KTC

KENTUCKY TRANSPORTATION CENTER

ROUTE DISRUPTION ANALYSIS

UK
UNIVERSITY OF KENTUCKY
College of Engineering

OUR MISSION

We provide services to the transportation community
through research, technology transfer and education.
We create and participate in partnerships
to promote safe and effective
transportation systems.

OUR VALUES

Teamwork
Listening and communicating along with
courtesy and respect for others.

Honesty and Ethical Behavior
Delivering the highest quality
products and services.

Continuous Improvement
In all that we do.

ROUTE DISRUPTION ANALYSIS

(Final Report)

By:

Adam Kirk

Transportation Research Engineer

and

Mei Chen

Assistant Professor of Civil Engineering

Kentucky Transportation Center
College of Engineering
University of Kentucky
Lexington, Kentucky

January 2007

1. Report Number	2. Government Accession No.	3. Recipient's Catalog No.		
KTC-07-1 / SPR289-05-1F				
4. Title and Subtitle		**5. Report Date**		
		January 2007		
Route Disruption Analysis		**6. Performing Organization Code**		
7. Author(s)		**8. Performing Organization Report No.**		
A. Kirk, M. Chen		KTC-07-1 / SPR289-05-1F		
9. Performing Organization Name and Address		**10. Work Unit No.**		
Kentucky Transportation Center				
College of Engineering		**11. Contract or Grant No.**		
University of Kentucky				
Lexington, Kentucky 40506-0281				
12. Sponsoring Agency Name and Address		**13. Type of Report and Period Covered:** Final; 06/05 – 1/07		
Kentucky Transportation Cabinet				
200 Mero Street		**14. Sponsoring Agency Code**		
Frankfort, KY				
15. Supplementary Notes				
16. Abstract				
17. Key Words		**18. Distribution Statement**		
Route Disruption, Security Planning, Long Range Planning		Unlimited		
19. Security Classification (report)	**20. Security Classification (this page)**		**21. No. of Pg: 32**	**22. Price $0**

Table of Contents

List of Figures

List of Tables

Introduction

In today's society, transportation has become a vital component of our economy, our national defense, our emergency response systems, and our day-to-day life. Disruption of major highway systems can have serious social, health, economic, security, and environmental consequences. Disruption of highway systems can result from natural or man-made causes, and it may be intentional or unintentional. Examples of the wide-ranging causes of highway disruption include weather, natural disasters, vehicle crashes, hazardous material spills, barge impacts with bridge piers, and acts of terrorism.

Disruption of key transportation chokepoints, such as bridges or tunnels, could have disastrous impacts on Kentucky. With this in mind, it would seem prudent to begin to develop strategies to prevent such events or to mitigate their impacts if they should occur. It is no doubt impossible, and probably unnecessary, to protect every segment of the surface transportation system. However, it is possible to identify those most critical segments where a disruption would have dire effects. For those segments, it is reasonable to expect that, over time, protection strategies can be developed, alternative routes can be provided, and contingency plans can be put in place.

The objective of this project is to analyze the major highway routes in and through Kentucky to determine the potential liabilities associated with disruption of these routes. The analysis assesses the availability of convenient by-pass routes and the anticipated impacts (mobility, economic, and others) of a disruption.

The results of this study will allow transportation decision-makers to identify those route segments in the Commonwealth that would cause the greatest adverse impacts if they were interrupted. This will allow the Transportation Cabinet to develop and implement an intelligent strategy for preventing or mitigating such an interruption. Such a strategy could include surveillance and/or other security measures, reinforcement to minimize damage, and/or providing redundancy in available routes. Implementation of the recommendations developed under this study will substantially increase the survivability of Kentucky's surface transportation system. Kentucky would then be much less vulnerable to a natural or man-made disruption to the flow of surface transportation system.

To focus the efforts of this study, the study routes to be evaluated were limited to the most heavily traveled routes in Kentucky, which serve as local, regional and national travel corridors for commercial and private traffic, representing the most critical elements in the surface transportation system. A list of study routes is identified below.

- Interstate 71
- Interstate 75
- Interstate 64
- Interstate 65
- Interstate 24

- Interstate 265
- Interstate 264
- Interstate 275
- Interstate 471

Literature Review

A comprehensive literature review was conducted to document existing studies that have examined the effects of major route disruptions. These studies have developed policies and procedures to identify potential impacts from route disruptions. The literature review has focused efforts on the evaluation of transportation infrastructure including roadways, bridges, tunnels and dams.

