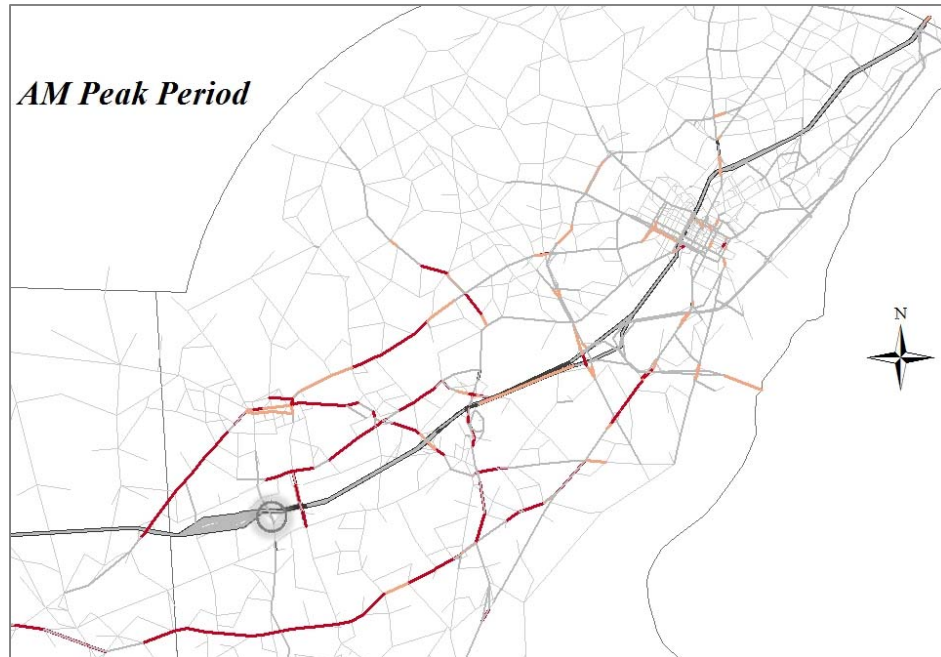


Figure 21 SR 896 AM Change in V/C Ratio

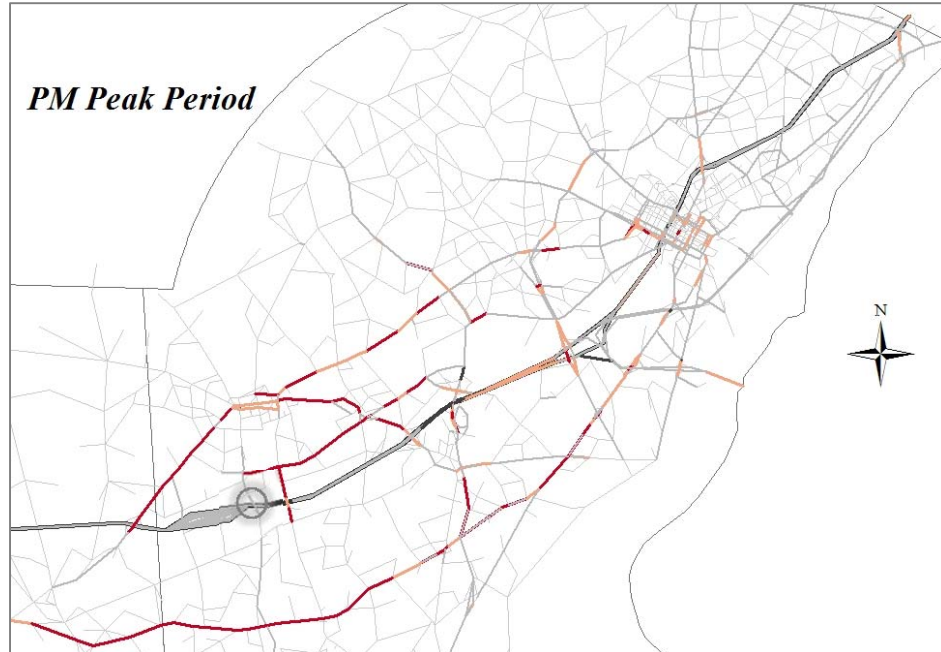


Figure 22 SR 896 PM Change in V/C Ratio

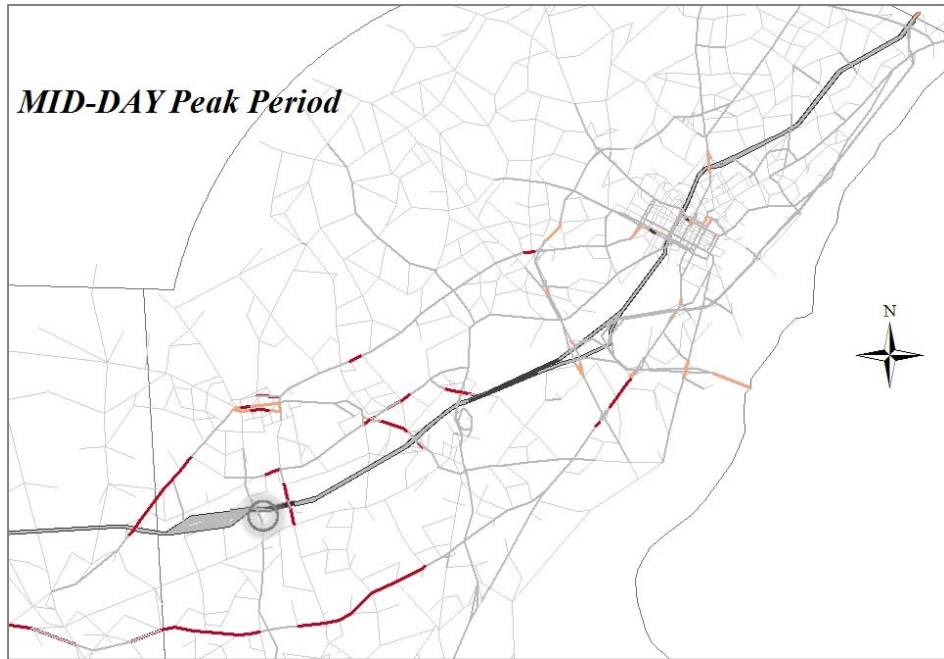


Figure 23 SR 896 MID-DAY Change in V/C Ratio

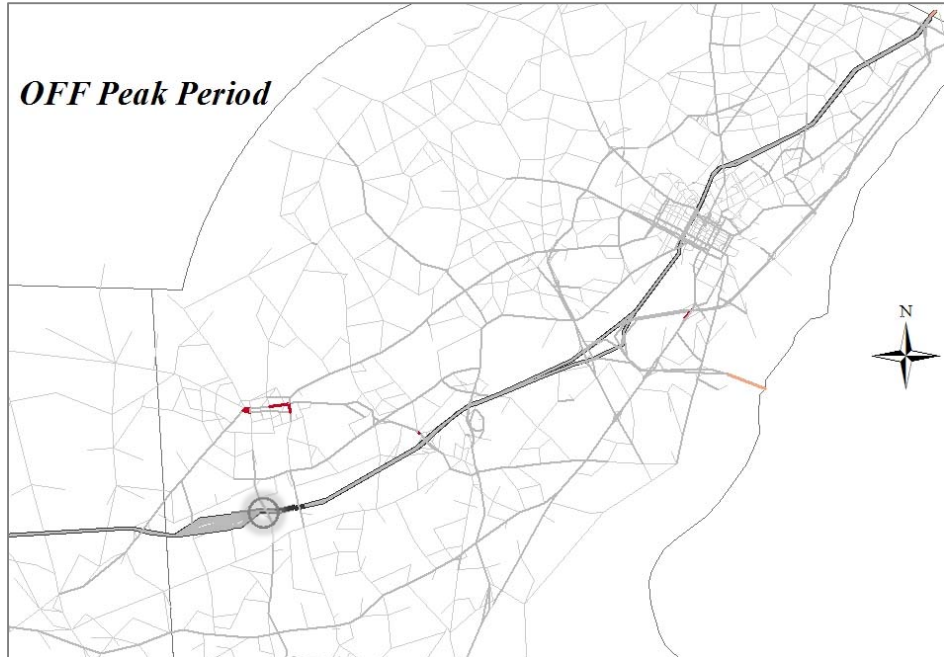


Figure 24 SR 896 OFF Change in V/C Ratio

5.3 Interchange SR 1

The magnitude of change in traffic conditions for the closure of SR 1 is less than the magnitude of change for SR 896 and US 202 closures. The effects of the interchange closure are primarily localized to arterials south of the City of Wilmington and to east-west routes versus north-south routes. The PM peak period is most affected by the closure than other peak periods with more extensive negative effects across the three measures of performance. The closure has the most influence on SR 2, SR 4, and US 40 in the region between the City of Wilmington and the City of Newark.

5.3.1 Change in Volume

The change in volume caused by the closure of the SR 1 interchange is not as large as the other interchanges and affects more links/roadways than the closure of SR 896 (Fig. 25 – Fig. 29). The majority of the links change in volume between -2,200 and + 2,500 trips. Traffic was diverted around SR 1 using the interchange immediately to the south and north onto the adjacent arterials. I-95 and I-495 decreased in volume.

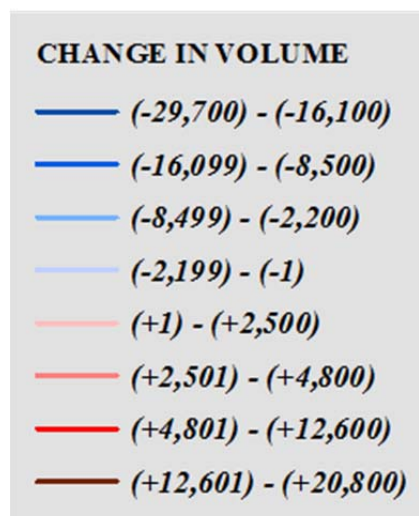


Figure 25 Legend SR 1 Volume

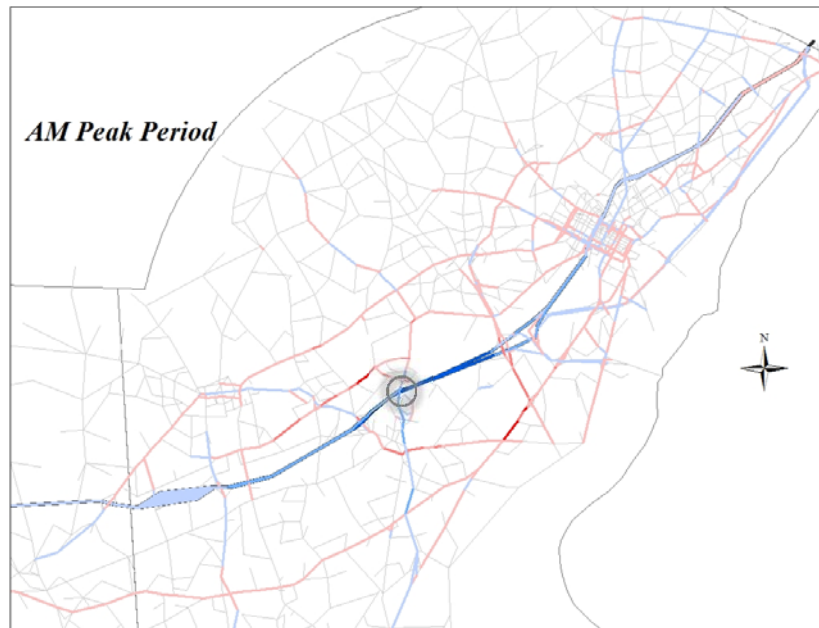


Figure 26 SR 1 AM Change in Volume

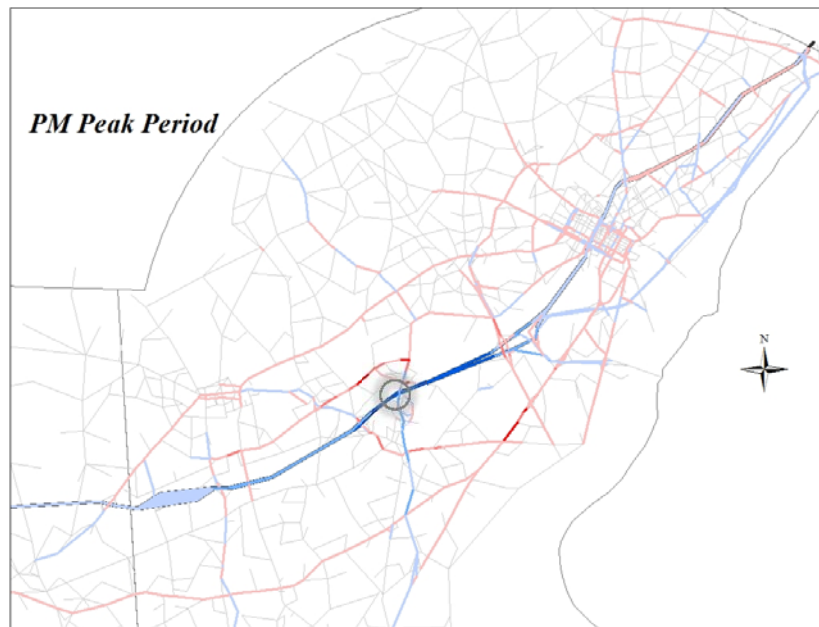


Figure 27 SR 1 PM Change in Volume

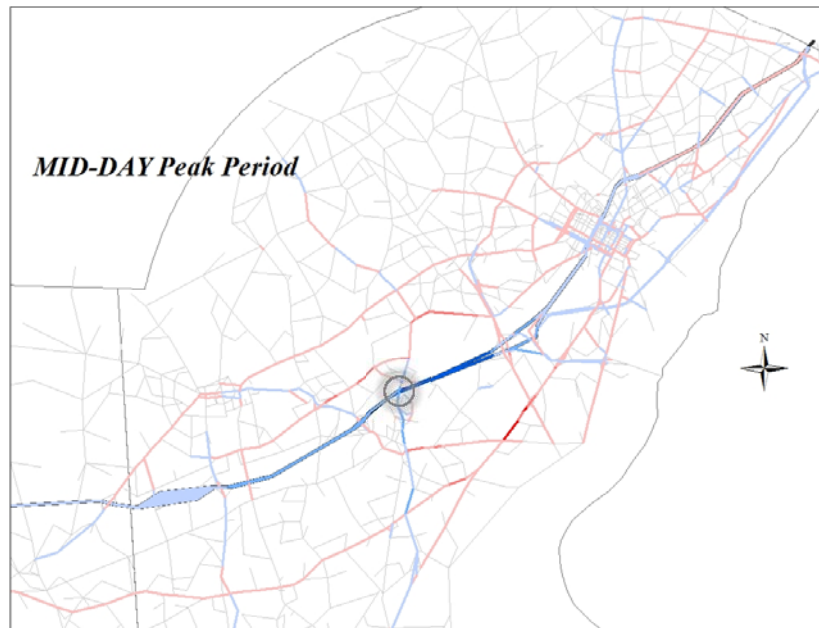


Figure 28 SR 1 MID-DAY Change in Volume

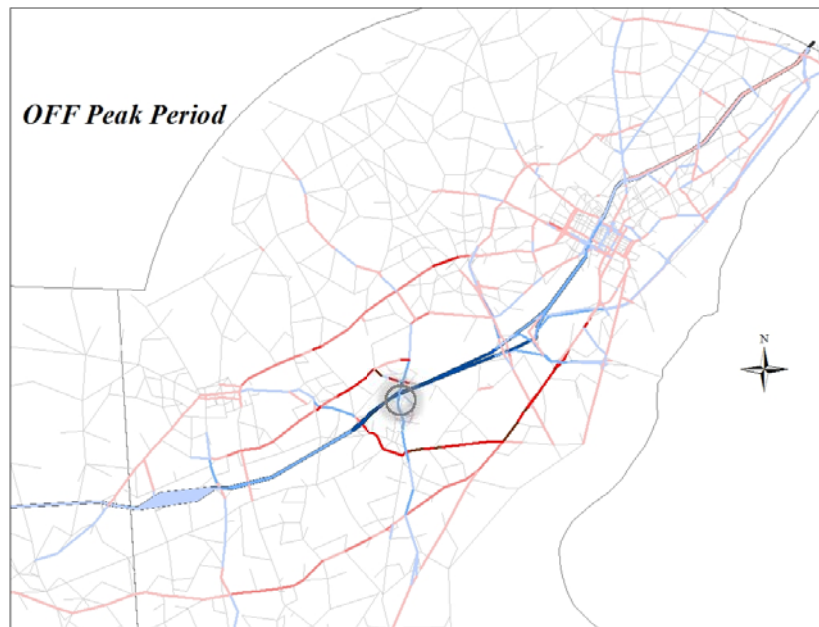


Figure 29 SR 1 OFF Change in Volume

5.3.2 Change in Congested Speed

The majority of links experience a reduction in speeds up to 20 mph and are localized to the arterials near the SR 1 interchange (Fig. 30 – Fig. 34). The greatest change in speed are contained to the interchange immediately south of SR 1 and along arterials to the south of I-95. Speeds on I-95 increase, specifically along the segment to the north of SR 1. Speeds are not affected by the closure during the off peak period.

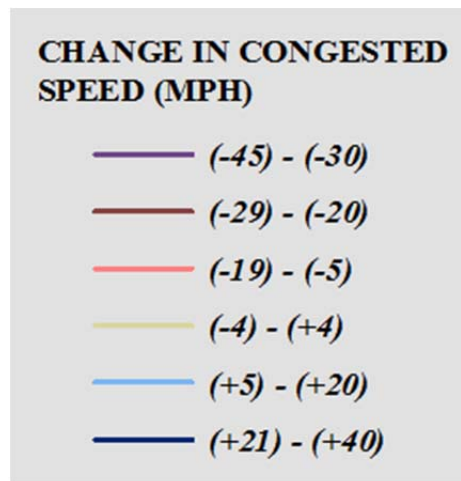


Figure 30 Legend SR 1 Speed

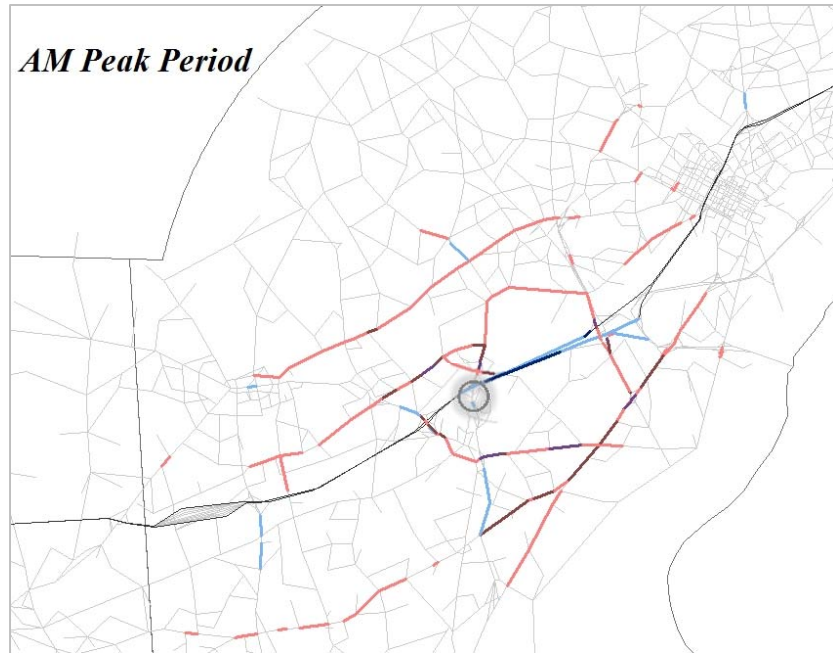


Figure 31 SR 1 AM Change in Congested Speed

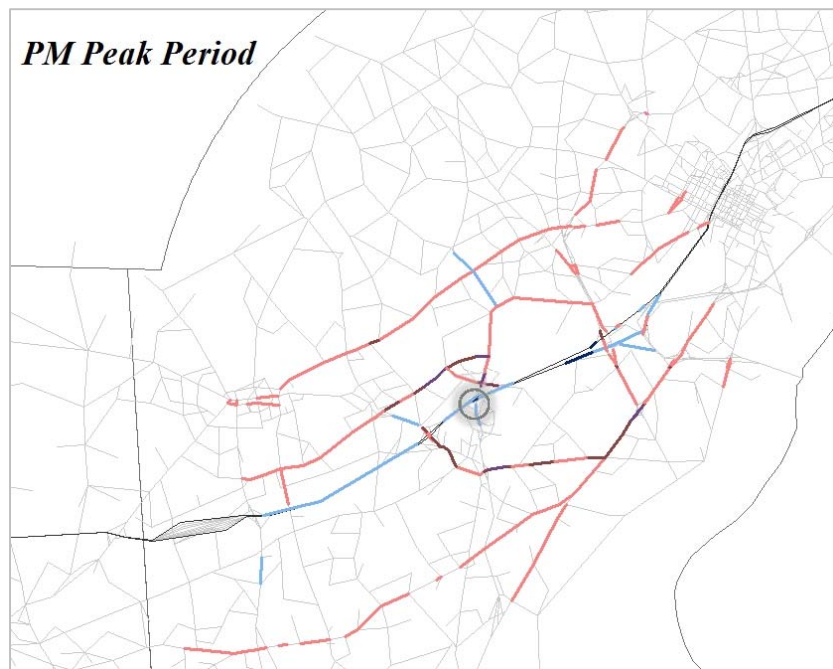


Figure 32 SR 1 PM Change in Congested Speed

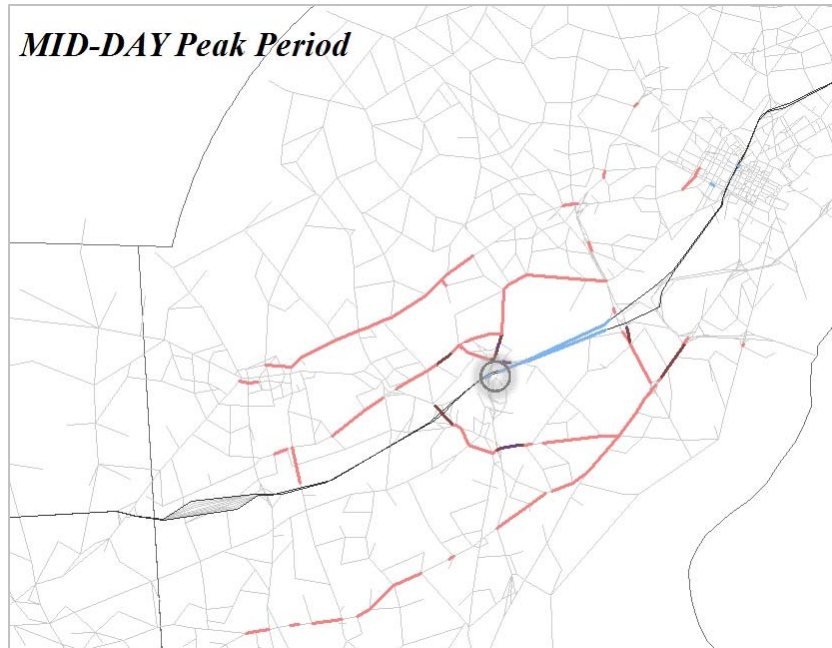


Figure 33 SR 1 MID-DAY Change in Congested

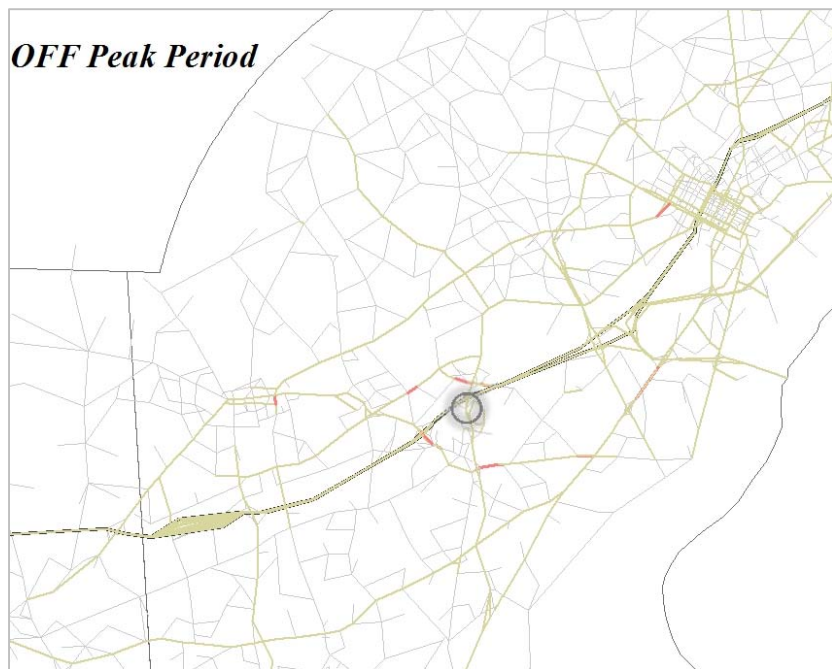


Figure 34 SR 1 OFF Change in Congested Speed

5.3.3 Change in V/C Ratio

The AM and PM peak periods are most influenced by the closure and the MID-DAY and OFF peak periods are minimally affected (Fig. 35 – Fig. 39). The v/c along I-95 remains below 0.85 except for segments around the I-95, I-495, & I-295 convergence. The interchange immediately south of SR 1, SR 273, and the arterials south of I-95 are most affected by the closure with v/c ratios greater than 0.85 prevalent in the region. This alternate route, SR 273 to US 40, will experience the most congestion if the SR 1 interchange were to close since the SR 273 arterial experienced the largest increase in volume and reduction in speed of the region.

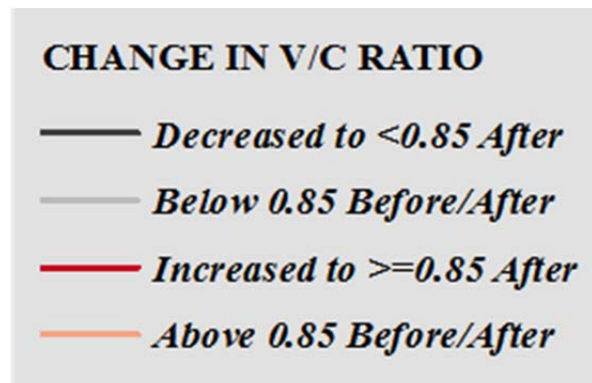


Figure 35 Legend SR 1 V/C

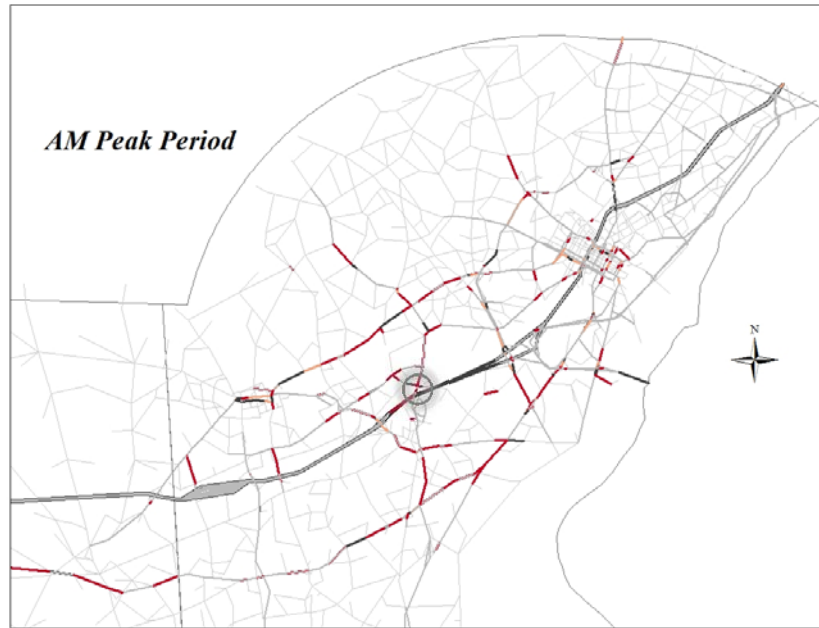


Figure 36 SR 1 AM Change in V/C Ratio

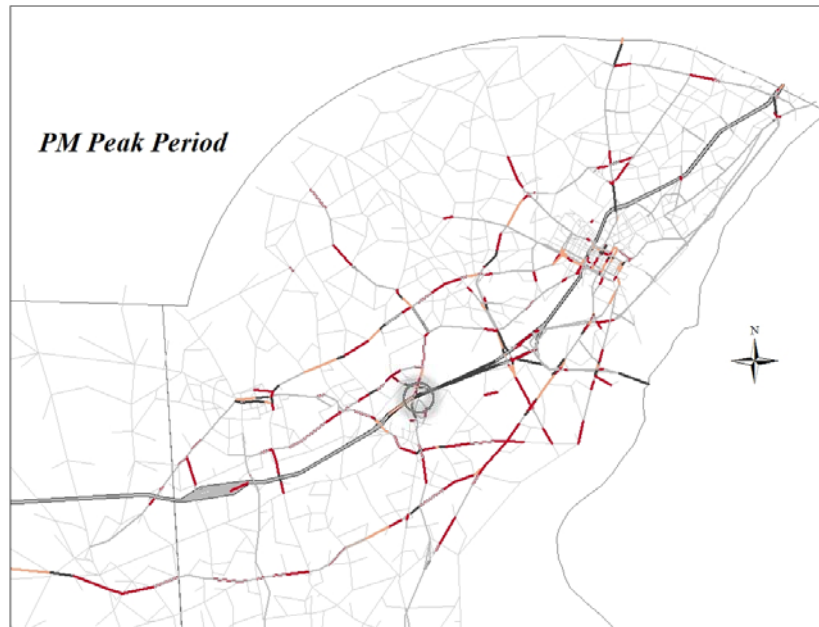


Figure 37 SR 1 PM Change in V/C Ratio

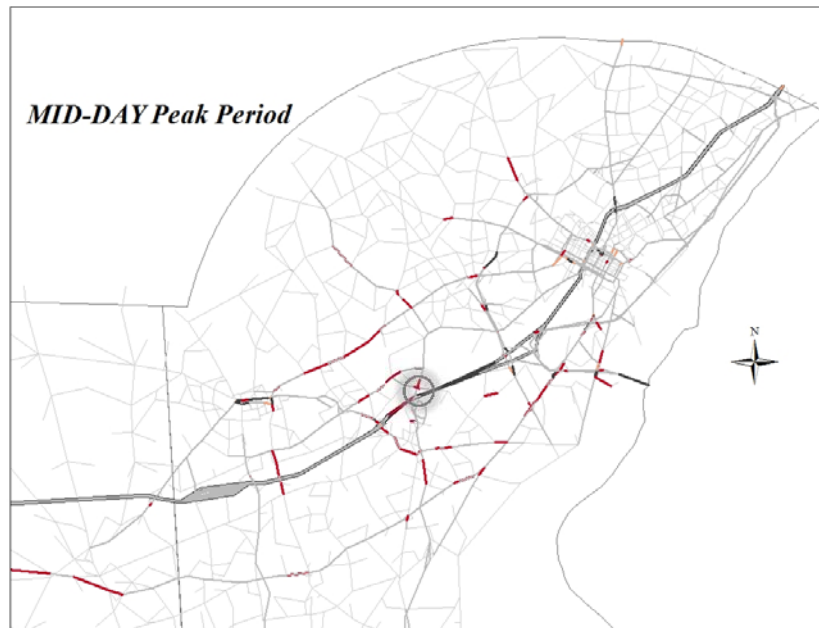


Figure 38 SR 1 MID-DAY Change in V/C Ratio

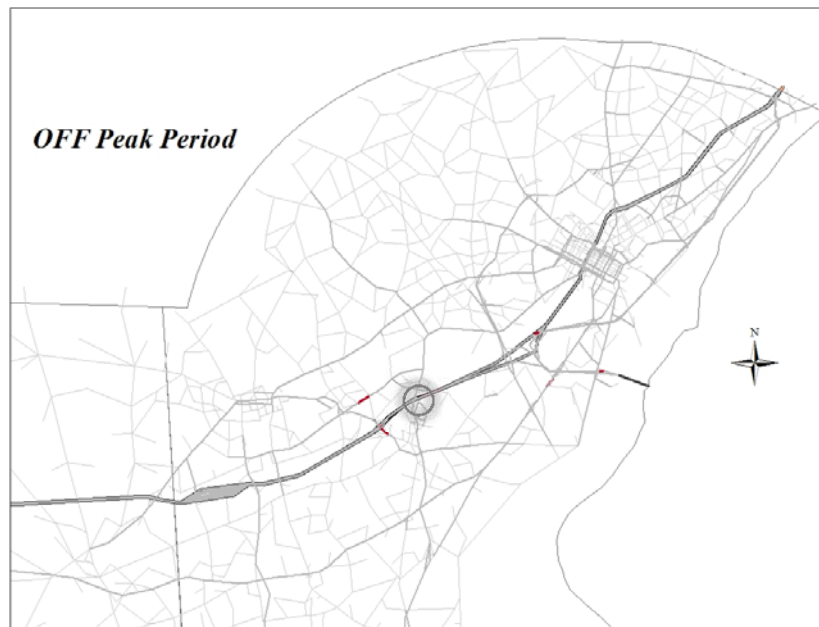


Figure 39 SR 1 OFF Change in V/C Ratio

5.4 Interchange US 202

Although the US 202 interchange has the lowest AADT of the three interchanges analyzed, its closure affects a greater radius around I-95 and on the entire length of the adjacent arterials from state line to state line than the previous two interchanges. A single peak period does not stand out as significantly more altered, however the MID-DAY peak period is less affected than the AM and PM peak periods. SR 2, SR 141, SR 4, to the north of I-95 and I-495, as well as US 40 to the south of I-95 are the arterials most influenced by the closure.

5.4.1 Change in Volume

The diverted traffic is distributed across the network more so than the scenarios of SR 896 or SR 1 (Fig. 40 – Fig. 44). Traffic is primarily assigned to I-495 to divert around the city. I-95 south of the City of Wilmington and I-495 experienced the greatest volume increase from 3,200 to 17,600 trips. In all peak periods, the arterials experienced a lower change in traffic oscillating between increases up to +7,300 and decreases up to -7,300 trips. The closure of SR 1 affected the volumes of roadways along the entire length of the I-95 corridor.

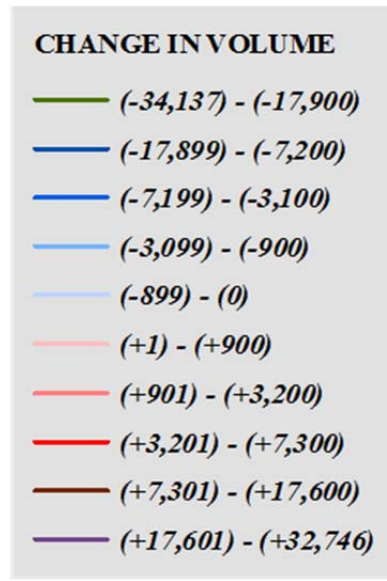


Figure 40 Legend US 202 Volume

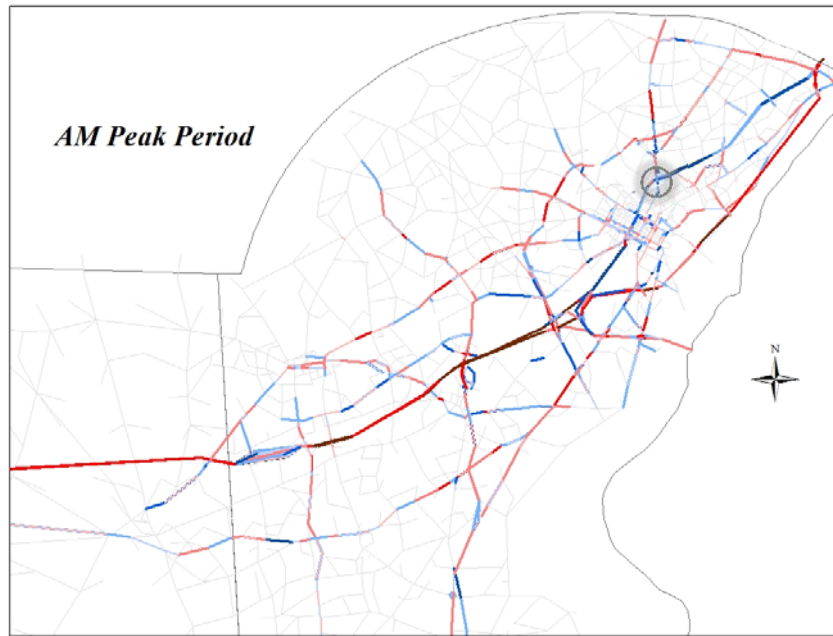


Figure 41 US 202 AM Change in Volume

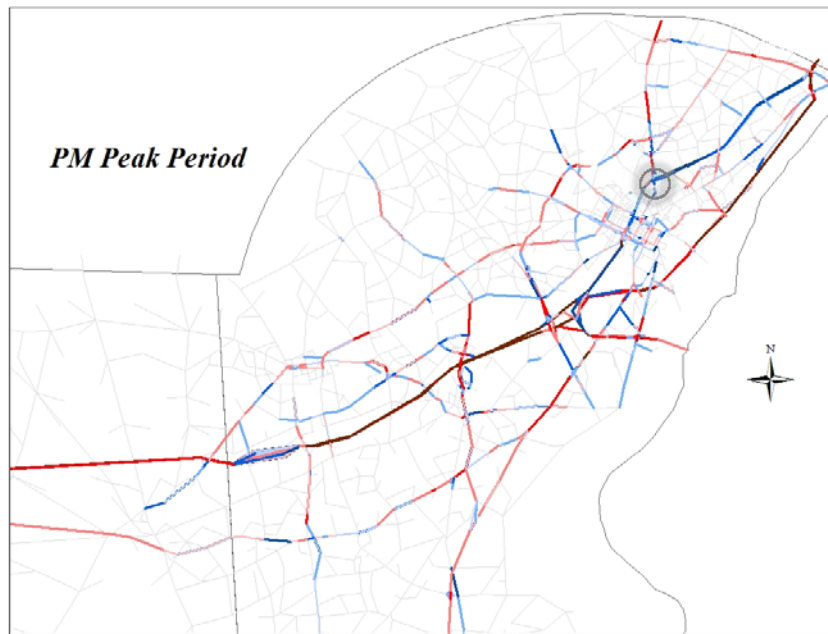


Figure 42 US 202 PM Change in Volume

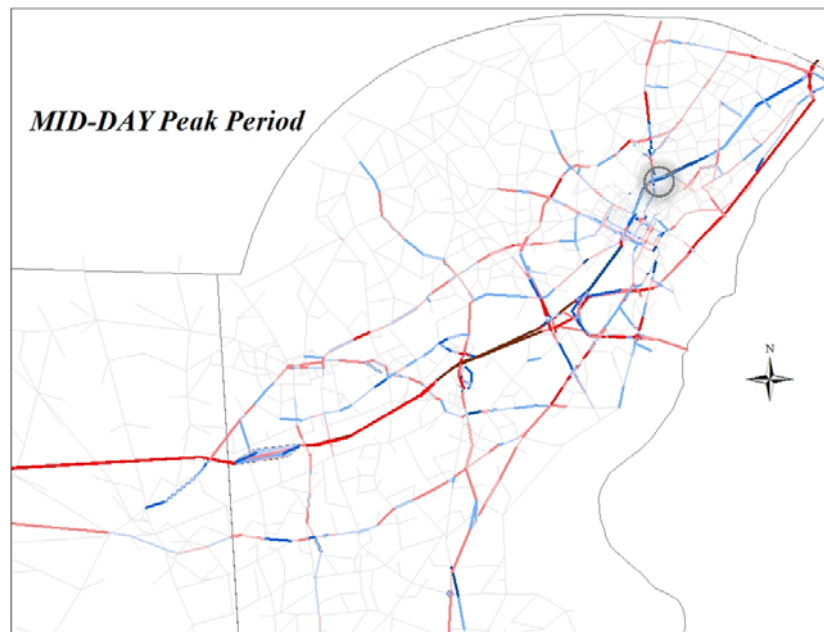


Figure 43 US 202 MID-DAY Change in Volume

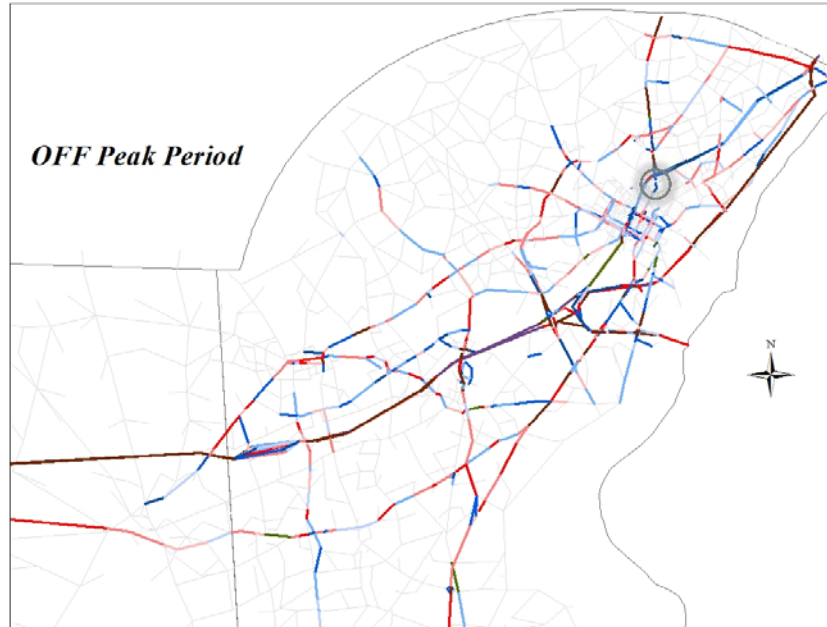


Figure 44 US 202 OFF Change in Volume

5.4.2 Change in Congested Speed

The majority of links throughout the four peak periods experience a change in speed within a +/- 20 mph range (Fig. 45 – Fig. 49). The closure induced changes in speed throughout the I-95 corridor and the variation in speeds is more sporadic than the SR 896 or SR 1 scenarios. Despite the increase in volume, I-95 and I-495 primarily experience an increase in speed except for links around the I-95, I-495, & I-295 convergence and specifically in the PM peak period. Again, SR 4 and US 40 are the most affected arterials.

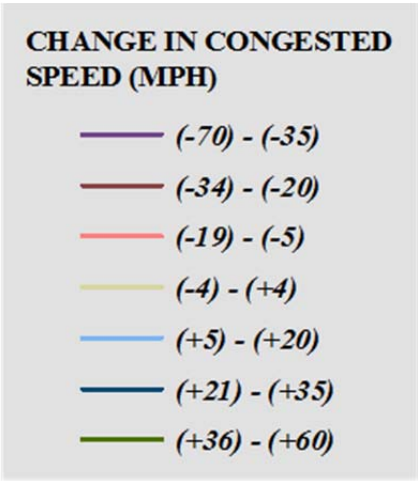


Figure 45 Legend US 202 Speed

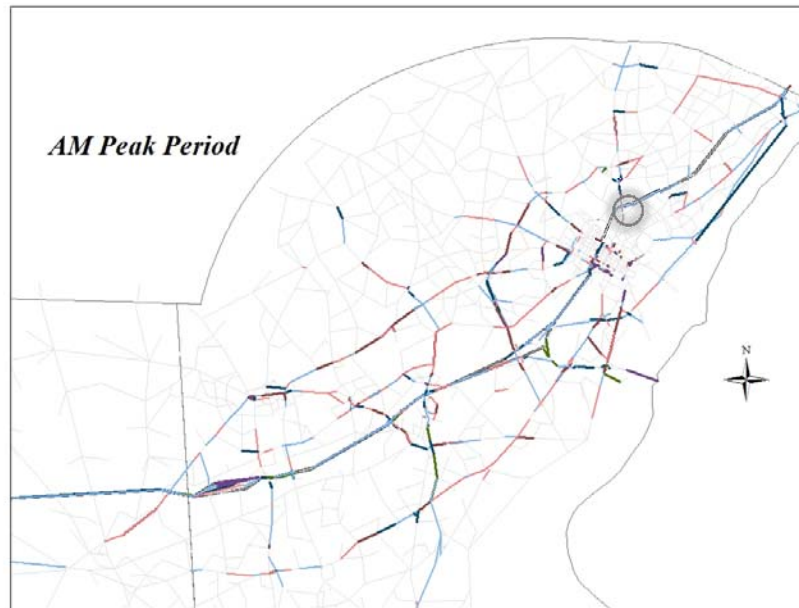


Figure 46 US 202 AM Change in Congested

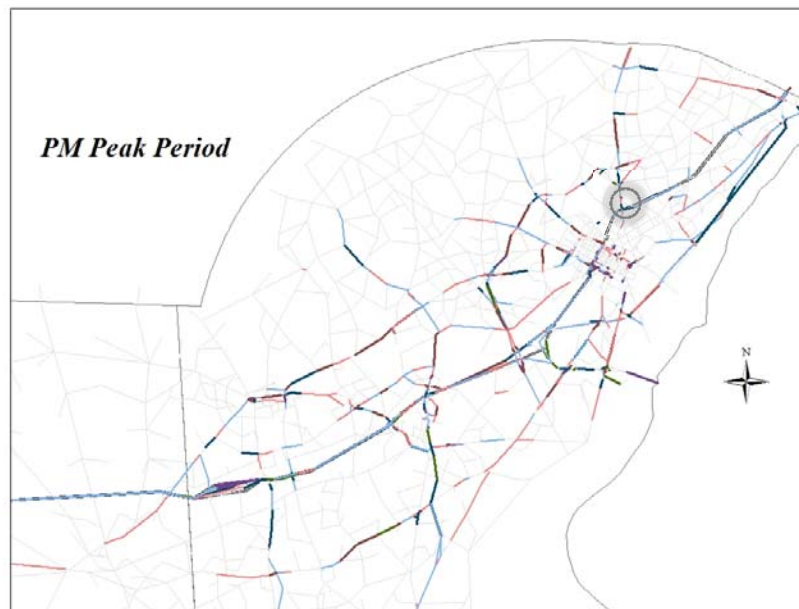


Figure 47 US 202 PM Change in Congested Speed

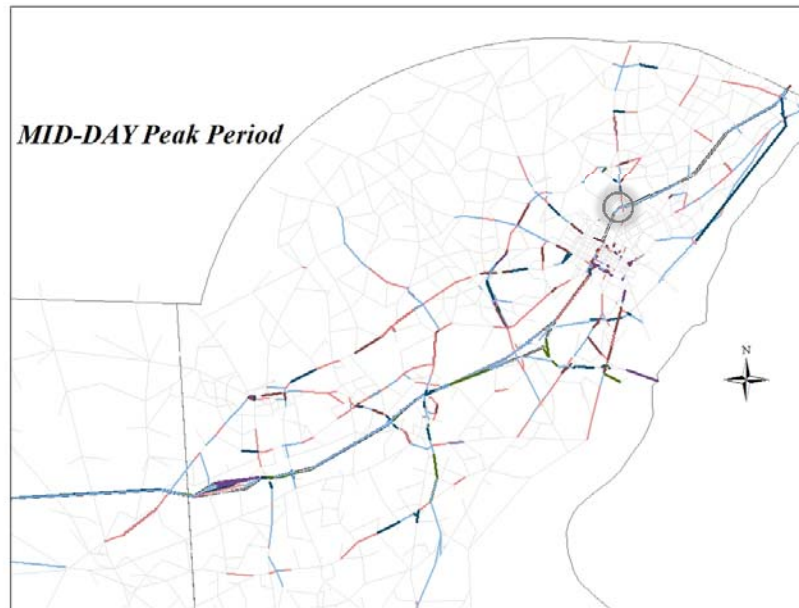


Figure 48 US 202 MID-DAY Change in Congested Speed

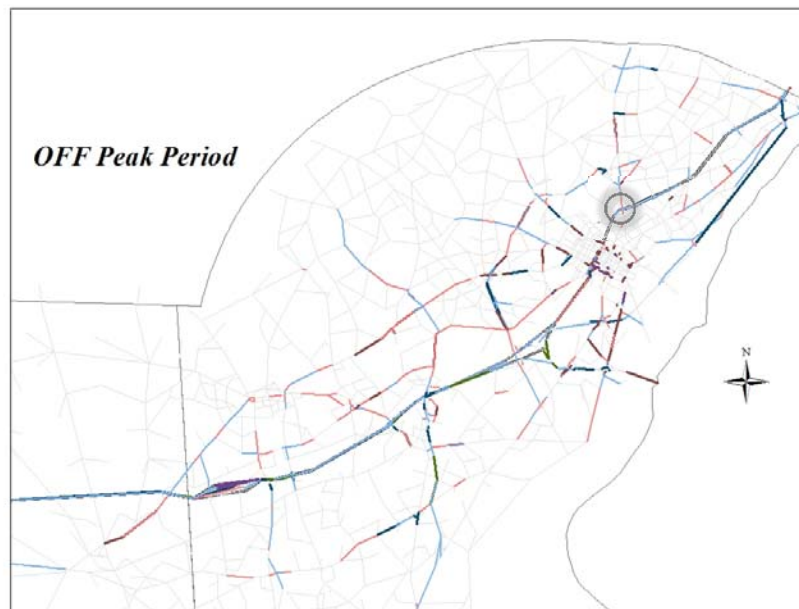


Figure 49 US 202 OFF Change in Congested Speed

5.4.3 Change in V/C Ratio

The number of links with a v/c greater than 0.85 are minimal and especially in comparison to the SR 896 and SR 1 scenarios (Fig. 49 – Fig. 53). The closure has little influence on the v/c ratio during the MID-DAY and OFF peak periods. Even though I-495 and I-95 south of the City of Wilmington experience the greatest increase in volume, the diverted traffic did not cause the v/c ratio to increase to above the 0.85 threshold. The network was able to balance distributing the vehicles across the network without causing the major routes to perform poorly. However, the area that experience the more adverse effects is the section of I-95 where it converges with I-495 and I-295, but the speed change is minor and the area may perform adequately under such a scenario. It has an increase of vehicles up to 17,600 and a v/c ratio of greater than 0.85 in the AM, PM, and MID-DAY peak periods but the change in speed is between +/- 20 mph. This scenario appears to be able to handle the diverted traffic from the closure well due to an increase in volume but a minor change in speed and v/c ratio