The purpose of this review was to document long term impacts of route disruptions. Methods of evaluating supporting facilities and other DOT infrastructure such as maintenance facilities and offices was not included in the literature review as it is outside the scope of the study. This focus aided in directing the development of analysis procedures and directing the implementation of the study.

The majority of literature that has been developed to addresses route disruptions has primarily been driven from a transportation security perspective focusing on emergency response plans and vulnerability assessments. This literature, while important, is limited in evaluating long range planning of highway infrastructure to mitigate route disruptions. A stated this study concentrates on the long term impacts of route disruptions and not on the congestion and emergency response efforts occurring immediately after an incident. Due to the many different potential causes of route disruptions, immediate impacts can vary significantly and can be unpredictable. These issues are more readily address by emergency response and security personnel.

The following sections of this document examine:

- Case Studies of Major Route Disruptions

- Methods of Estimating Impacts of Route Disruptions

- Applications of Route Disruption Analysis.

Case Studies of Major Route Disruptions

Route disruptions can be caused by a myriad of different incidents including long term major construction, infrastructure failure, natural disasters and intentional unplanned disruptions. However, the common result, regardless of the cause, is a significant disruption of traffic flow resulting in increased travel time, lost productivity and impacts on commerce and public services [1]. Several case studies have been examined which involved long term impacts to the transportation network and examine the ability of the transportation network to respond to these disruptions. The following case studies were examined as part of this review [2].

- Terrorist attack, New York City/Washington D.C., September 11, 2001

- Rail Tunnel Fire, Baltimore, Maryland – July 18, 2001

- Earthquake, Northridge, California, January 18, 1994

These cases are discussed in further detail in the following sections.

Terrorist Attack– September 11, 2001

While the terrorist attacks of September 11, 2001 saw a total shutdown of the nation's transportation services within the days immediately following the attacks, several key transportation facilities in New York and Washington, D.C. were damaged and long term route closures were prevalent due to new security measures.

New York City, NY. New York City is the most densely populated urban area in the nation; and the region is heavily dependent upon its transit system, which is the most widely used public transportation network in the nation. The typical weekday transit ridership for all transit modes in New York City is 7.6 million riders per day. The World Trade Center served as the major intermodal transportation hub for Lower Manhattan. The Cortlandt subway station and the PATH World Trade Center station were both severely damaged during the collapse of the Twin Towers.

The surface transportation network returned to normal slowly after September 11. However, certain segments of the transit infrastructure within the World Trade Center area were still out of service and motor vehicle restrictions remained for Midtown and Lower Manhattan. A SOV ban remained on crossings into Lower Manhattan, vehicles were still being checked at key crossings, and commercial vehicles restrictions were in place for the Holland Tunnel for over a year. Due to damage to the PATH WTC station PATH subway service only operated to Midtown Manhattan.

The New York City subway system was able to restore service to all but four stations in Lower Manhattan but saw security-related service delays increase markedly since September 11. Due to the increased congestion and security related delays public and private ferry service saw a 91 percent overall growth in their use after September 11, the highest since the 1940s. Transit services in the area became extremely congested.

The primary factor that allowed the New York region to maintain mobility in the days and months following the attack was a dense network of redundant transportation infrastructure. The infrastructure consists of a pattern of local streets connected to arterials along the perimeter, a multitude of subway lines, on-street bus service, water ferries, and pedestrian facilities. Due to the redundancy in the system, specifically in terms of transit and alternate mode choices, the city was able to provide adequate mobility despite the significant route disruptions.

Washington, D.C. Metropolitan Area. The Washington, D.C., metropolitan area is among the most complex multi-jurisdictional regions in the United States. State and local governments, along with federal agencies and regional transportation agencies, gives rise to significant challenges in coordination and cooperation. Operating agencies with responsibility for major highways in the area include the Maryland DOT, the District of Columbia Department of Public Works (Transportation Division) (DDOT), and the Virginia DOT, as well as the National Park Service (NPS) for the region's parkways and the Arlington Memorial Bridge. The Washington Metropolitan Area Transit Authority (WMATA) operates the Metro rapid transit system and the bulk of surface bus service in the region.

In the Washington metropolitan area, congestion around federal facilities and military bases caused by new security procedures continued to present transportation-related problems after the event. These problems ranged from relatively minor closures and restrictions, such as the street closings near the White House and truck restrictions around the Capitol, to significant issues such as the closure of a major commuter route that passes through a Northern Virginia military base. WMATA managers made several changes in response to the events of September 11 to handle the increased demand in transit ridership and meets new security concerns.