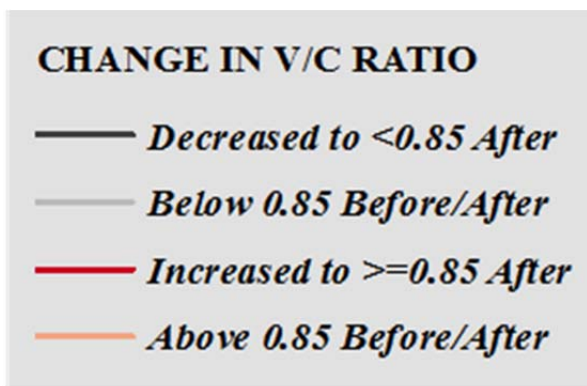


Figure 50 Legend US 202 V/C

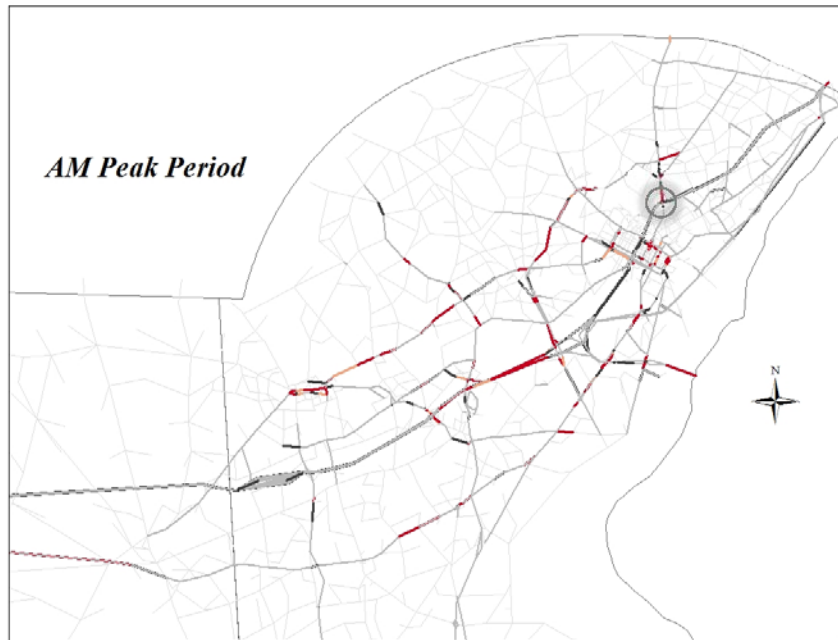


Figure 51 US 202 AM Change in V/C Ratio

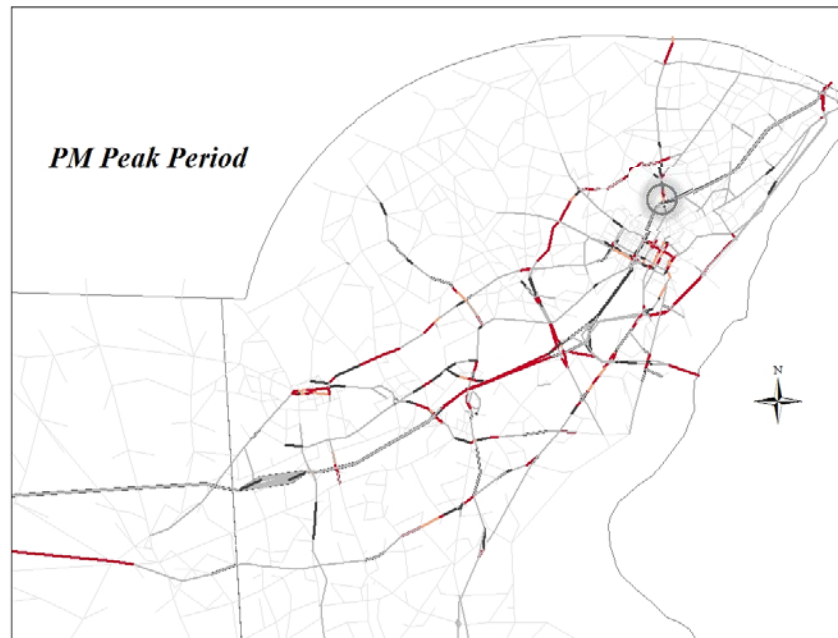


Figure 52 US 202 PM Change in V/C Ratio

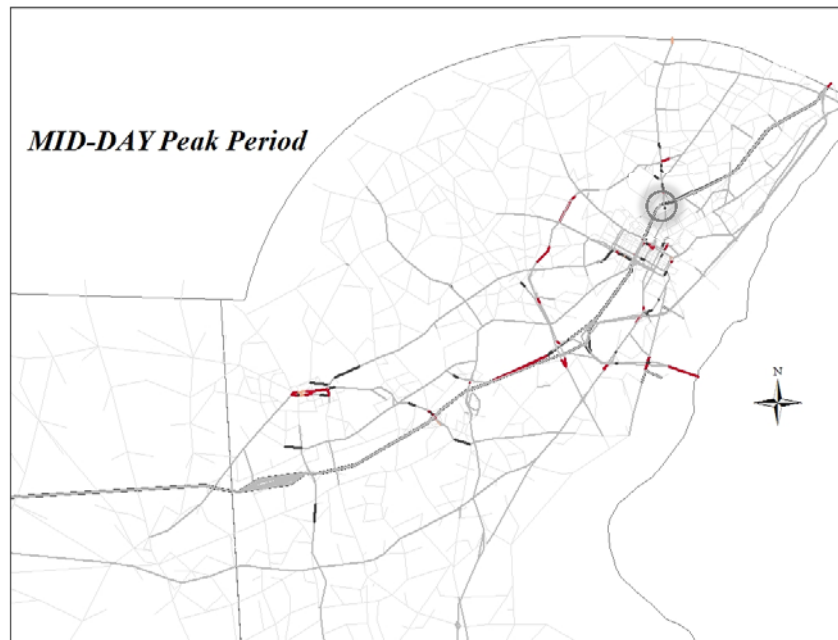


Figure 53 US 202 MID-DAY Change in V/C Ratio

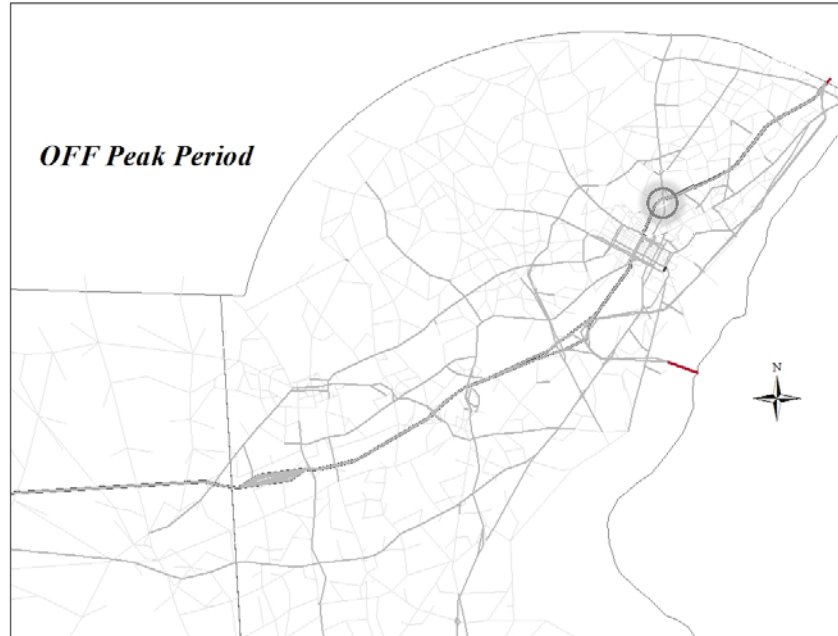


Figure 54 US 202 OFF Change in V/C Ratio

5.5 Induced Trips

Under the previously discussed analysis, the before and after scenarios used identical trip tables implying that the same number of trips were generated despite the closure and were only assigned to the network in differing patterns. In reality, there is a probability that if users were aware of a significant closure they could possibly choose not to make a trip especially if it was perceived that the travel time would take significantly longer than under normal conditions. To look into this possibility, another scenario using the full model was run inputting two separate road networks; one with the full network and a second with deleted links around the SR 896 and I-95 interchange to simulate a closure of that interchange. With this procedure, the model produced two different trip tables for the before and after scenario allowing for an analysis of the change in number of trips.

To simplify the results, the TAZ's were grouped into 35 districts to create only 35 origins destinations pairs (O-D pairs) based on the districts and not the TAZ's. Three O-D pairs were selected and shown in the Table 5. 1) Cecil County, MD to New Castle County, DE 2) Cecil County, MD to the Delaware Memorial Bridge and 3) Cecil County, MD to I-95 at the the Pennsylvania state line. These pairs essentially simulate traffic to/from Maryland to Delaware or through Delaware to Pennsylvania or New Jersey.

Based on the results in the Table 5, there was a reduction in the number of trips made for each of the three O-D pairs. New Castle County has the highest reduction in trips at 2,000 and the Pennsylvania state line has the least reduction in trips at 73. Under this scenario, only SR 896 was analyzed but a closure of US 202 or SR 1 could produce a different change in the number of trips.

Table 5 Induced Trips Volumes for SR 896 Closure

		New Castle County	Delaware Memorial Bridge	PA State Line
OPEN	Cecil County	32,351	2,487	540
CLOSED		30,301	1,658	467
CHANGE		-2,049	-829	-73

Chapter 6

LIMITATIONS & FUTURE RESEARCH

6.1 Limitations of the Methodology

While optimization models produce effective and efficient alternate routes, the routes are based on a system in equilibrium and not necessarily a realistic view of the network. The outputs of the model show a snap shot of the network after a specific interval of time when users are aware of the closure and are directed and diverted appropriately. At this point, the system has had time to balance. While this analysis provides an understanding of the congestion caused by such a closure, the optimization characteristic of the model does not allow for either variations in decisions made by trip makers or a snapshot of the network within moments after the closure. A different methodology would need to be used if knowledge of the traffic conditions within a finite amount of time after a closure was desired.

Using the change in the value performances measure from the before and after scenarios provides an understanding of the magnitude of the impacts of an interchange closure. However, this analysis method can misrepresent certain impact as evident in the off peak periods. The off peak periods created the greatest change theoretically implying that it was the poorest performing period regardless of whether a positive or negative value is consider adverse for a specific performance measure. From an understanding of the actual traffic conditions during off peak periods, this period is not the worst performing but only the one that experiences the greatest change. Links under this peak period begin with less trips than other peak periods therefore allowing

for a greater change. Utilizing a change in values measure is only appropriate for certain scenarios and assessments are more complete if an analysis of traffic conditions includes a normalized performance measure, such as the v/c ratio, to show that such a magnitude in change may not cause the roadway to perform poorly or fail.

6.2 Future Work

Creating new timing plans for coordinated signals based on the additional volume the arterials experience is a possible future work of this paper. After assessing traffic conditions over the network and determining an alternate route, the next step in the diversion strategy process is to analyze the chosen arterial specifically the signal timing of the signalized interchanges along the arterial.

The network and specifically the freeway analysis could also be expanded by a more detailed assessment. Instead of using the v/c ratio for a performance measure of the freeways, determining the density of freeway segments in accordance with the Highway Capacity Manual could provide a more accurate view of the traffic conditions. Since other freeway-arterial interchanges along the corridor are more utilized in a scenario when another interchange in the corridor is closed, it would be interesting to assess the ramp influence area level of service of the adjacent interchanges (theoretically, these are the interchanges that are influenced the most by the closure). This expansion would allow for an understanding of the operation of other heavily influenced interchanges under abnormal conditions.

Chapter 7

CONCLUSION

A closure of a freeway-arterial interchange will undoubtedly affect the roadway network of the corridor in an adverse manner but the unknown remains how until such closures as modeled. It is evident from this research that one solutions does not fit all as each of the three interchanges analyzed for this paper resulted in different prevailing traffic conditions affecting different parts of the network at different expanses. Research such as this one is most essential to state planners and traffic management centers in order to better prepare them in directing traffic around incidents and closures in an effort to return a system to normal operations.

Much of the previous research on this topic involves the closing of a single direction of traffic on freeway. While this type of closure may statistically be more probable, a closure of an interchange involving two important links in a network, a freeway and a major arterial, has a greater chance of influences a network on a larger scale both in magnitude and expanse. Interchanges serve as nodes of a system providing transfer points and thus attracting a considerable number of users. Their operational efficiency is imperative to the overall efficiency of a network. It is common for state departments of transportation to have re-routing plans for segments of a freeway but less common to have re-routing plans for an interchange.

As the US road network evolves, with emerging congestion and growing vitality for the economic health due to the shipping industry's interdependency, its resiliency and reliability becomes paramount as does alternate route planning research.

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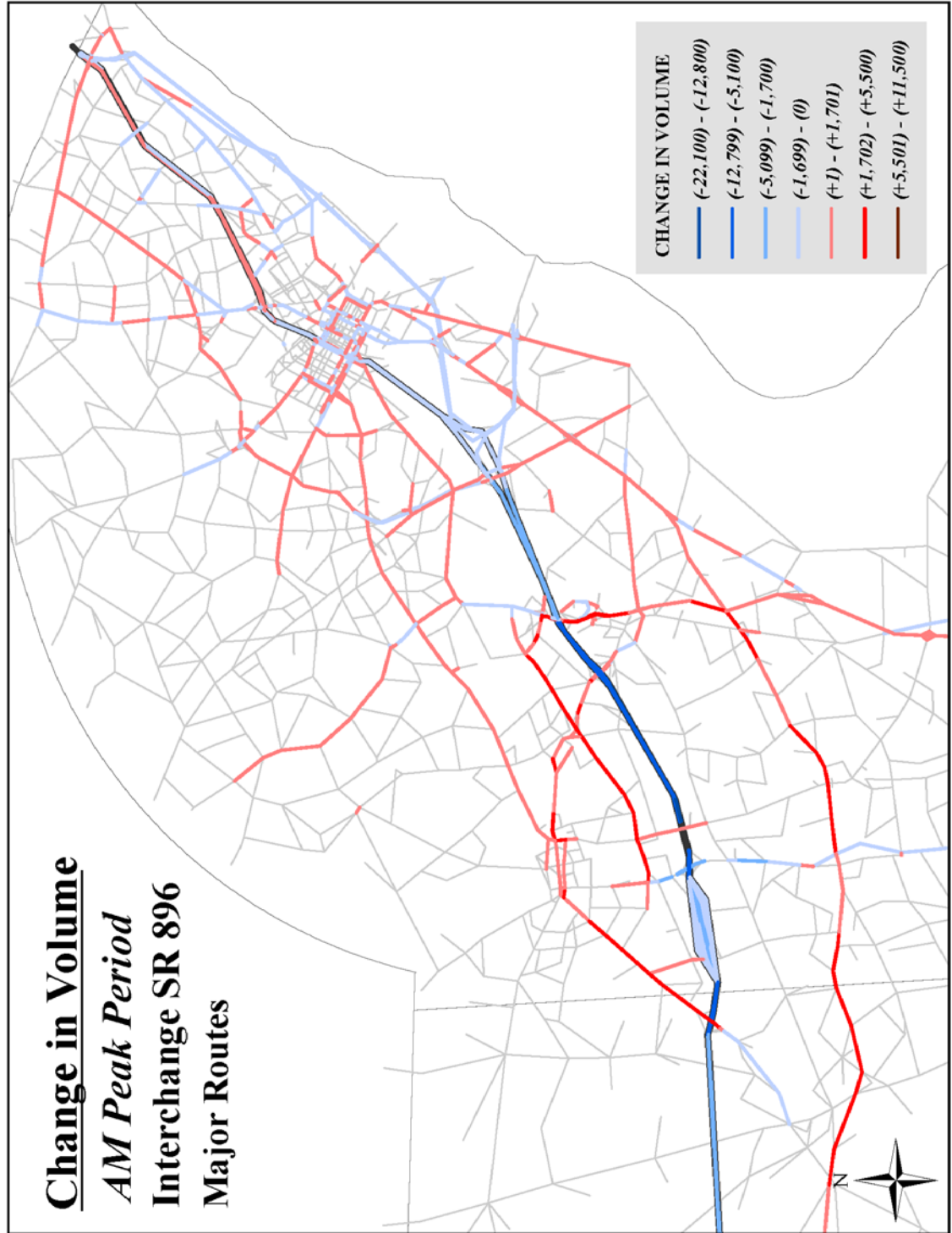
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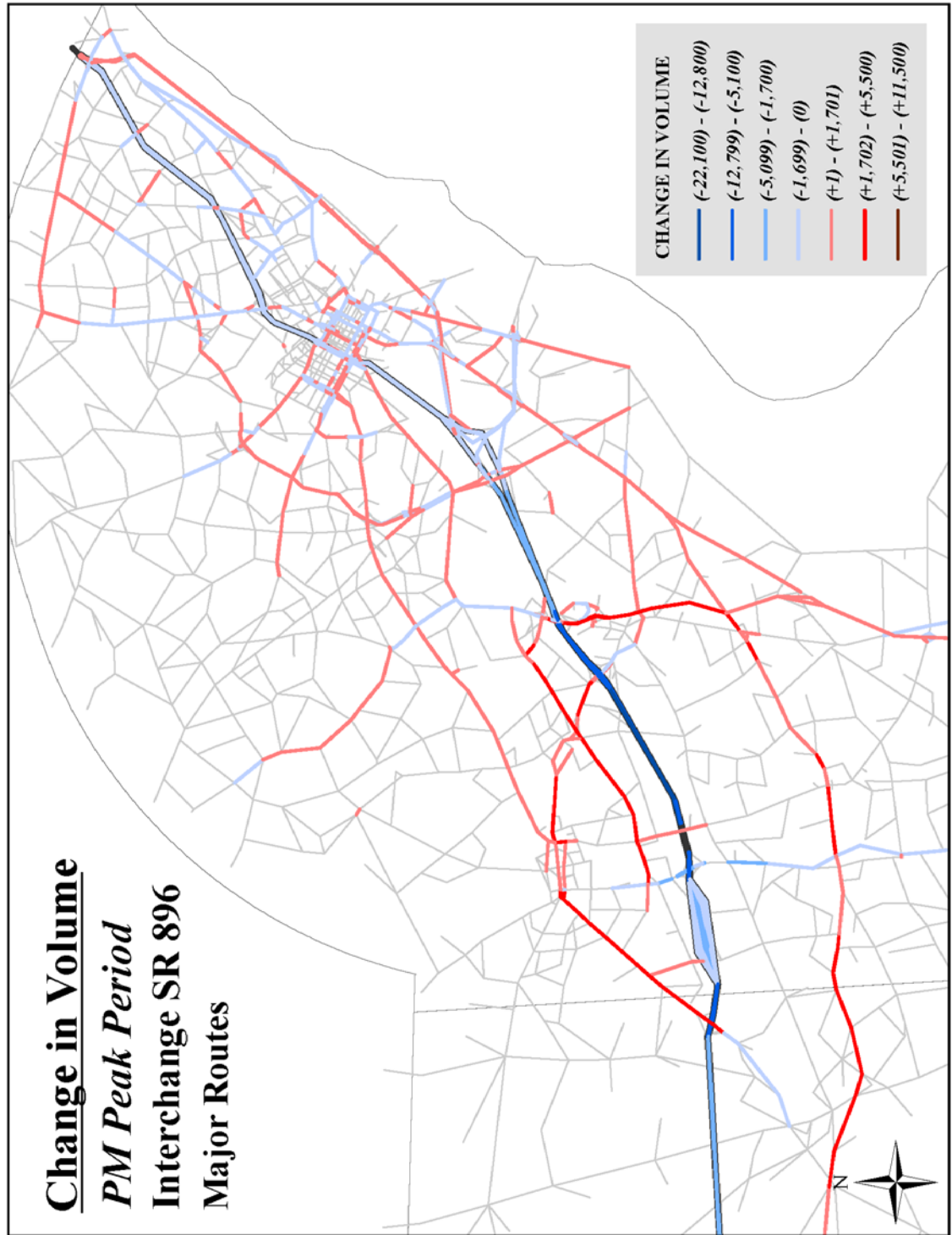
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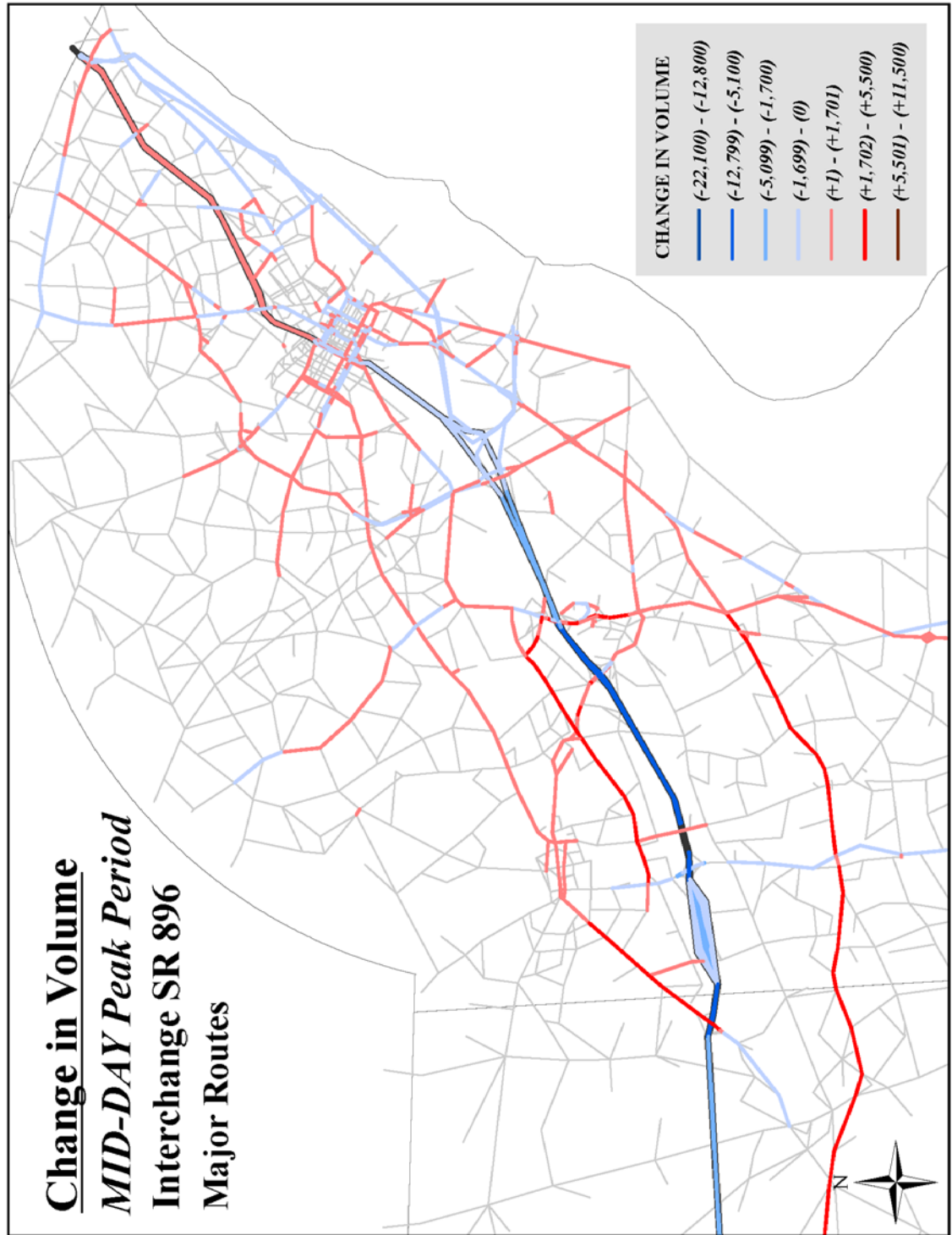
APPENDIX