In the Washington, D.C., area, the highway departments were able to take advantage of reversible lanes to help increase the volume of traffic that could exit the area on the morning of September 11. WMATA staff had the ability to reroute their subway lines to avoid crossing the Potomac River Bridge. Since the attack, WMATA Management has considered is the construction of a second rail tunnel through the central rail system to provide redundancy in case of problems to the main line.

Rail Tunnel Fire, Baltimore, Maryland – July 18, 2001

On Wednesday, July 18, 2001, a 60-car CSX freight train entered the Howard Street Tunnel in downtown Baltimore carrying hazardous materials. The engineers felt the train lurch and come to a stop. The engineers noticed smoke coming from the tunnel, evidence of a fire somewhere among the cars. The problem was further complicated when a break in a forty-inch water main located under the intersection of Howard and Lombard Streets, almost directly above the site of the derailment, spilled water into the tunnel and onto the street.

The Howard Street Tunnel is along CSX's major freight through-route on the Northeast corridor, from the southern states through Washington, D.C., and Baltimore and on to New York and Philadelphia. Before the accident, there were an estimated 28 to 32 freight rail trains passing through the tunnel daily.

Howard Street is the extension of I-395, which serves as a major north-south arterial for the city and runs adjacent to Oriole Park at Camden Yards and the Baltimore Ravens' football stadium. It is also close to the Inner Harbor and the National Aquarium, the heart of Baltimore's tourist area.

MdTA operates an extensive mass transit system within the City and the surrounding region. The Central Light Rail Line travels a 29-mile corridor, with an average daily light rail ridership of about 30,000 passengers. MdTA also operates the Baltimore Metro subway system, with daily ridership of 45,000 passengers, and a citywide bus service, with daily ridership of approximately 250,000 people. Commuter rail service (MARC) is operated between Baltimore and Washington, DC.

For five days following the incident, the Howard Street tunnel, MARC services and streets in the vicinity of the tunnel and the water main break remained closed, and all vehicle traffic was diverted. The major long-term impact from the tunnel fire was on the Central Light Rail Line which runs directly over the Howard Street Tunnel and the water main. Reconstruction of the light rail bed and tracks took a total of 53 days.

In response to the disruption of light rail and commuter rail service, MdTA quickly instituted a "bus bridge" to supplement service. Because the freight tunnel serves as the main CSX route along the eastern seaboard, freight movement became a problem. Working cooperatively with its main competitor, CSX operators were able to reroute their freight traffic onto Norfolk Southern tracks to help alleviate some of the freight congestion.

Earthquake, Northridge, California – January 17, 1994

On Monday, January 17, 1994, at 4:30 a.m., an earthquake shook Los Angeles, California damaging over 114,000 structures spread over 2,100 square miles. The most severe damage caused by the Northridge earthquake was on I-5, the main north/south artery in Southern California connecting the Los Angeles to Northern California. Structural damage to roads, and utilities also occurred in the I-10 corridor, which connects Los Angeles and Santa Monica. Eastbound SR 118 had completely collapsed at two separate places closing the entire section of highway between I-405 and I-210 in both directions.

Geographically, Los Angeles is separated from central and northern California by the San Gabriel Mountains to the north and San Bernardino Mountains to the northeast. Access over the mountains is limited to two major freeways: I-5, and SR 14. East-west traffic is mainly dependent on I-10.

The Los Angeles area is a critical intermodal transfer point for the west-to-east movement of goods across the United States. The Port of Los Angeles is the busiest intermodal freight port in the United States and among the 10 busiest ports in the world, with over 3,000 vessels arriving per year. Trucks leaving the port are typically headed for the major Southern California interstates I-5 and I-10 for distribution throughout the country. The I-5 corridor is especially important to Northern Californians who depend on I-5 freight movements destined for the Sacramento area and other cities in northern California.

The Los Angeles highway system has a fairly extensive set of redundant arterial and local streets serving the urbanized portion of the area. At the time of the earthquake, the Los Angeles DOT was implementing a "Smart Corridor" project to divert freeway traffic onto the arterial streets during times of heavy congestion. Using this system after the earthquake allowed agencies to minimize some of the traffic congestion that occurred as a result of the closing of the damaged interstate highway segments. But to the north, the canyons and valleys restricted the number of alternative roads. Because of this, fewer options were available for rerouting traffic, and these areas experienced the heaviest traffic backups in the weeks and months after the earthquake.

Estimating Impacts of Route Disruptions

As is evident from the case studies, when critical components to the transportation infrastructure are removed, significant impacts to the mobility of the region is compromised. To accurately gain an understanding of the potential impacts of route disruptions on numerous infrastructure assets within a region or state it is imperative to develop a systematic approach to ensure an objective and fair evaluation. Once the potential impacts associated with a route disruption on highway elements can be identified, countermeasures including

transportation improvements, security and emergency response modifications can be directed towards the most critical infrastructure.

While case studies can provide anecdotal analysis of potential impacts of transportation route disruptions, it is extremely difficult to quantify potential long term impacts. This is due to the myriad of potential causes, duration and extent of possible route disruptions, as well as the complexity of identifying changes in travel pattern characteristics and the interconnectivity of transportation on all aspects of the social and economic activities. Although the route disruption may be confined to a very small area, the impacts on the flow of traffic can be widespread [1]. The disruption of links in the highway transportation network reduces connectivity and available bypass routes and removes capacity from the system. Moreover, route disruptions are unpredictable and uncontrollable except in the case of extended construction work. Furthermore, the recovery from a major disruption takes place over an extended period of time and travel patterns and behaviors have been shown to change continuously as users adapt to the new conditions [3]. Due to these complicating factors limited studies have been performed which aim to identify the potential impacts of unplanned route disruptions.

Several methods of evaluating route disruption impacts have been developed for other applications such as construction programming, security enforcement and travel demand forecasting which may be transferable to this application. These methods include quantitative and qualitative analysis.

Road-User-Cost Method

A traditional approach to quantifying impacts on traffic flow and capacity changes is to implement a road-user cost method, which can be successful in identifying costs of road construction and incident delays. Literature review shows that there are various methods to estimate the delay in work zone. While the most common used method is called the road user cost method, which estimates total travel delay based on capacity/queuing analysis of a roadway with decreased capacity.

The magnitude of the delay depends on the variation of traffic volume over the disruption period, and the magnitude of the capacity reduction. Delay typically increases with the reduction in the number of lanes on a facility, lane widths and shoulder widths.

The road-user-cost method is useful in quantifying the impacts of short-term, minor roadway disruption, when minimal roadway capacity can be maintained. It is not applicable when examining complete route closures over extended periods of time, due to the inability to quantify delays resulting from route detours and mode changes.

Estimating Travel Behavior Changes

As indicated above, travel behavior and patterns can significantly change due to a route disruption, resulting in travel demand, trip rate, travel mode and occupancy changes. Travel behavior has also been observed to constantly change and evolve over time of day, day of week, and even after days, weeks and months after the continued disruption of a route. Most causes of significant route disruptions, such as natural disasters, are not predictable and the reconstruction period may implement constantly changing detours and temporary traffic

6

control throughout the project evolution [4]. Based on all of these factors the determination of travel behavior changes resulting from a route disruption is a difficult undertaking.

Giuliano and Golob [4] conducted a study based on the 1994 Northridge Earthquake in California to analyze the impacts of the earthquake on travel behavior changes by examining the travel patterns in two heavily damaged transportation corridors. The study established screenlines on each corridor, and estimated the total number of person-trips crossing the screenlines. From traffic volumes and transit usage estimates person trips were estimated on both freeway and parallel arterial corridors.

Commuter surveys were also conducted to identify travel patterns changes over time. Survey respondents whose home or work was located in the impacted area were more likely to make changes in the time they left home to go to work and in their route choice than commuters in other areas. By analyzing these data as well the estimates of total person-trip, the route disruption impacts were analyzed.

While this research aids in quantifying the effects of historical events and provides a basis for general impacts of route disruptions, it does not provide an effective means of predicting the impacts associated with specific route segments.

McNally et al. [5] also analyzed the transportation impacts of the 1994 earthquake by developing a regional transportation model through the examination of observed traffic volumes from ITS deployments. This study gathered data from major travel routes using recorded loop volumes at various freeway locations over a period several months to provide an accurate reflection of the shift in travel patterns due to the restrictions imposed by the earthquake damage. Six travel demand models were created corresponding to the six data set dates: one pre-quake, and five post-quake scenarios extending over a 5 month period.

Developing a travel demand model, which is calibrated on observed conditions, can provide additional insight into the changes in travel behavior and thus aid in the quantification of potential impacts. However, the methods presented above are limited to a single data point, the 1994 Northridge Earthquake, and is restricted to local utilization due to the unique set of alternate modes and routes available in the region. Due to these reasons the ability of such a model to predict travel behavior changes due to differing disruptions is limited. Moreover, the development of this type of model is extremely data intensive and therefore not widely applicable in terms of the study at hand.