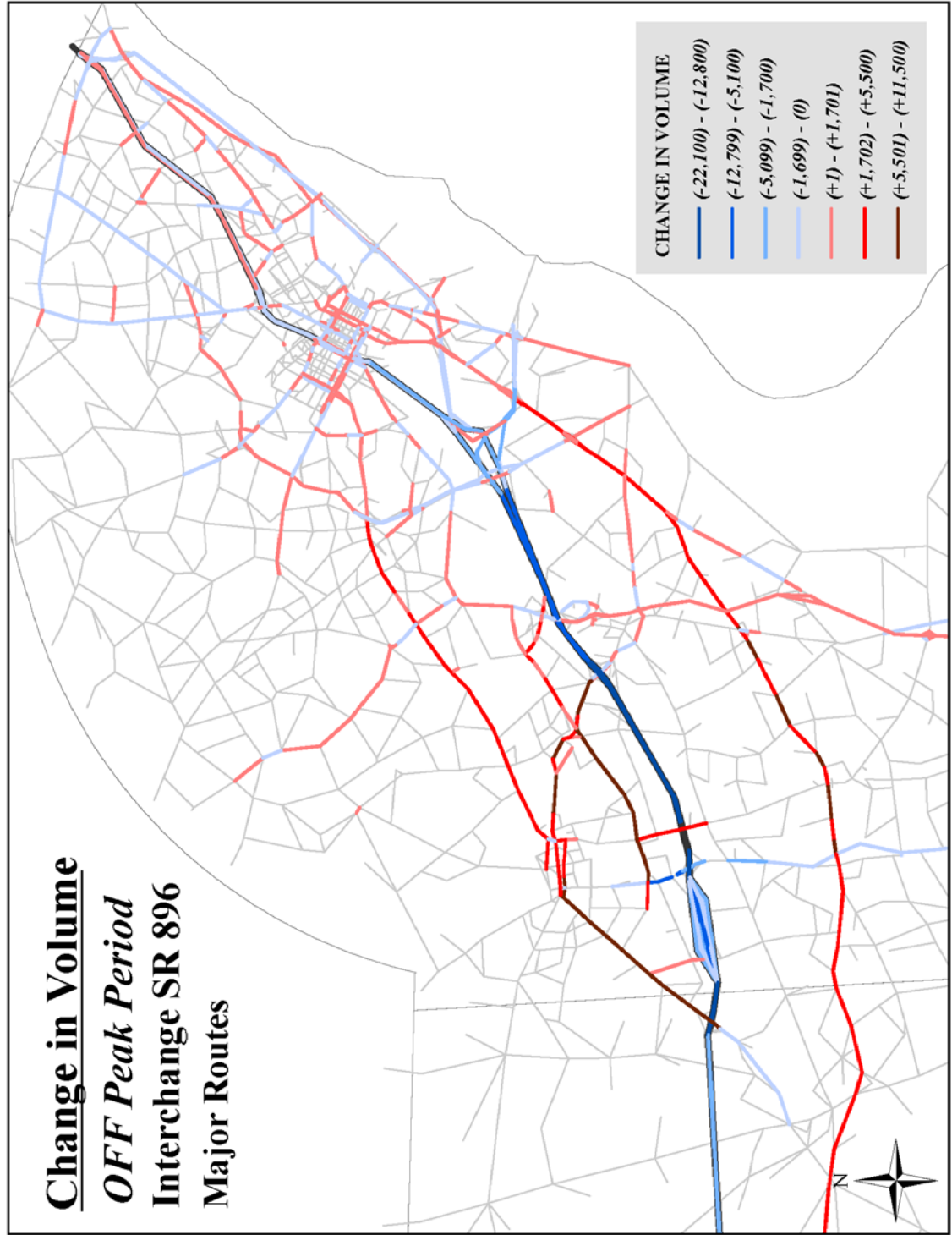
Appendix A

ENLARGED MAPS : INTERCHANGE SR 896



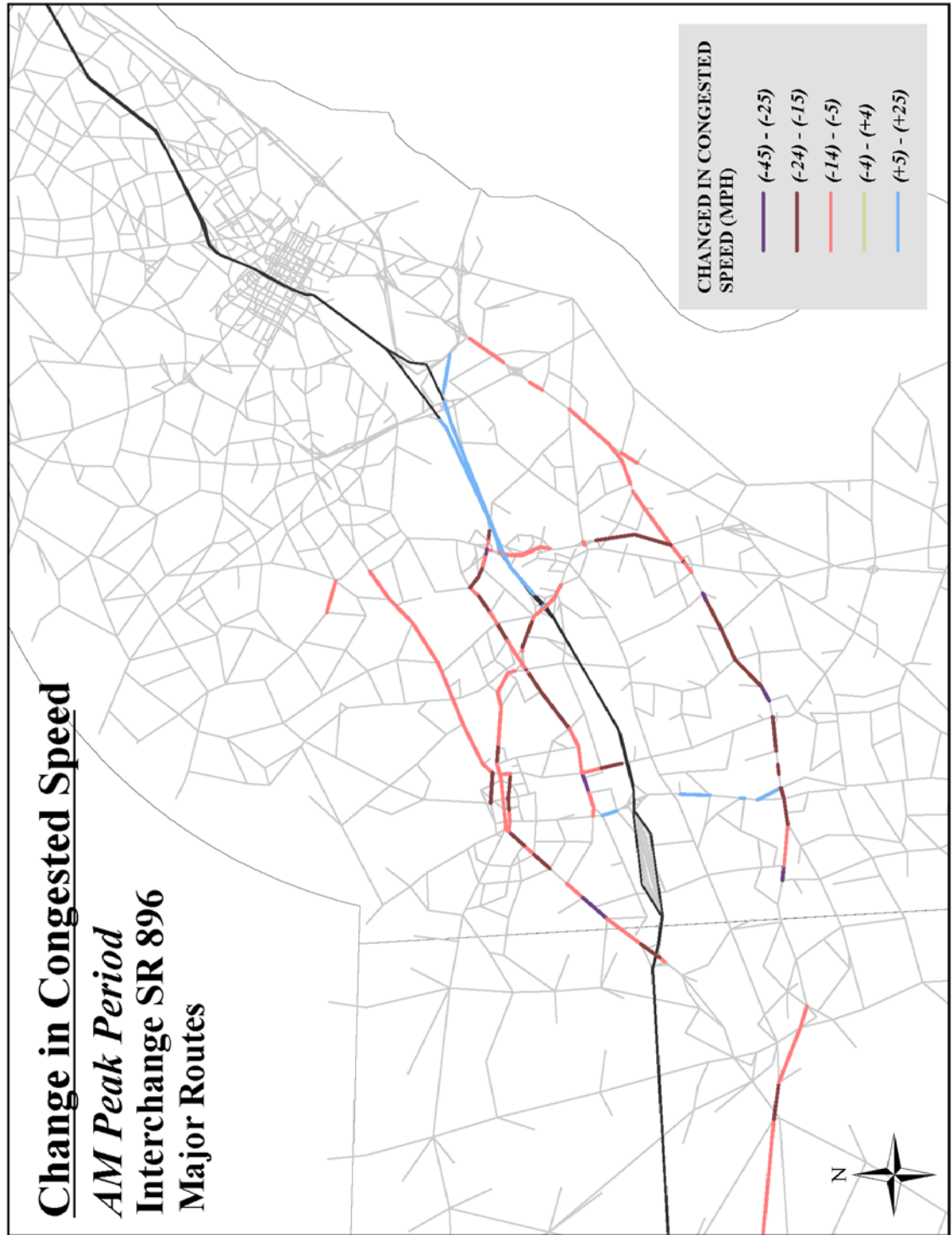


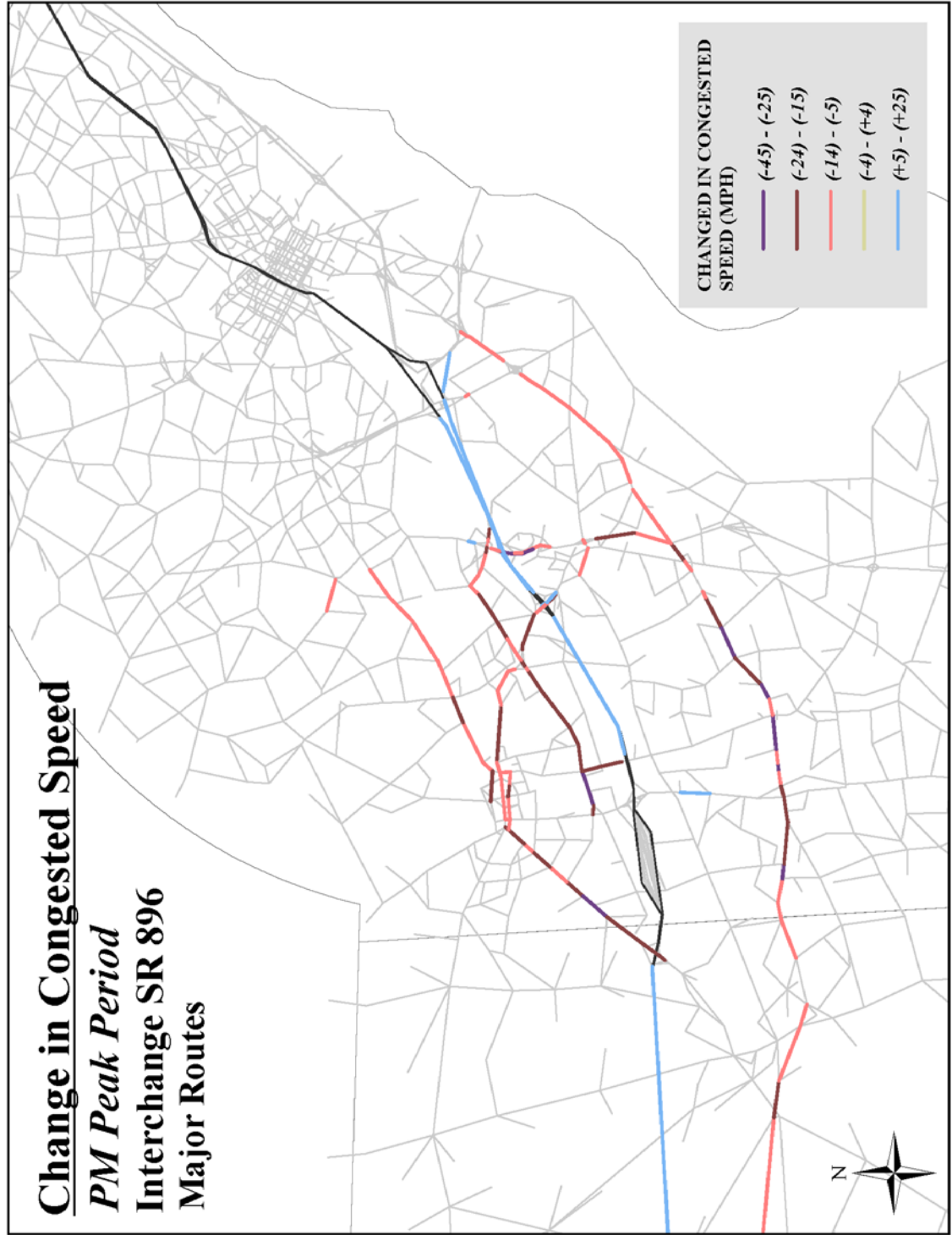




Change in Congested Speed

AM Peak Period
Interchange SR 896
Major Routes



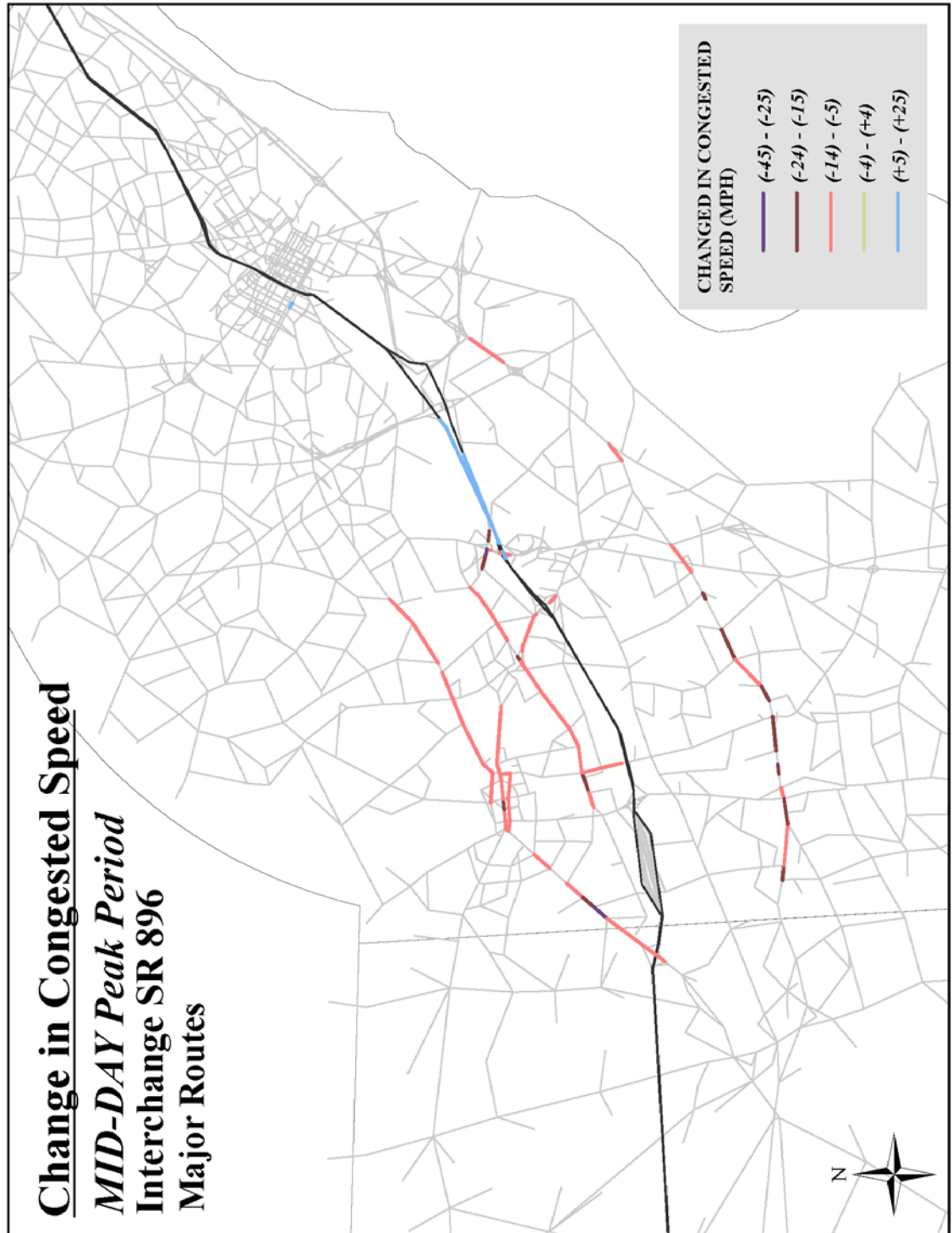


Change in Congested Speed

MID-DAY Peak Period

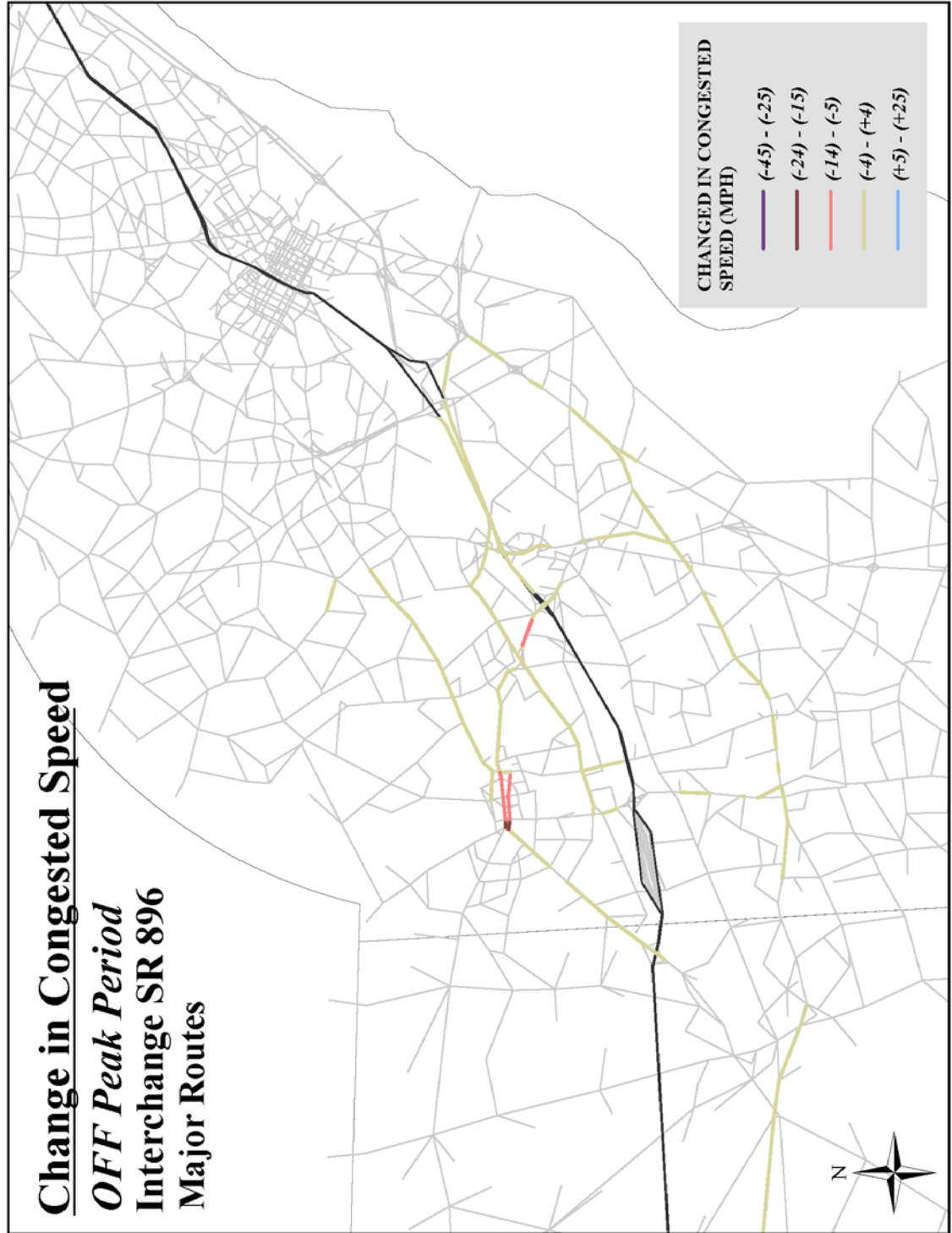
Interchange SR 896

Major Routes

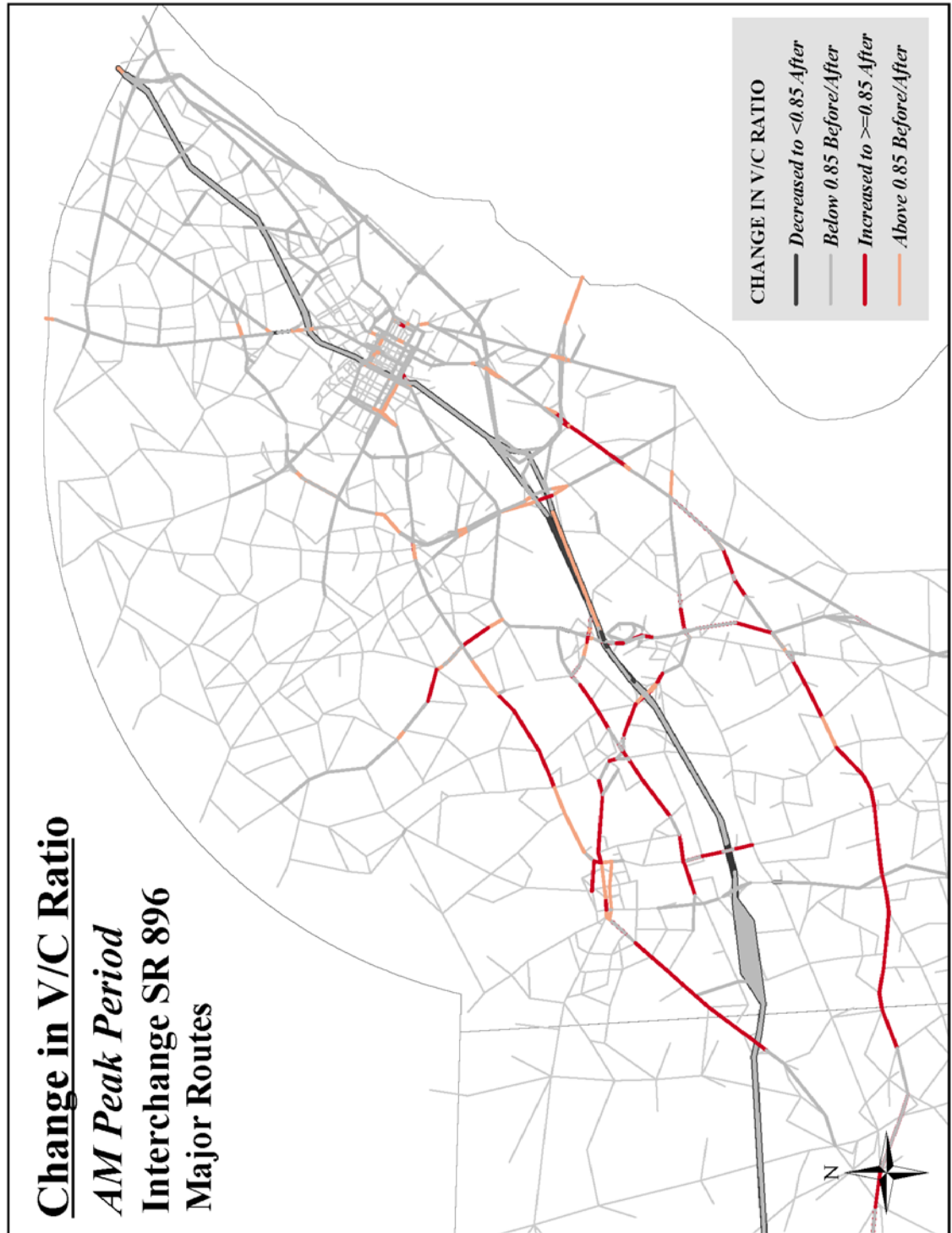


Change in Congested Speed

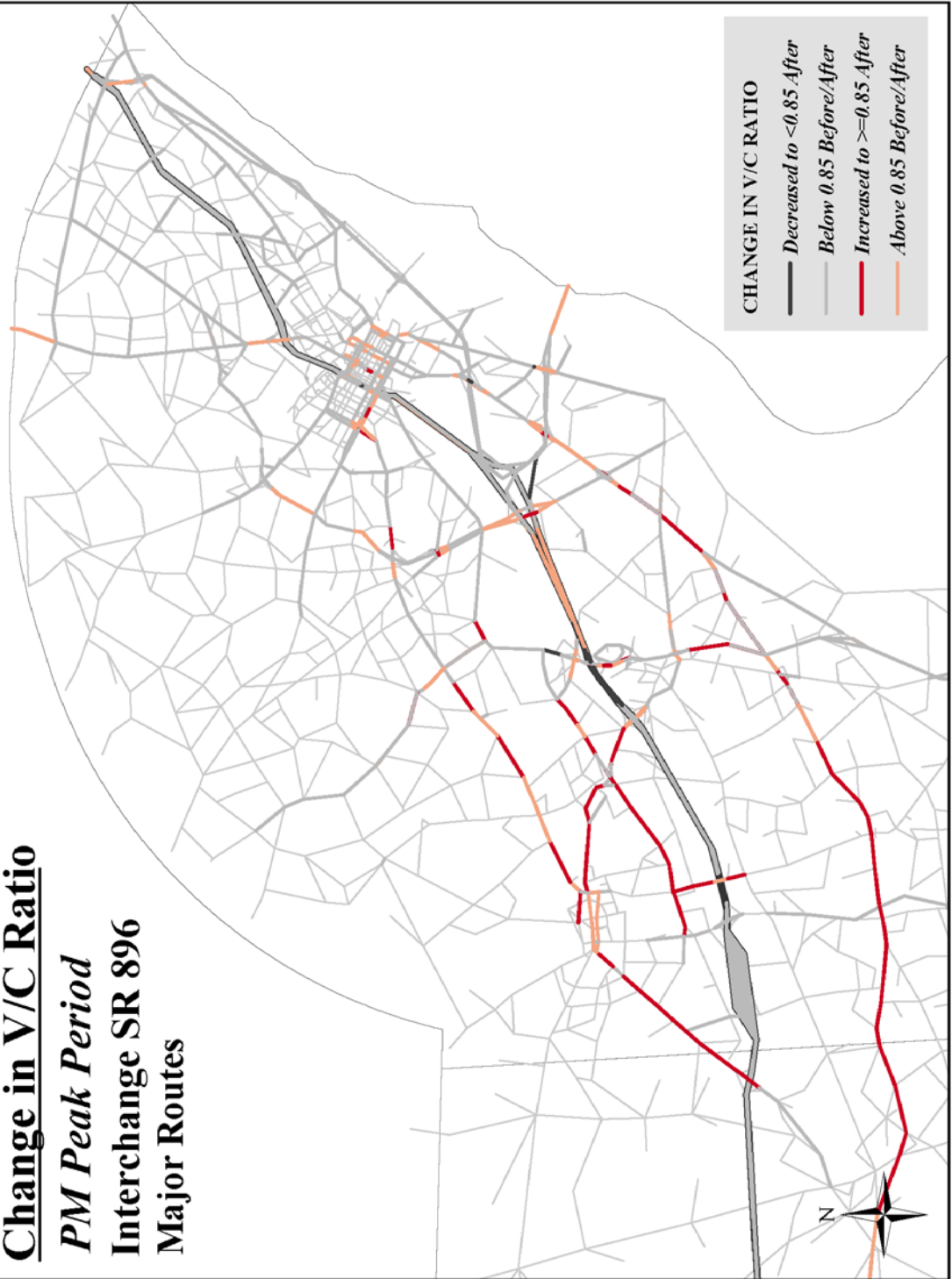
OFF Peak Period
Interchange SR 896
Major Routes

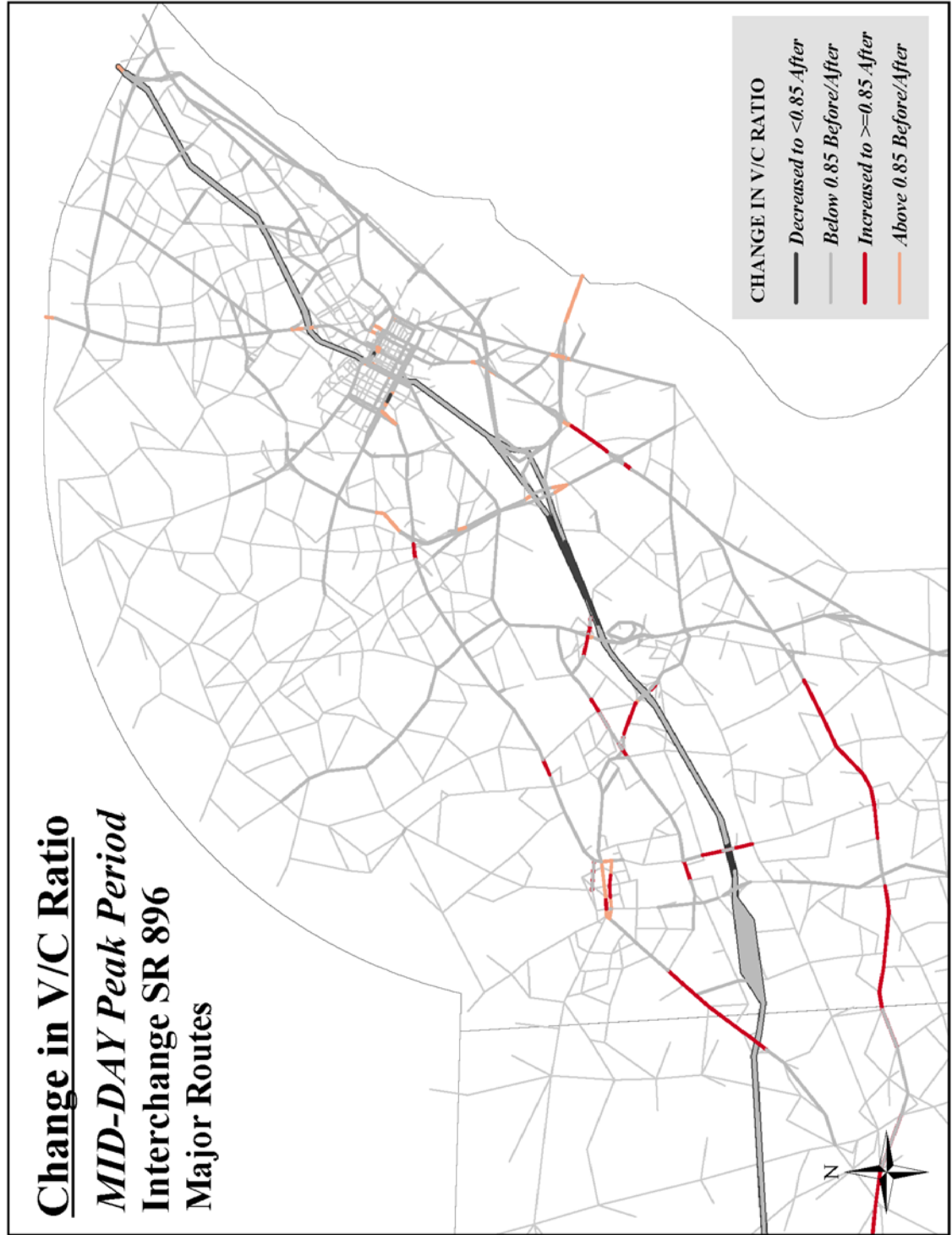


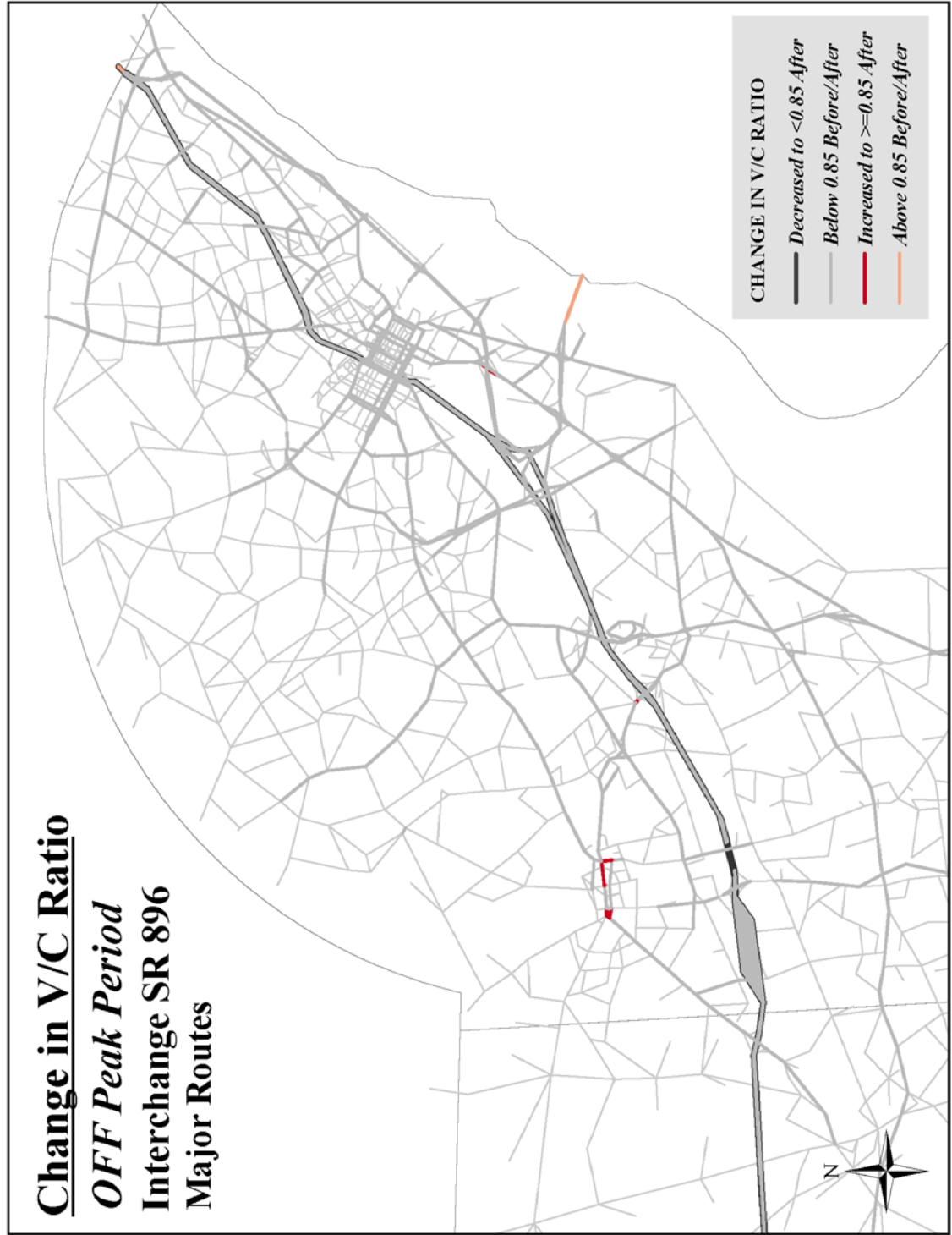
Change in V/C Ratio
AM Peak Period
Interchange SR 896
Major Routes



Change in V/C Ratio
PM Peak Period
Interchange SR 896
Major Routes



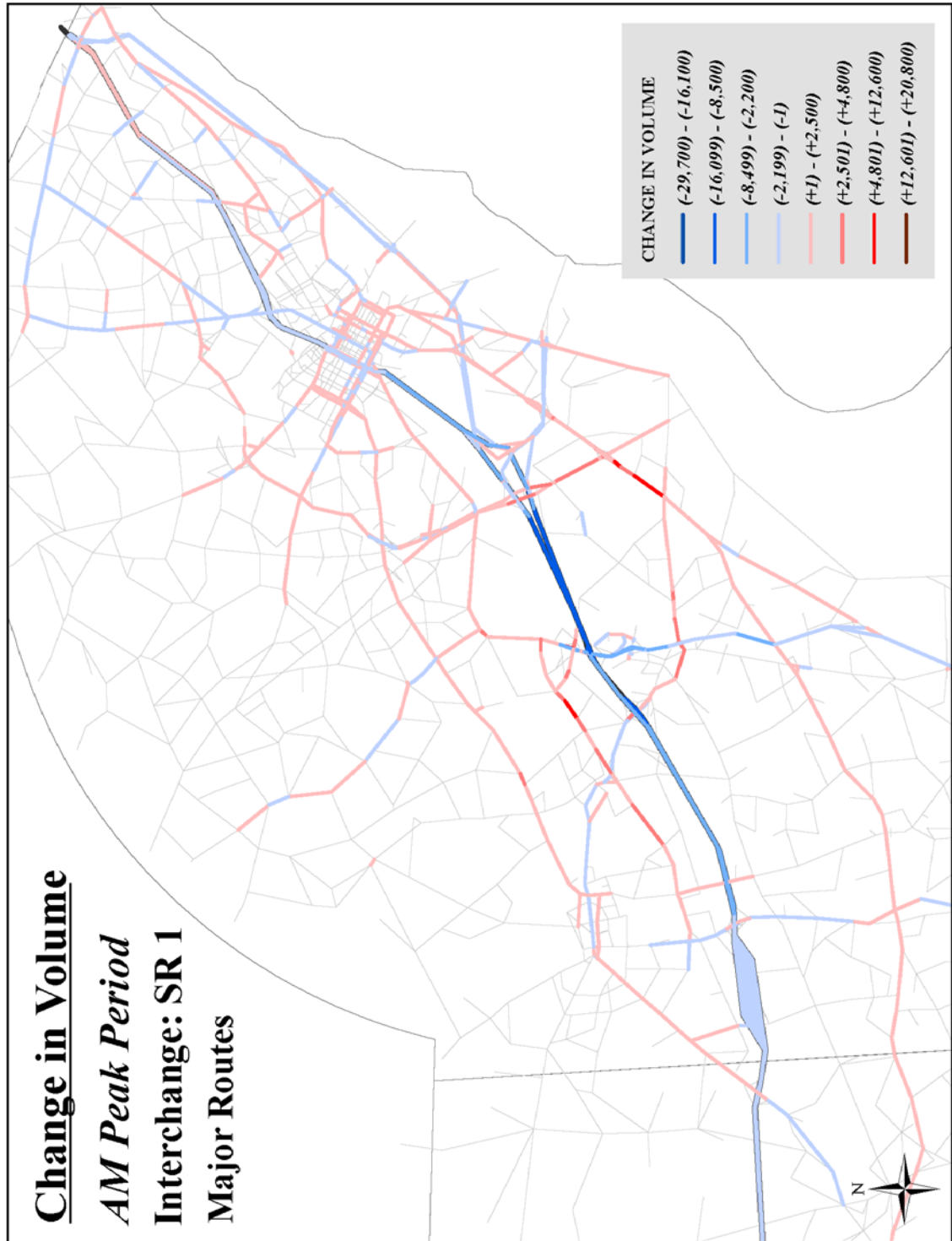




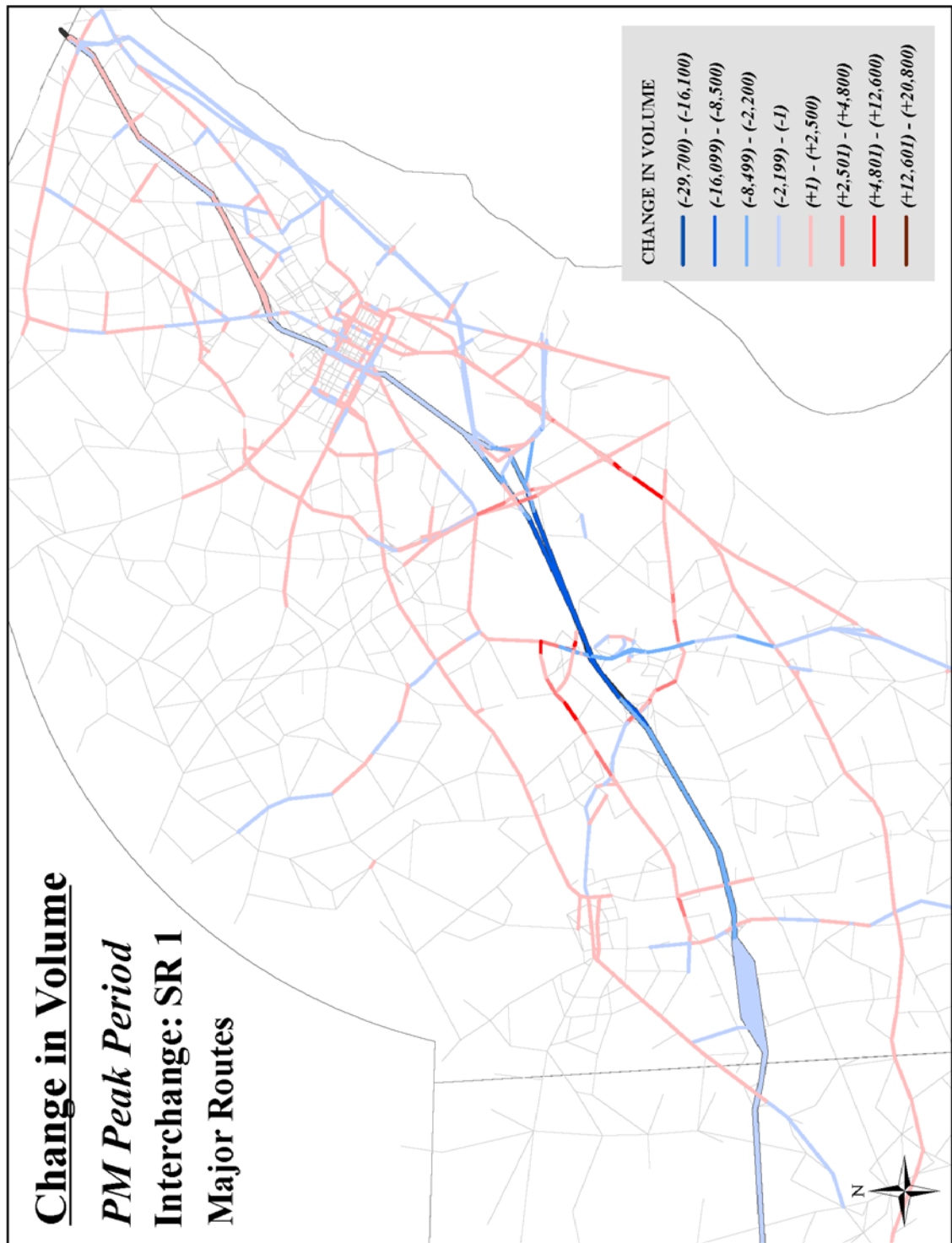
Appendix B

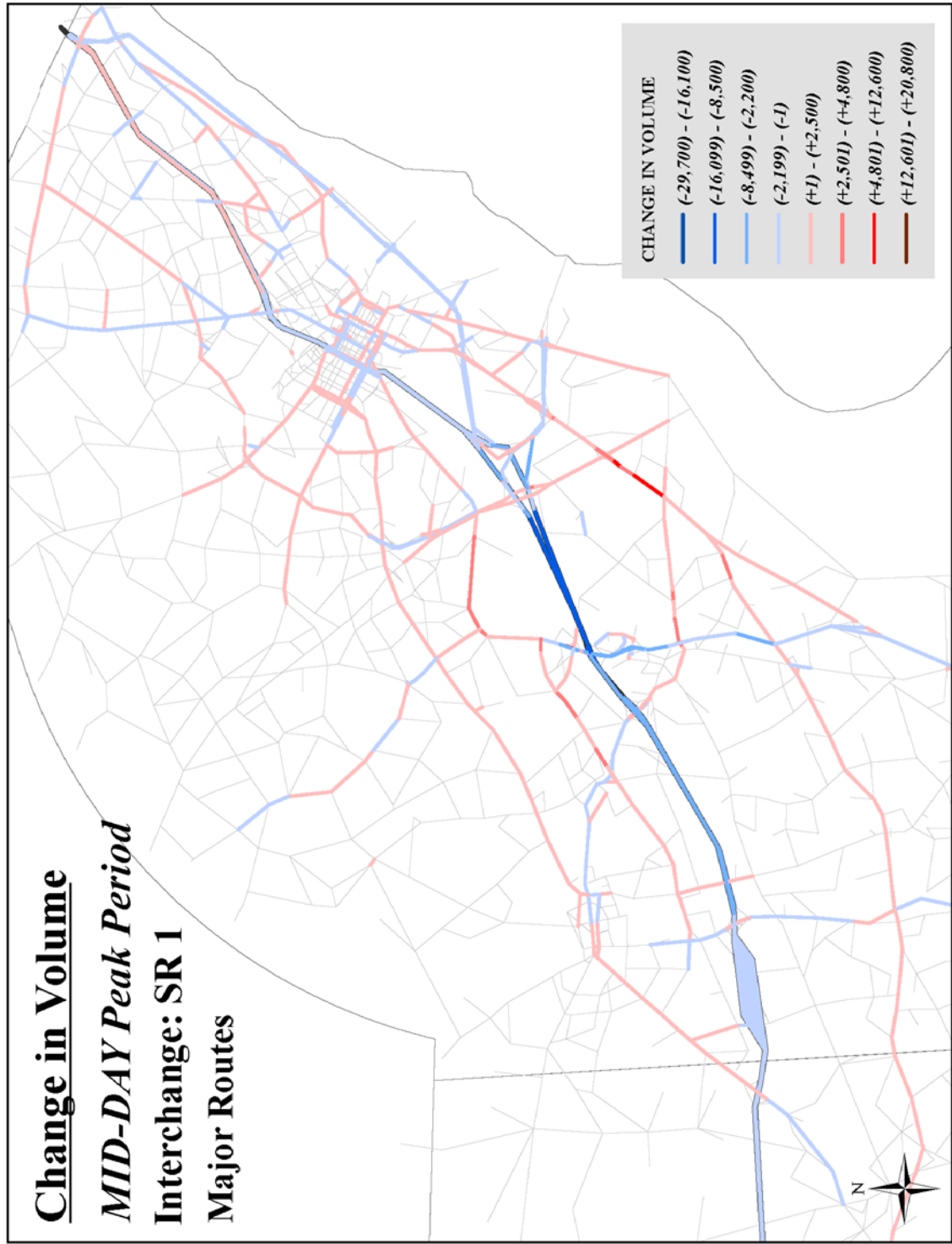
ENLARGED MAPS : INTERCHANGE SR 1

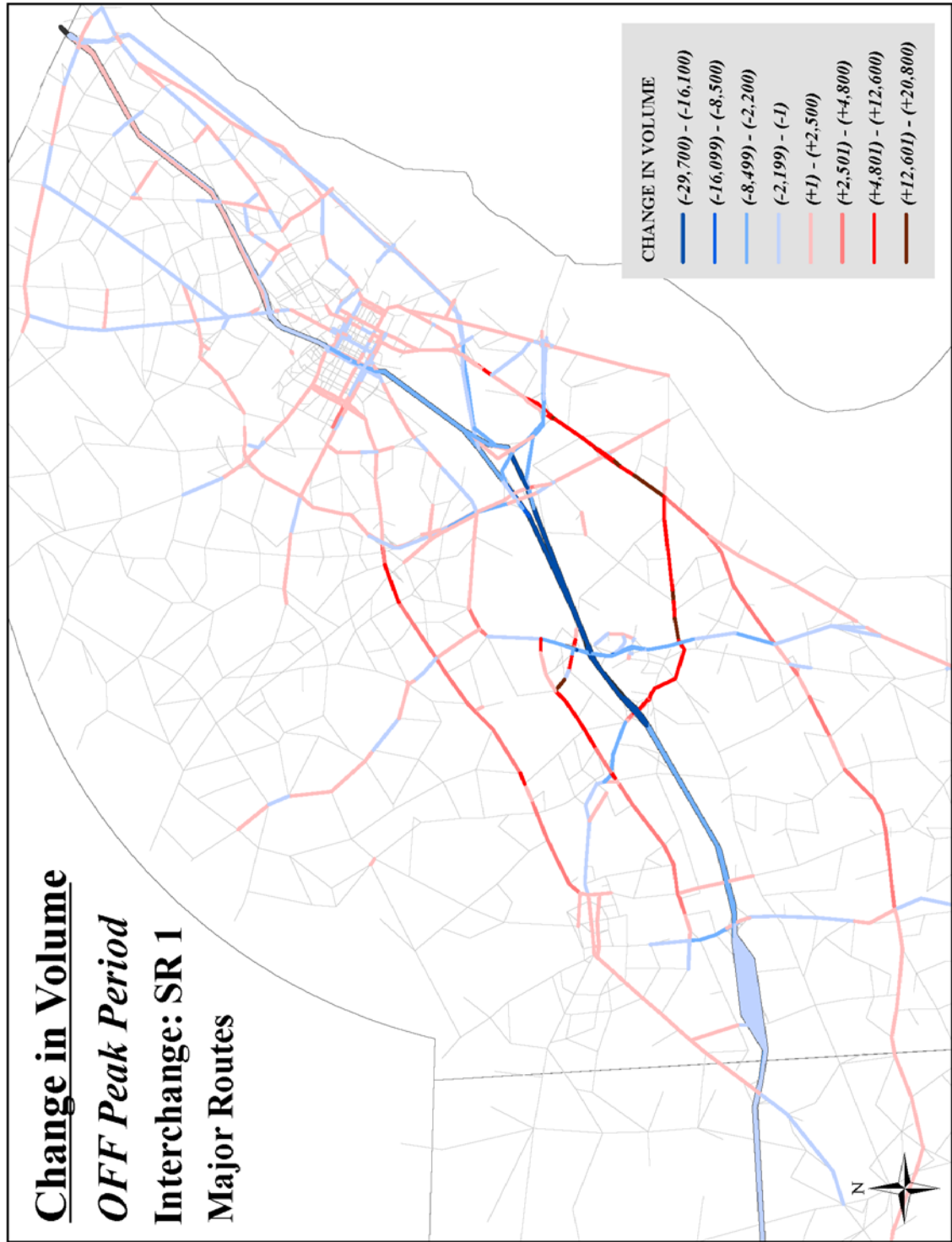
Change in Volume
AM Peak Period
Interchange: SR 1
Major Routes



Change in Volume
PM Peak Period
Interchange: SR 1
Major Routes

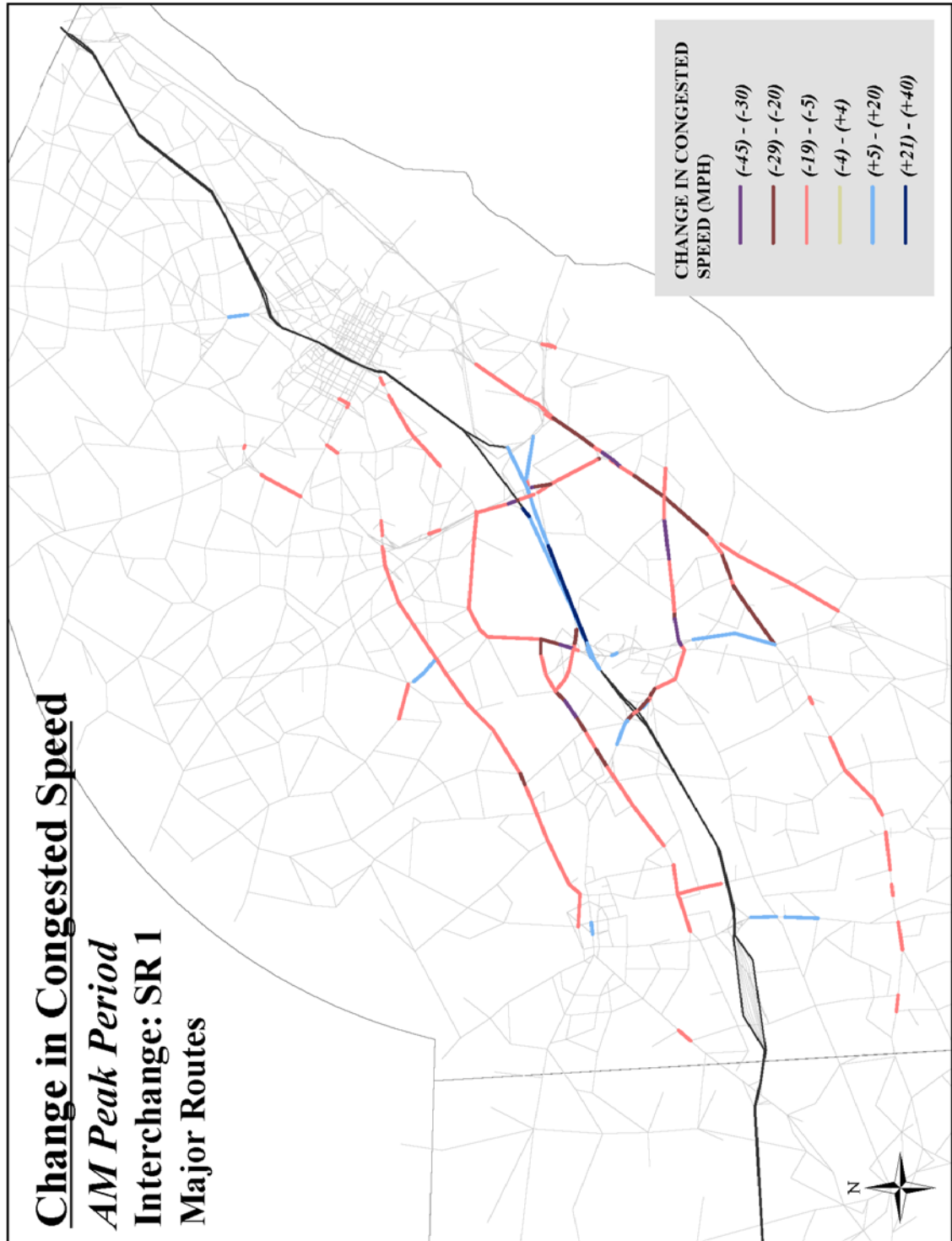






Change in Congested Speed

AM Peak Period
Interchange: SR 1
Major Routes

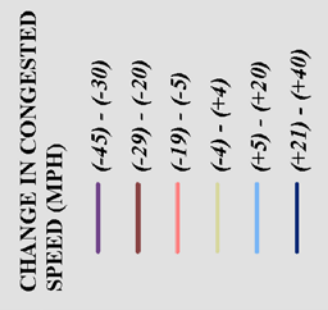


Change in Congested Speed

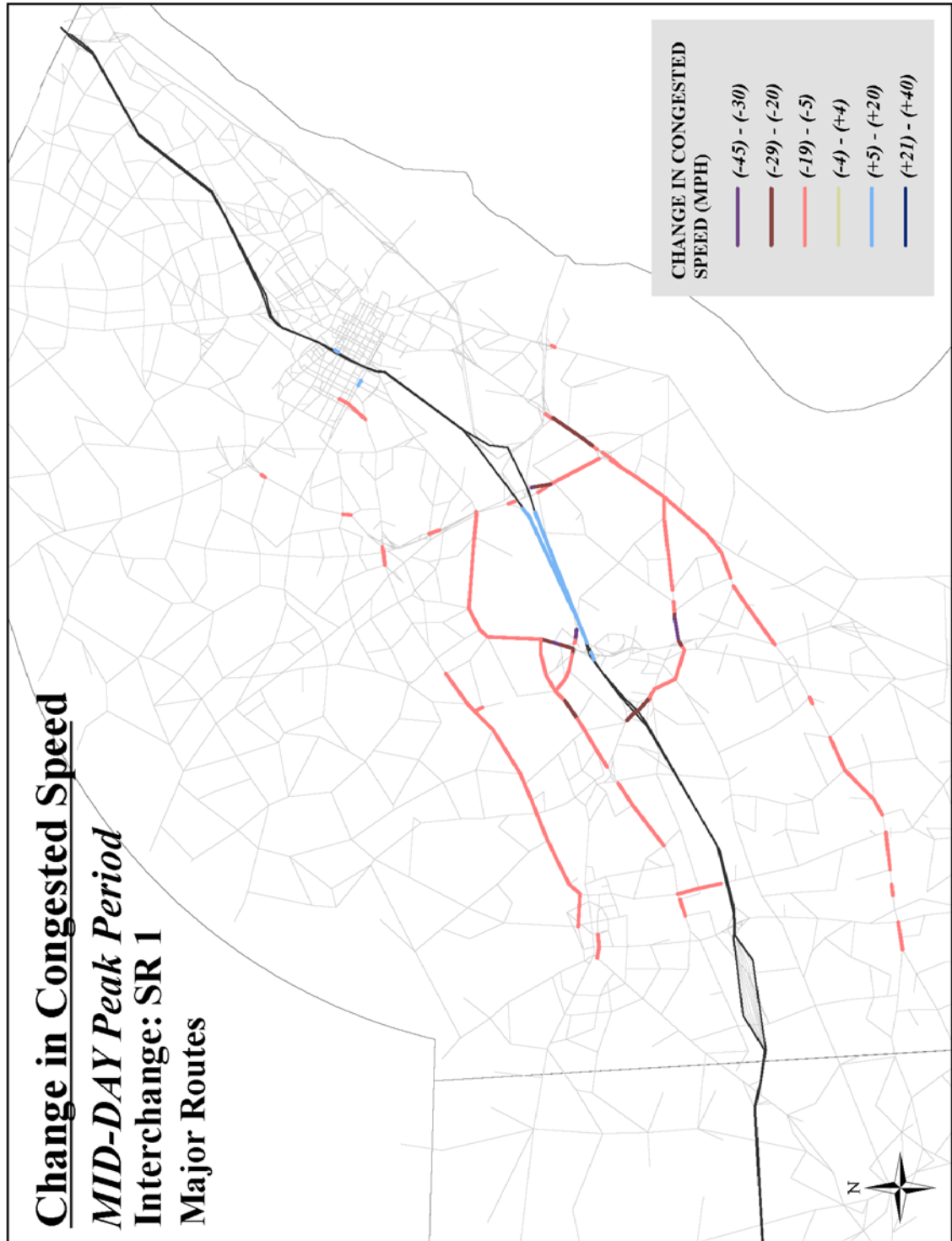
PM Peak Period

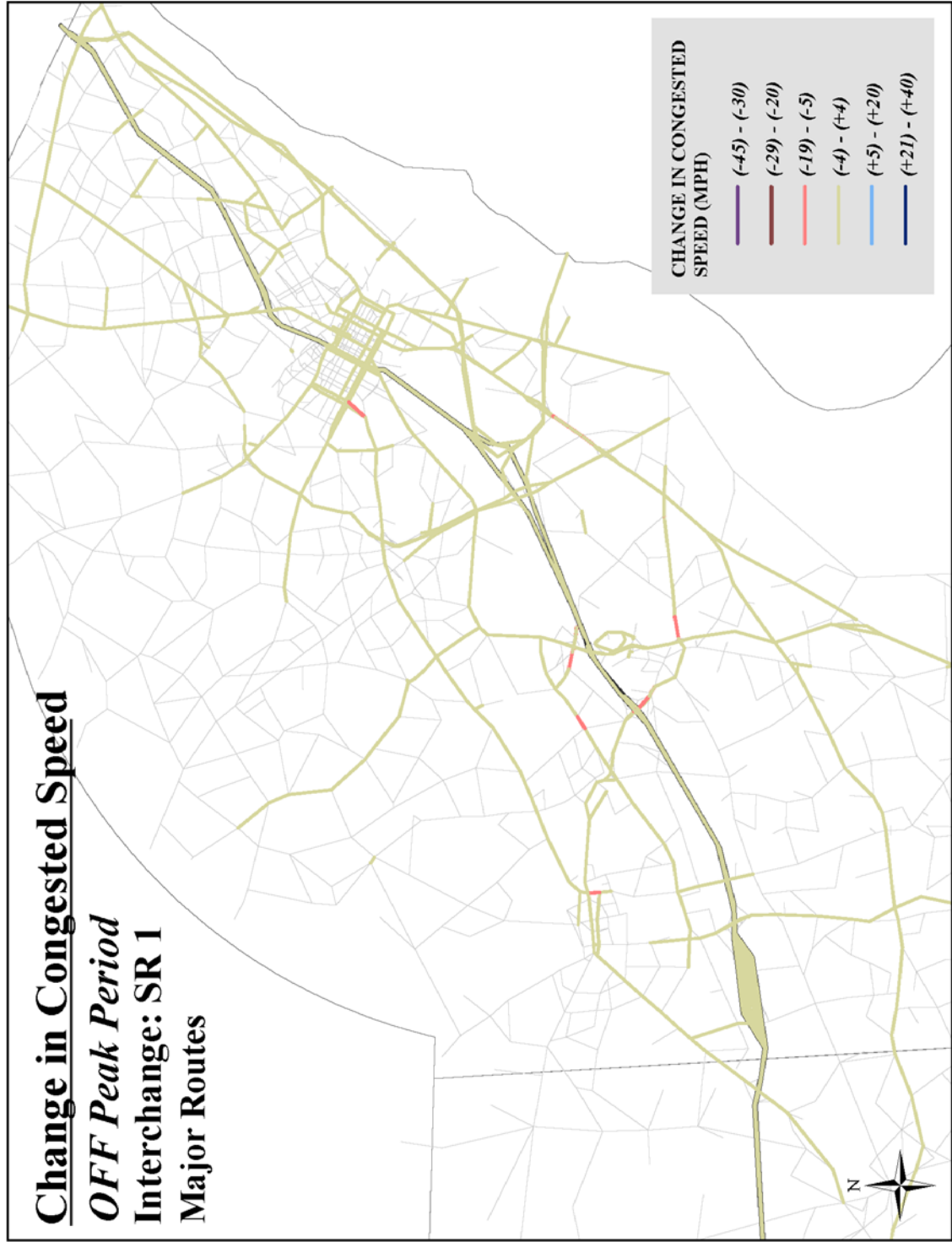
Interchange: SR 1

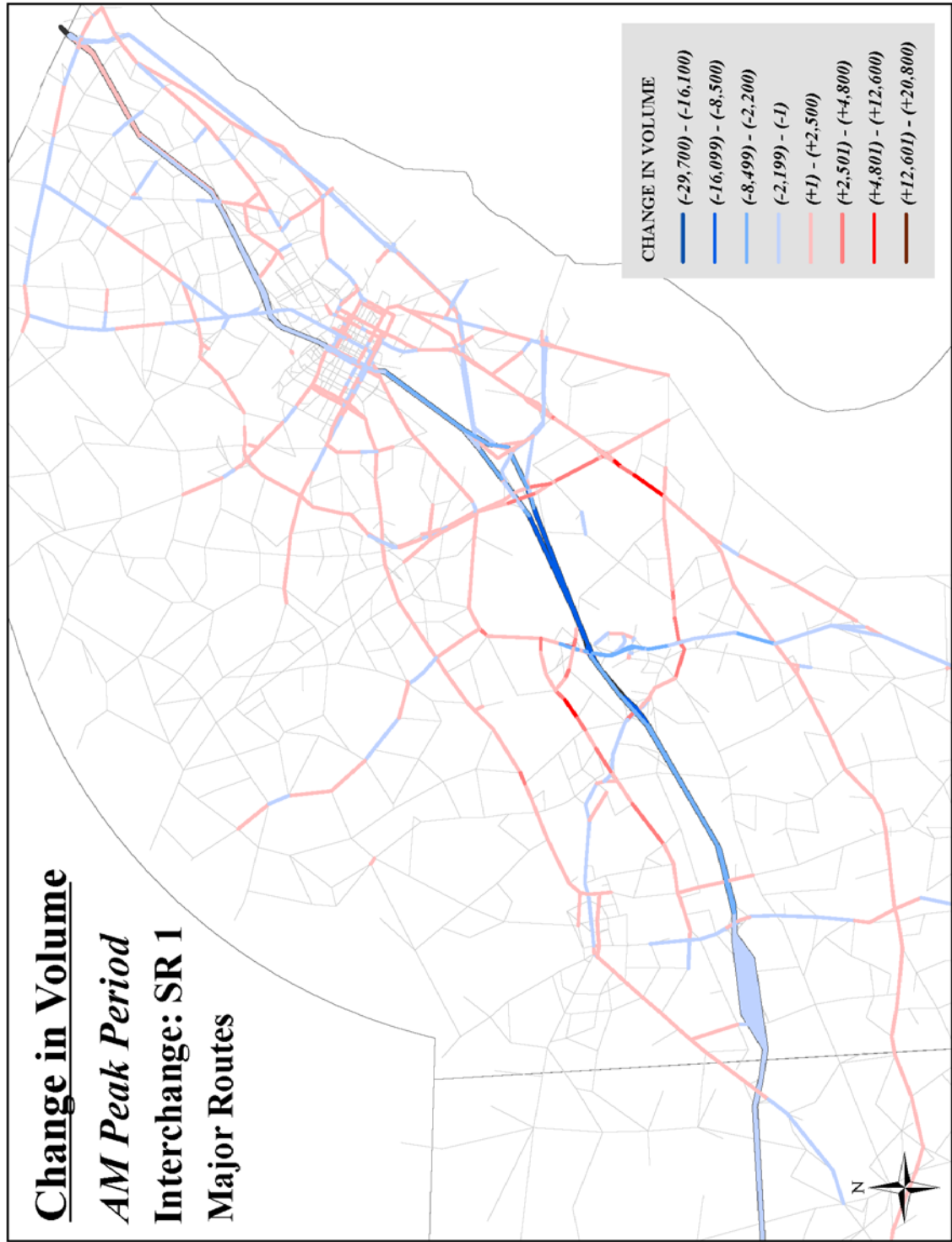
Major Routes

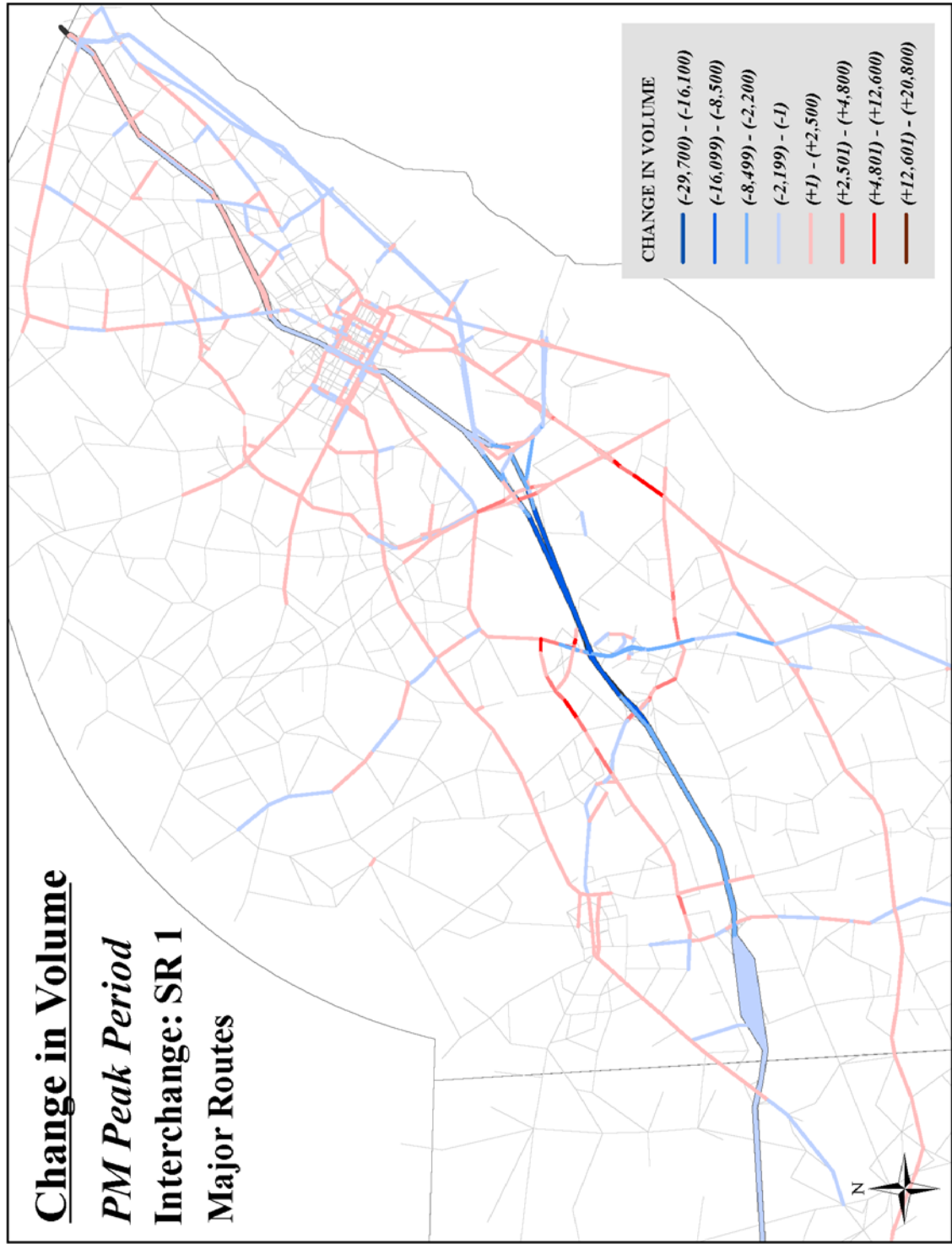


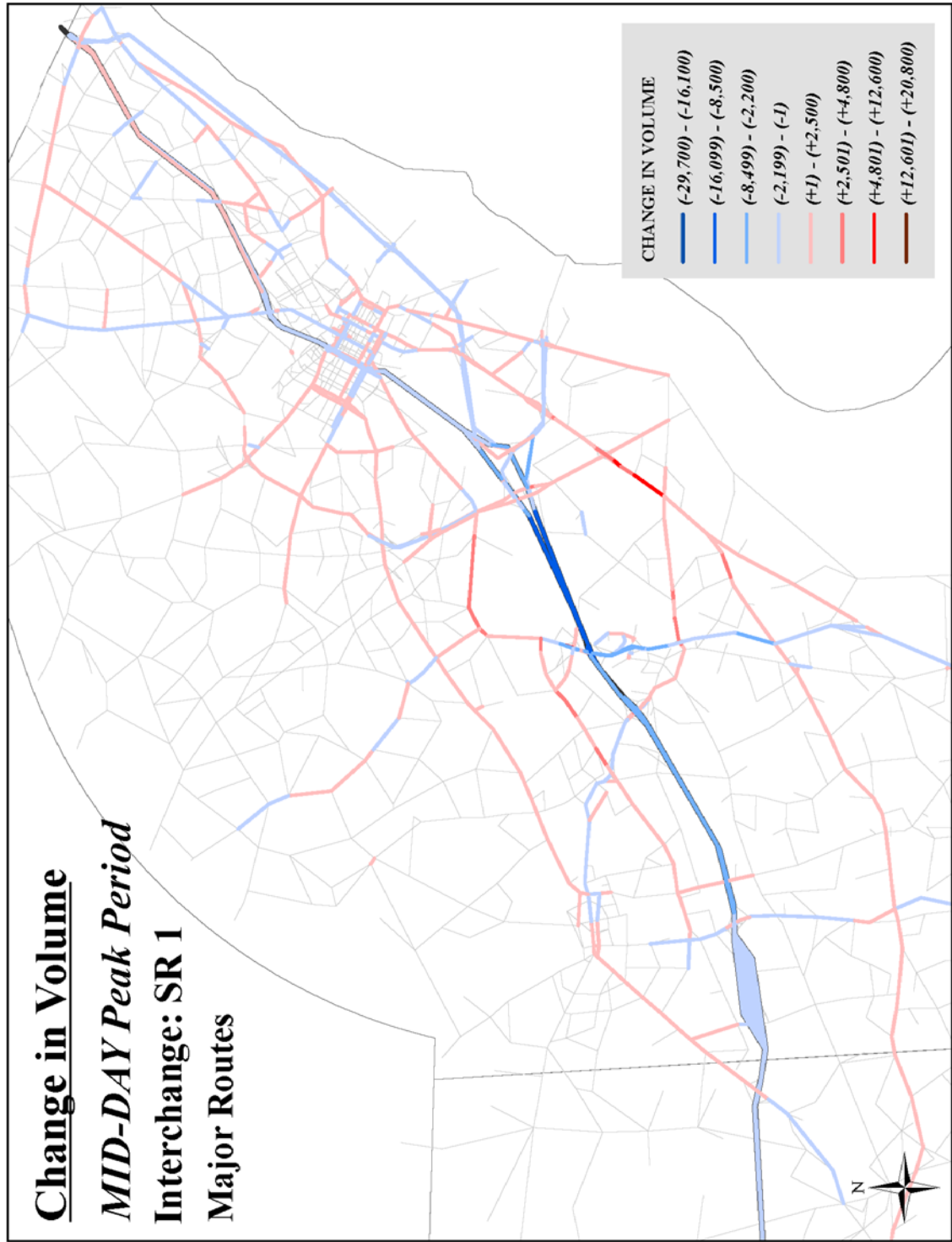
Change in Congested Speed
MID-DAY Peak Period
Interchange: SR 1
Major Routes

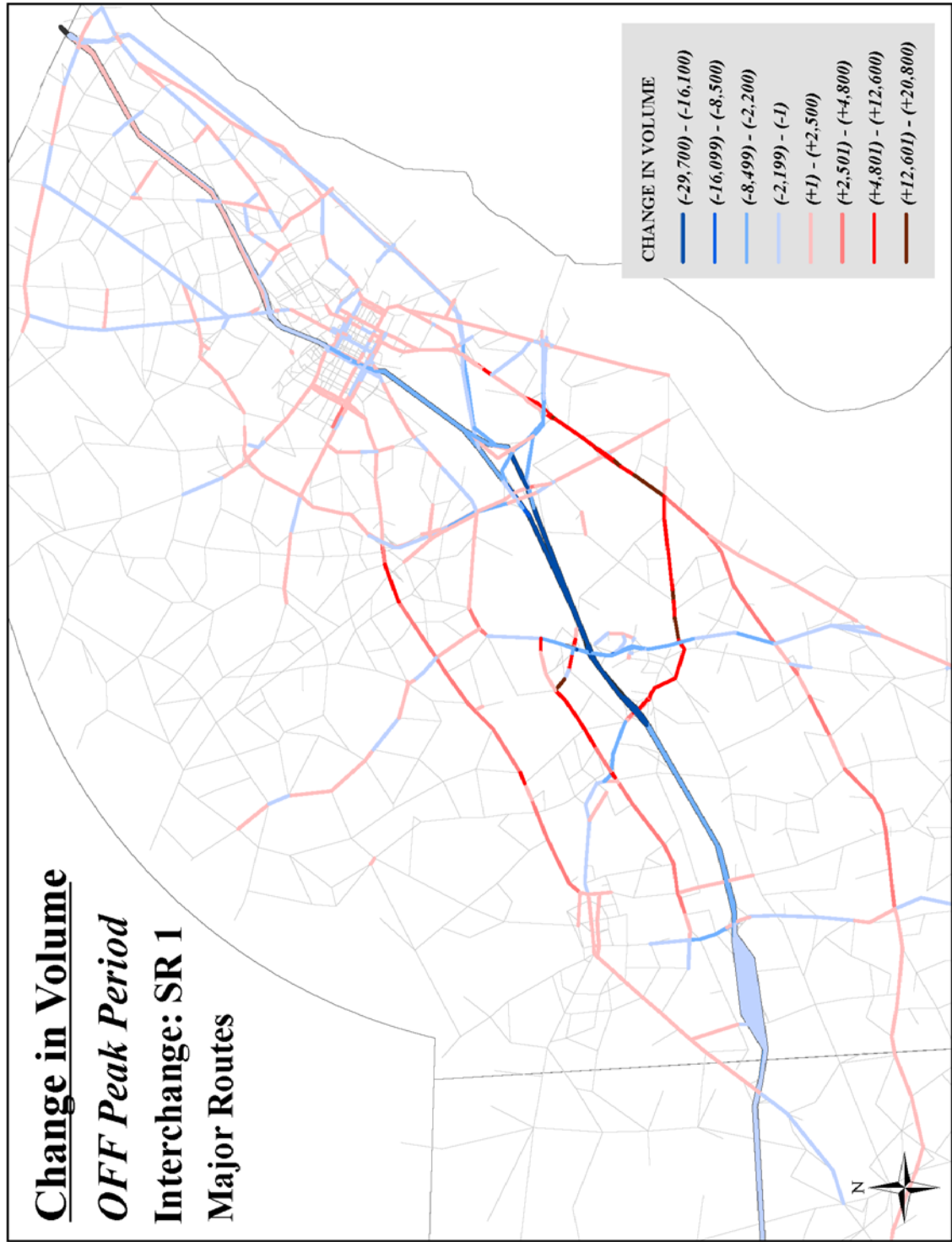










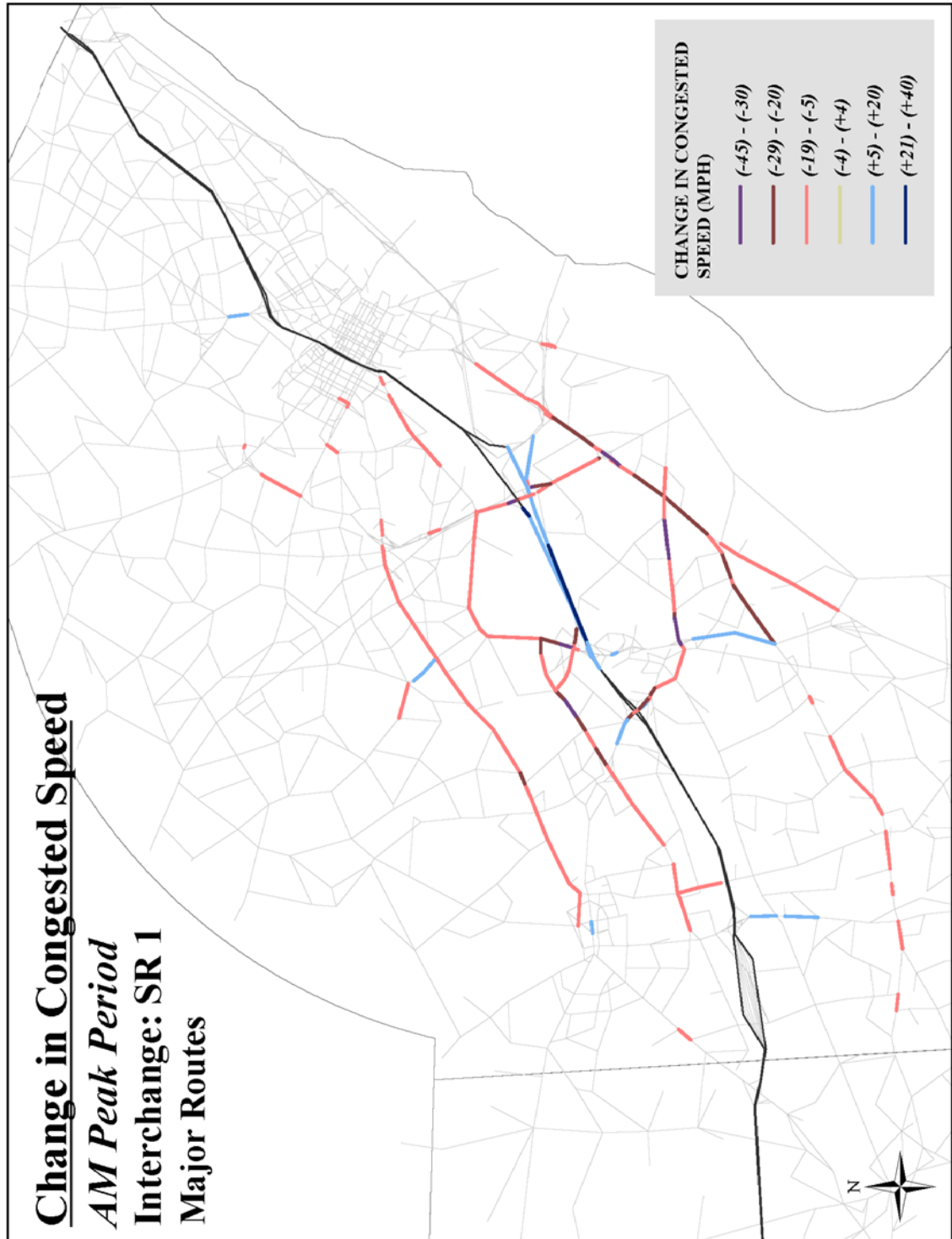


Change in Congested Speed

AM Peak Period

Interchange: SR 1

Major Routes

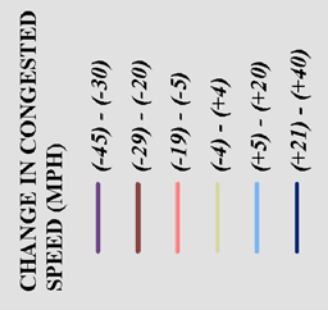


Change in Congested Speed

PM Peak Period

Interchange: SR 1

Major Routes

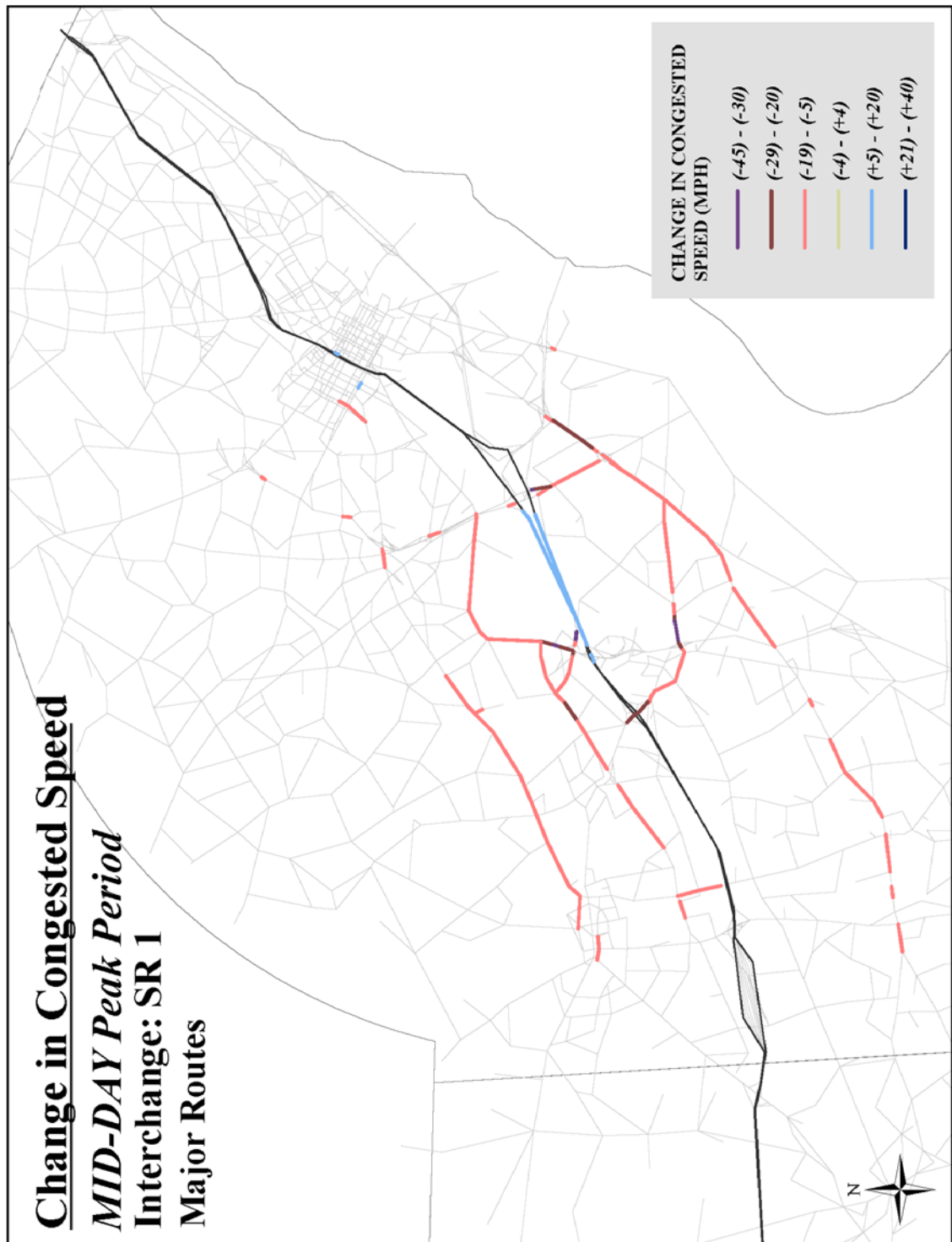


Change in Congested Speed

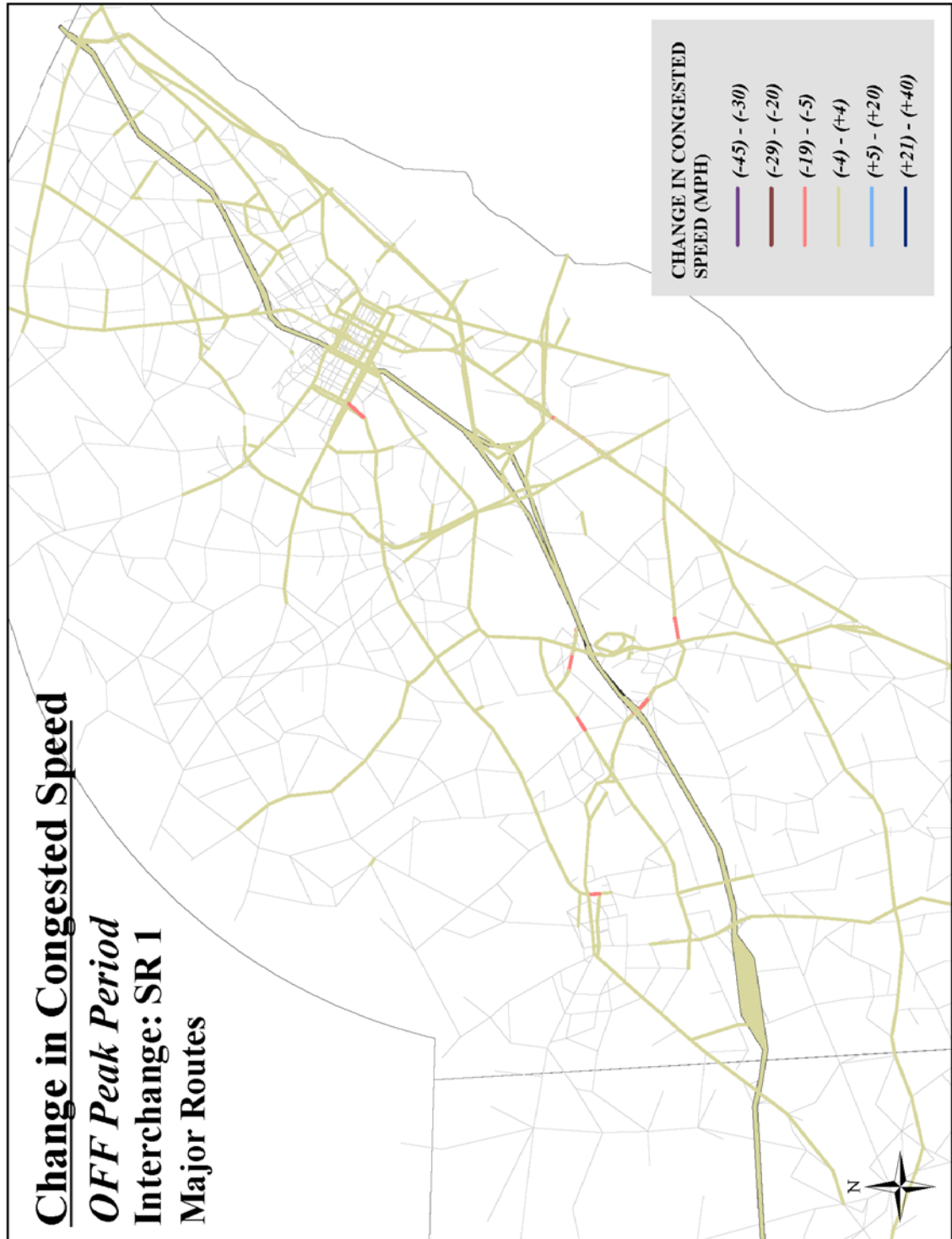
MID-DAY Peak Period

Interchange: SR 1

Major Routes



Change in Congested Speed
OFF Peak Period
Interchange: SR 1
Major Routes

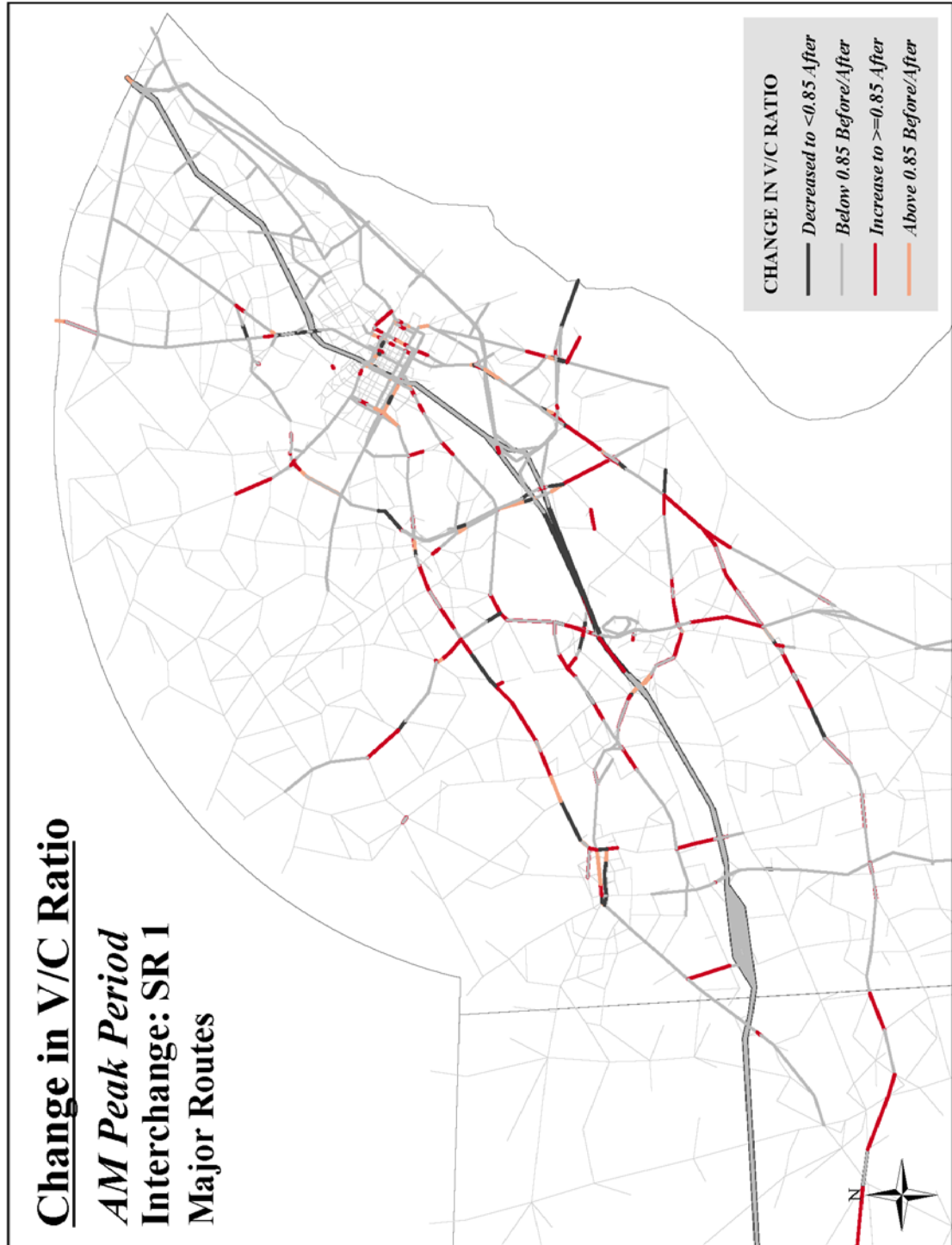


Change in V/C Ratio

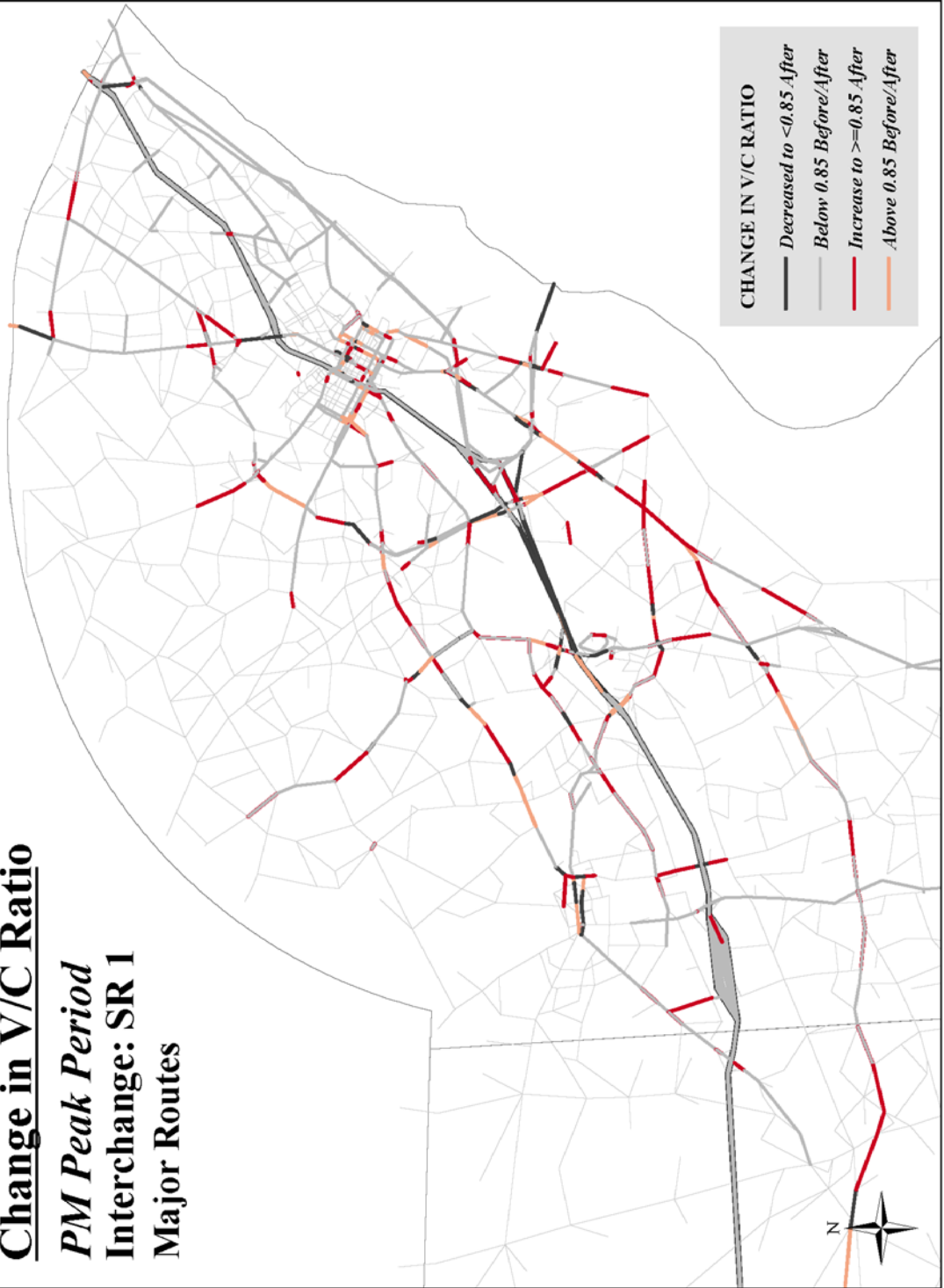
AM Peak Period

Interchange: SR 1

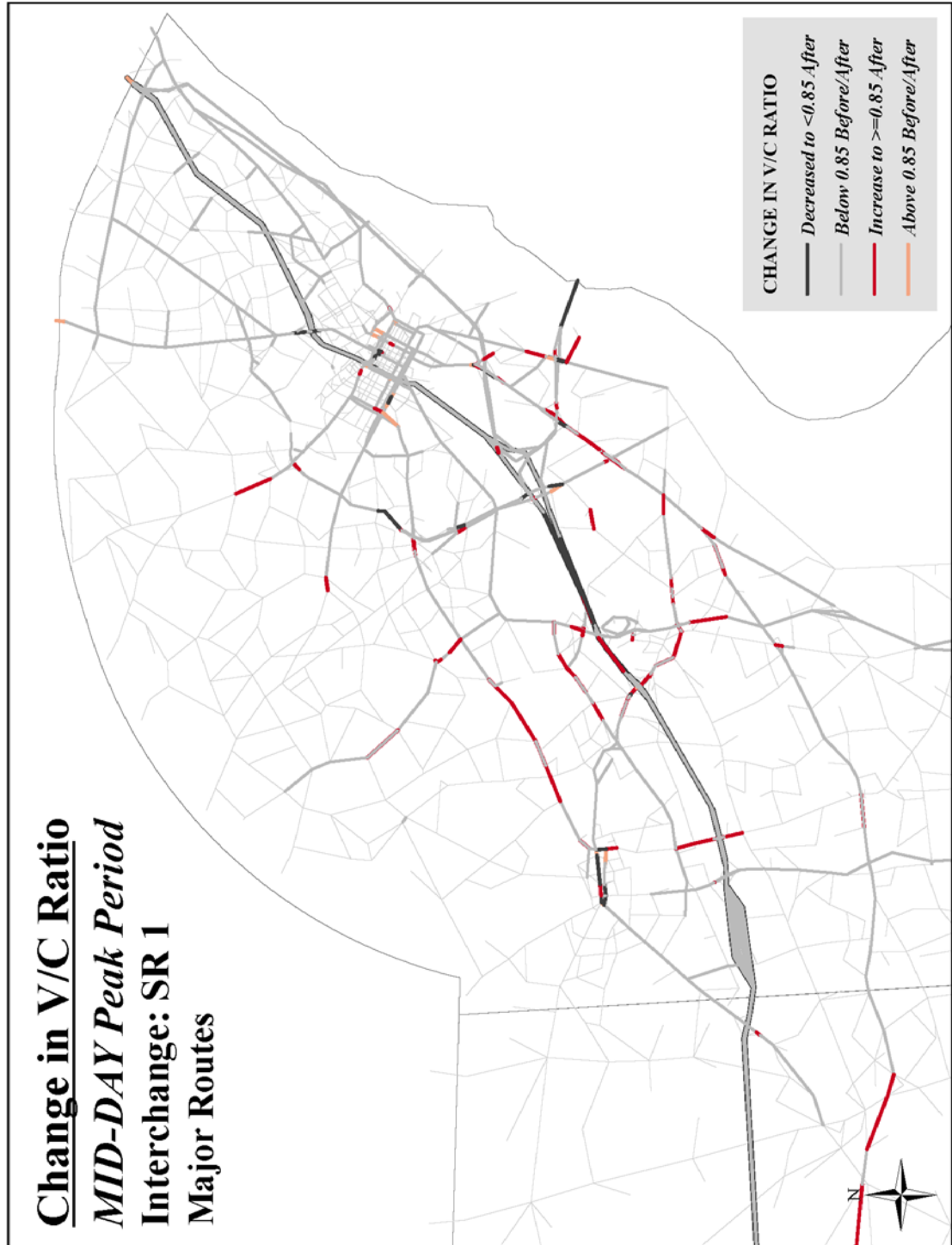
Major Routes



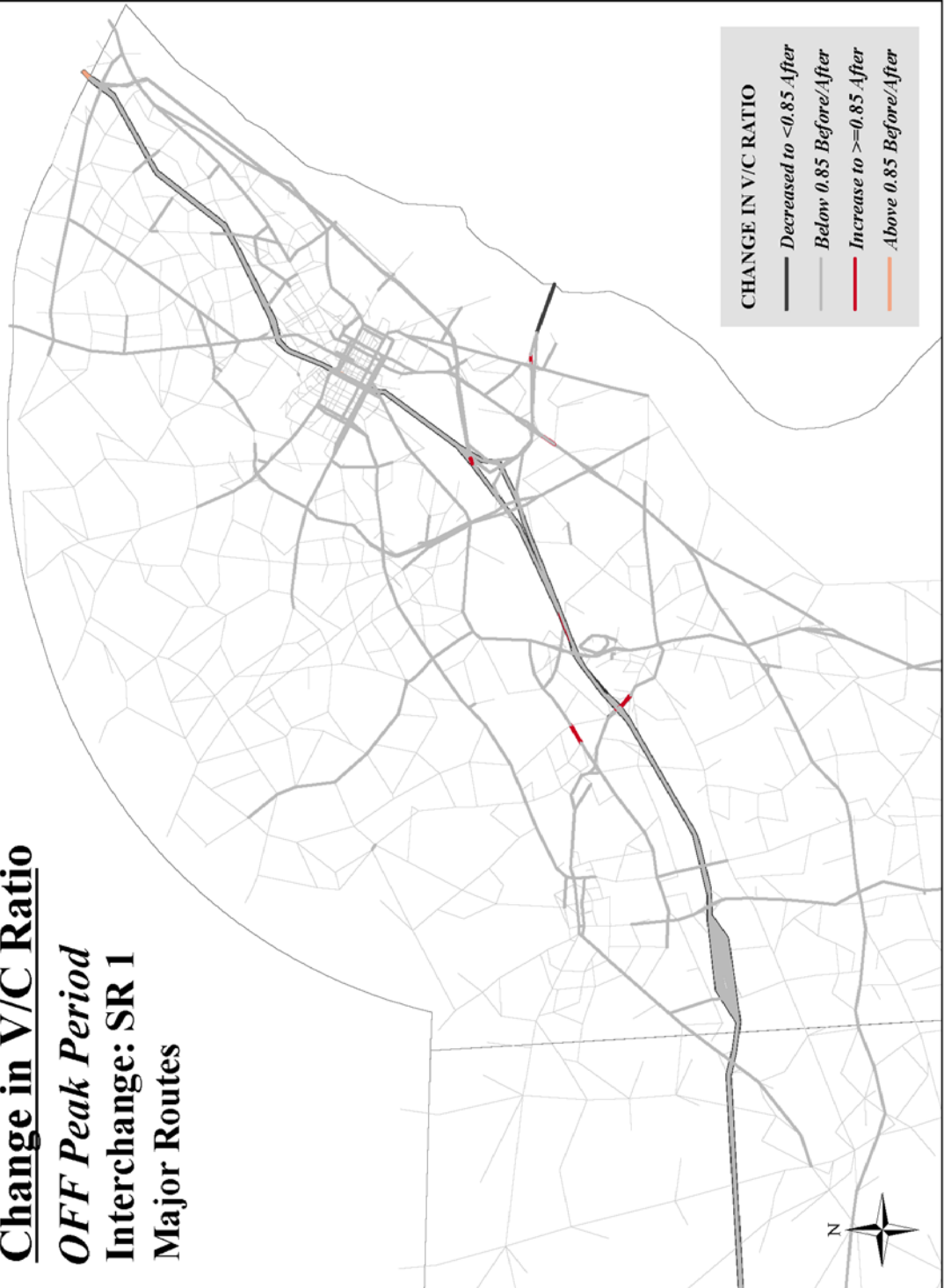
Change in V/C Ratio
PM Peak Period
Interchange: SR 1
Major Routes



Change in V/C Ratio
MID-DAY Peak Period
Interchange: SR 1
Major Routes

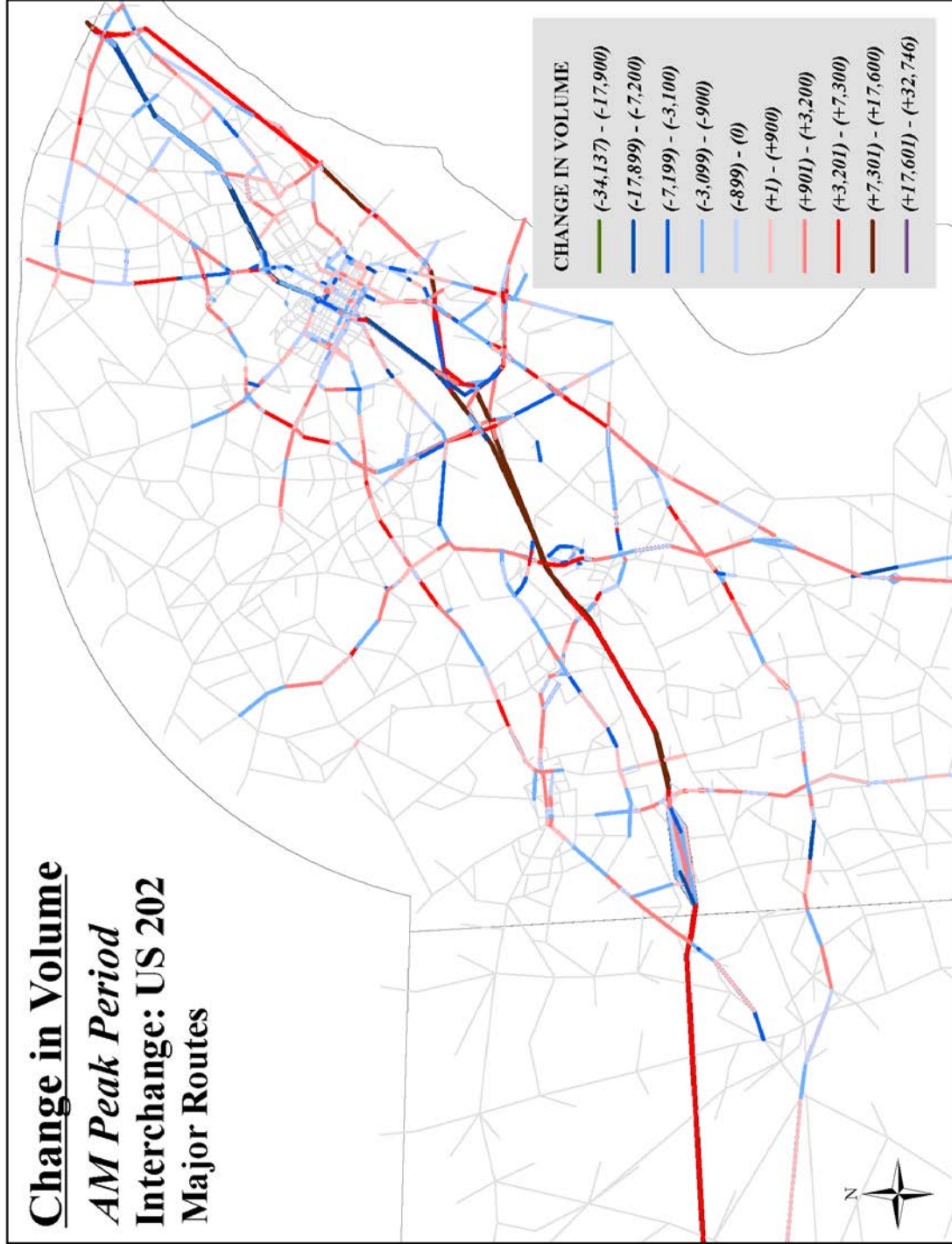


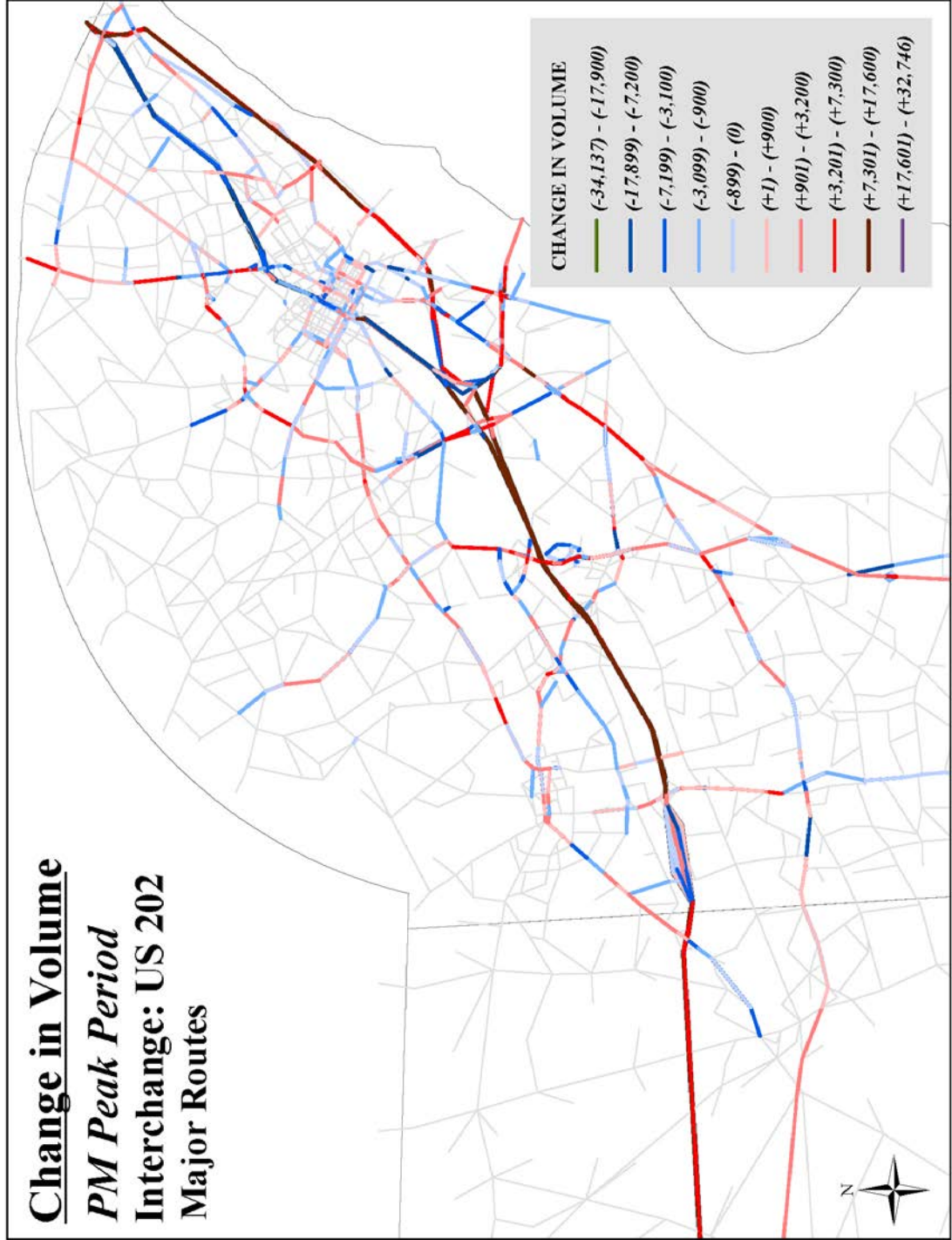
Change in V/C Ratio
OFF Peak Period
Interchange: SR 1
Major Routes

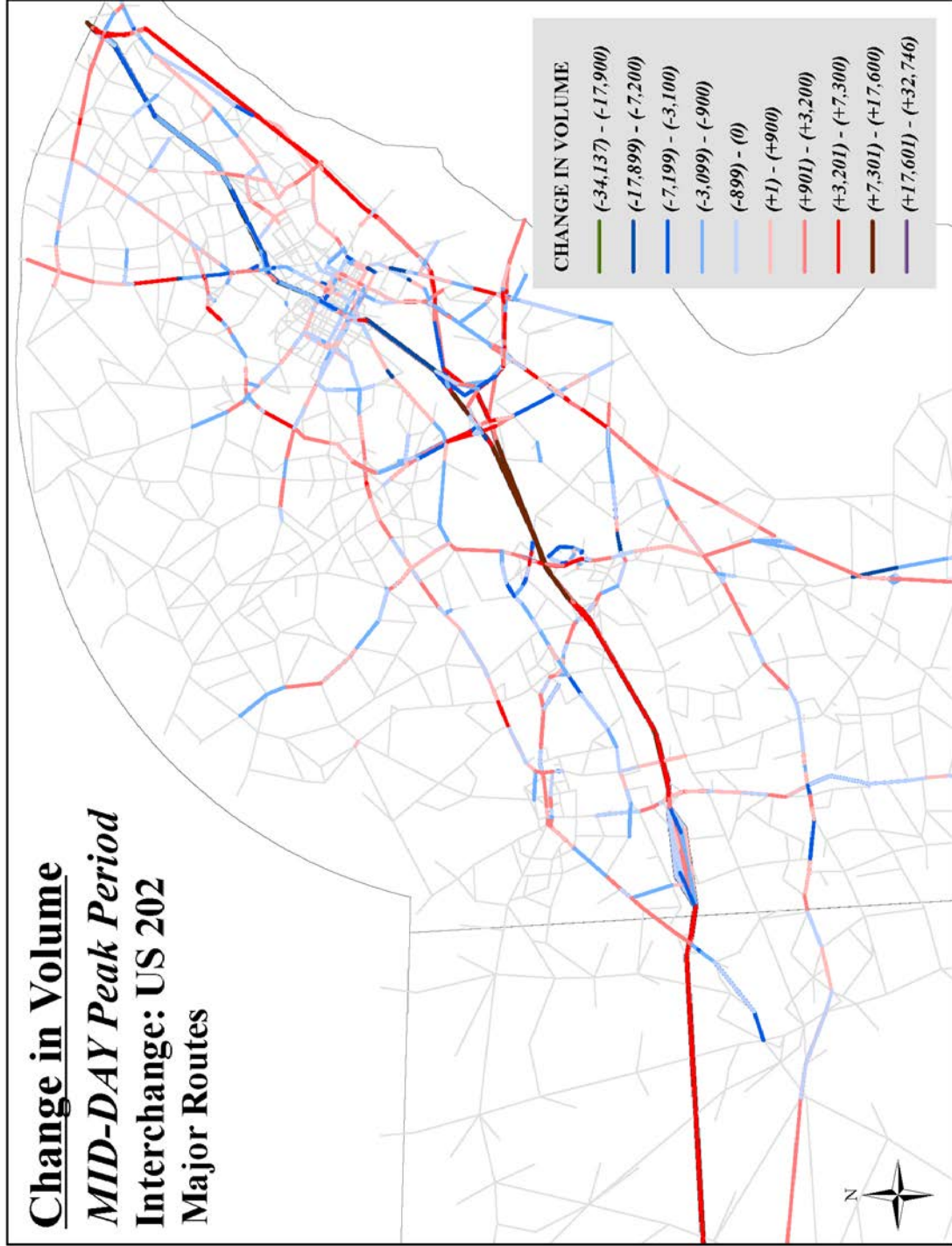


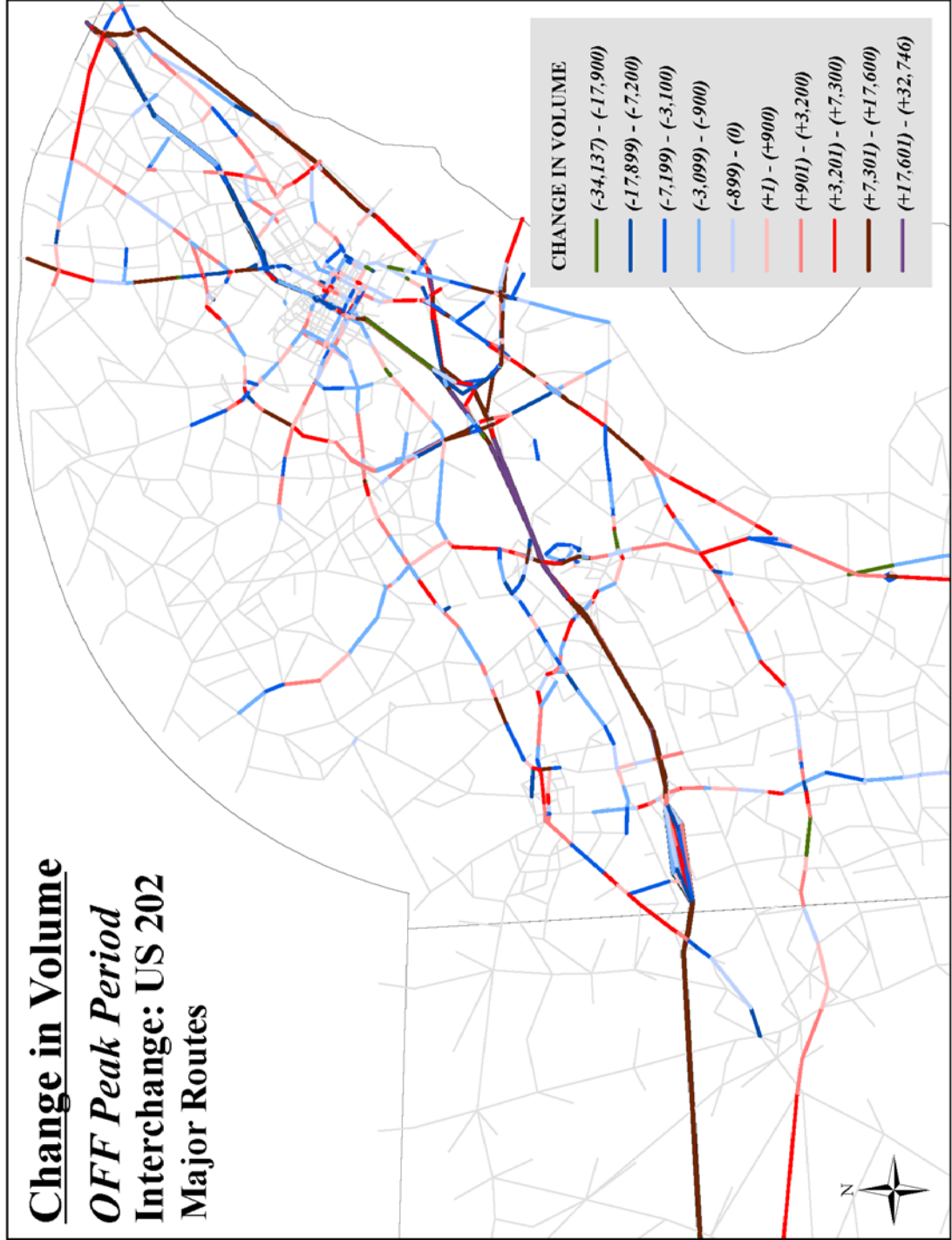
Appendix C

ENLARGED MAPS : INTERCHANGE US 202







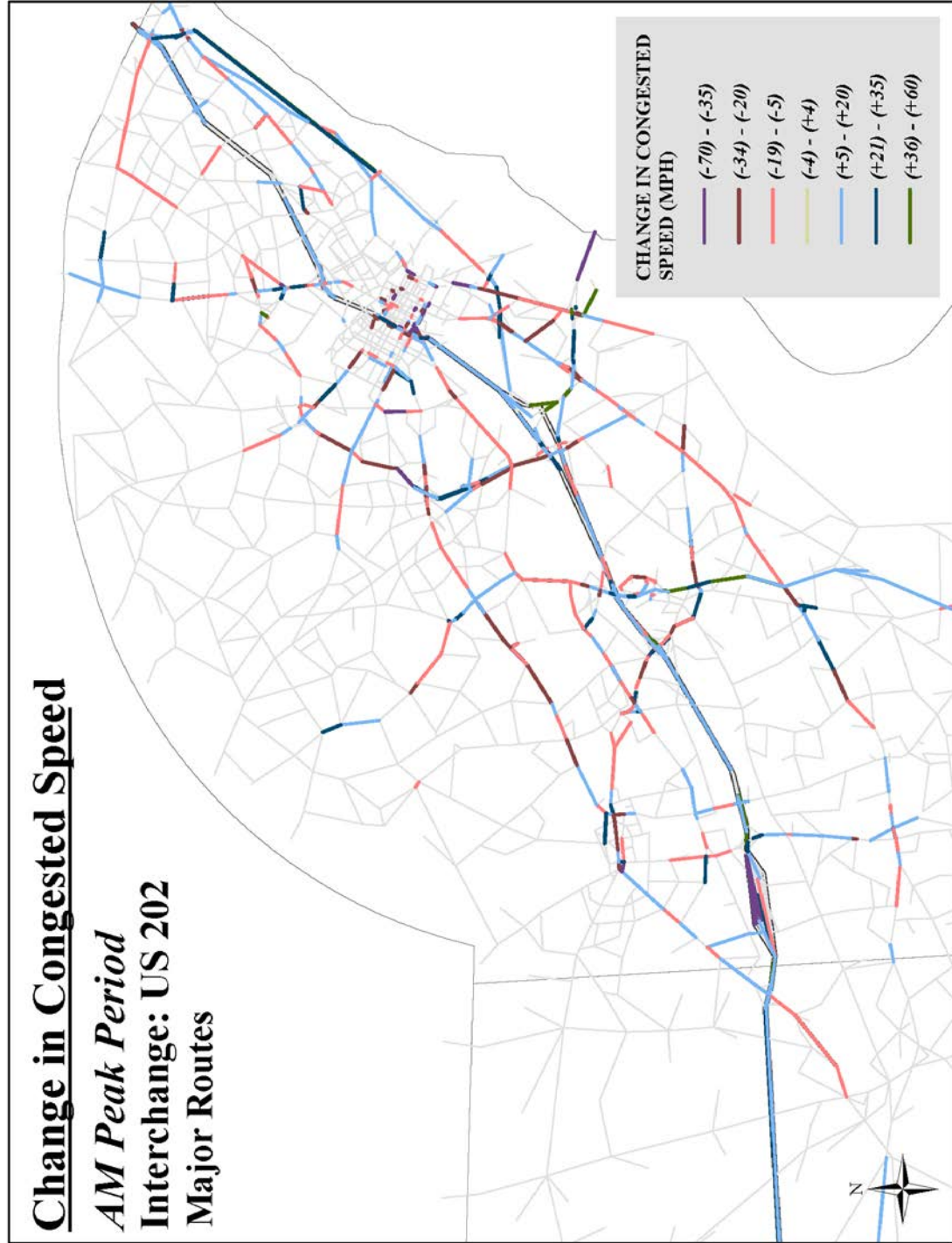


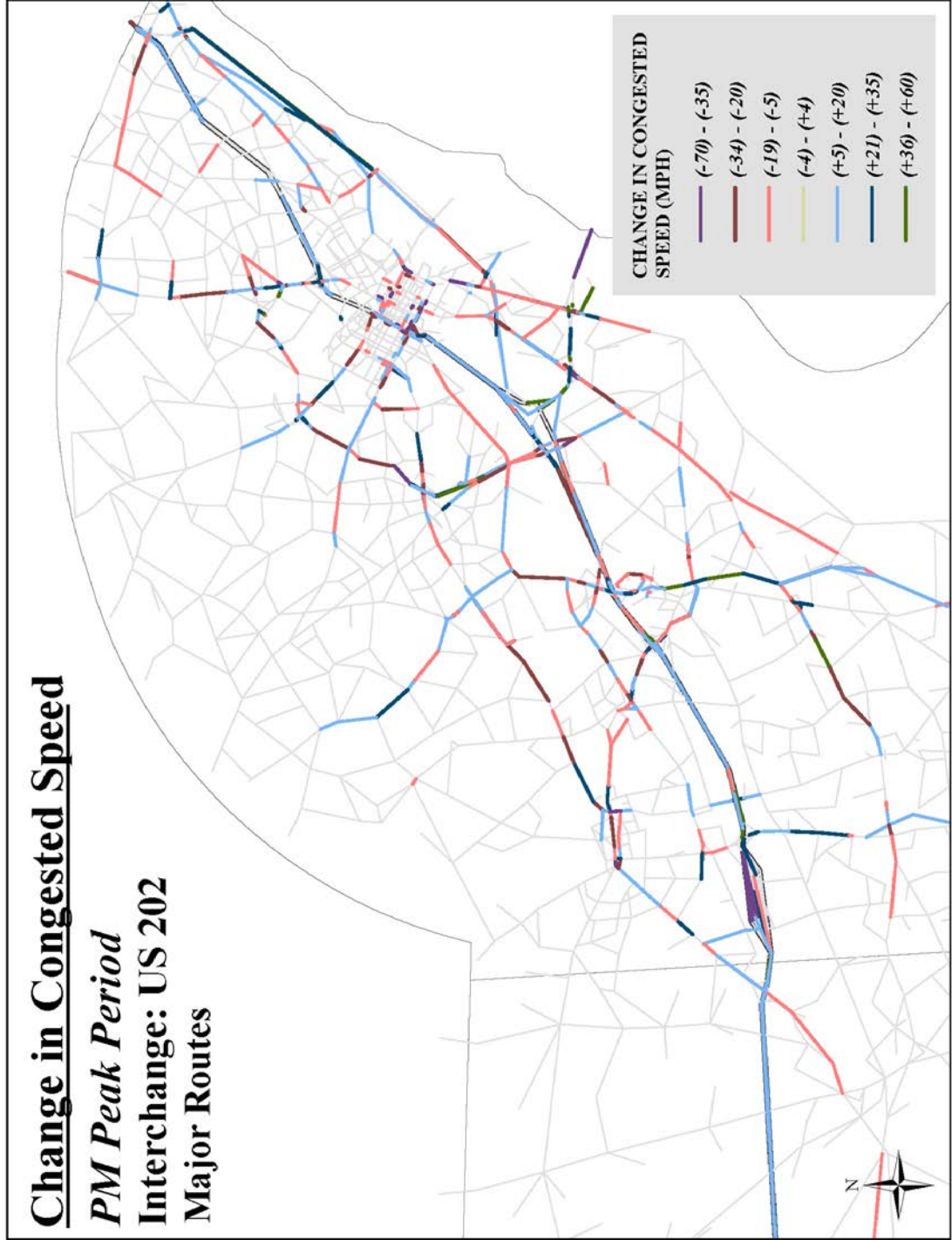
Change in Congested Speed

AM Peak Period

Interchange: US 202

Major Routes



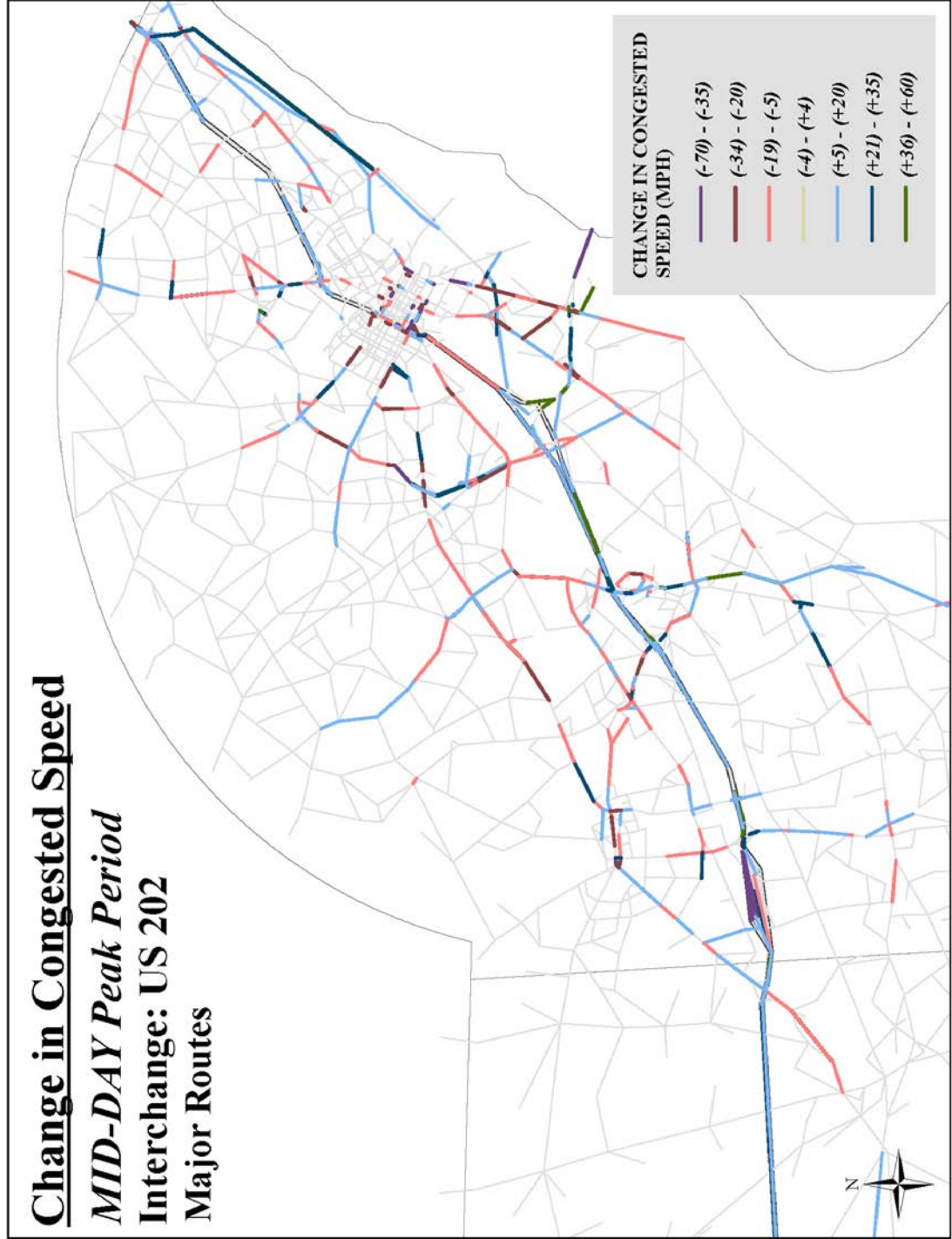


Change in Congested Speed

MID-DAY Peak Period

Interchange: US 202

Major Routes



Change in Congested Speed

OFF Peak Period

Interchange: US 202

Major Routes