Qualitative Critical Asset Evaluation

Due to the limited application and extensive data requirements necessary for the quantification of potential impacts of route disruptions, as outlined above, additional methods for evaluating route disruption impacts were identified through the literature review. Several studies aimed at increasing transportation security have developed qualitative procedures for identifying the risk associated with a certain infrastructure element. These approaches allow for the evaluation of statewide infrastructure inventories to aid in security countermeasure development while minimizing data requirements.

The American Association of State Highway and Transportation Officials prepared *A guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection* in response to the terrorist attacks of September 11, 2001 [6]. Since the release of the AASHTO Guide to Highway Vulnerability Assessment was released several states have also developed state risk management guides. Specifically *The State of New Mexico Terrorism Risk Management Process Guide* elaborates on many of the concepts and processes outlined in the AASHTO guide [7]. While the focus of these reports is to develop emergency response procedures and implement highway security measures, they first establish a methodology for identifying "critical assets". The New Mexico guide defines critical assets as "those assets deemed "critical" for achieving an agency's primary mission."

Critical assets are identified and prioritized through the evaluation of a set of criteria defined as "Critical Asset Factors". The New Mexico guide further defines the critical asset factors to be those factors which are an "indication of the conditions, concerns potential consequences and capabilities that might cause a department to label the asset 'critical.'" Some of the critical assets identified include:

- Consequences to Public Service

    o Critical to Emergency Response Functions and Services/Evacuation Route

    o Critical to Government Continuity

    o Military Importance

    o National Strategic Importance

- Consequences to the General Public

    o Availability of an Alternate

    o Economic Impact, effect on resources and wealth of a region

    o Functional Importance

    o Symbolic Importance

    o Loss and Damage Consequences

    o Replacement Cost

    o Replacement/Downtime

    o Social Impact

Both guides proposes a matrix evaluation where each criteria is scored on a set scale for each factor, e.g. 1-10, and each critical asset factors is assigned a weight through qualitative or quantitative assessment. The weighted score of each asset is then summed for the total score,

which is assigned to the asset. While this method does not allow for the direct quantification of route disruption impacts, it does allow for the relative ranking of infrastructure in terms of impact severity, allowing for improved planning and decision making.

Xia and Chen further expanded on these factors, identifying static and dynamic characteristics of highway elements that affect the criticality of the infrastructure [8]. This study also went beyond identifying critical assets and started to identify potential data sources for these factors to begin developing real-time risk indices for highway infrastructure. Factors identified and potential data sources/surrogates included the following.

- Strategic Importance/Functional Classification. To be used to identify elements that are crucial to the national or regional connectivity.

- Commercial Vehicle Data indicating potential economic and strategic impacts.

- Identification of Alternative Highway components that have the ability to perform the function of the primary facility. Comparison of alternative route functional classification is identified as a surrogate for identifying the capability of the alternative route to serve the primary function of the disrupted segment.

In addition, to evaluating individual characteristics of highway elements Srinivassan, [9] proposed the idea of evaluating assets at the system and network level to identify links on critical paths through the network or which serve as a leg to a hub and spoke system. This can be measured by determining the number of paths that share a given link and examining the availability of alternative routes for specific origin destination pairs. This analysis should also extend beyond the examination of automobile traffic and should also consider the number of intermodal connections serviced by the element.

The majority of previous studies have concentrated on examining the links of the highway system almost exclusively. However, impacts to mobility can be most pronounced when a node connecting several links and/or modes is disrupted. This is evident from examining the transportation impacts brought about by the September 11 attacks at the world trade center, which served as a major multi-modal hub for the New York subway system and the Baltimore Rail Fire which occurred near the junction of heavy and light rail lines, harbor access and intestate and surface streets. The disruption of such an important node can cause significant mobility impacts, disrupting countless multi-modal routes and reducing the effectiveness of potential alternate modes/routes.

Based on the methodologies and critical asset factors identified above it will be possible to develop a list of critical asset factors and direct the study towards evaluating the potential consequences of route disruption and identifying applicable data sources.

Disruption Impact Estimating Tool – Transportation

An analytical tool, disruption impact estimating tool – transportation (DIETT), was developed through the NCHRP Project 20-59(9) to help the identification and prioritization of transportation choke points (TCPs) at state level [10]. Economic impact of route disruption in terms of costs associated with disruption on freight shipments is the primary measure used in DIETT. This cost is the sum of increased cost of freight movement due to detours and increase inventory costs caused by the relative uncertainty of deliveries through the detour.

In estimating the cost of freight movement, information on driver salaries, fuel, operation and maintenance, shipper profit, and other business costs are implicitly included in the model. The net cost of shipment through the detour is the product of the length of detour, level of congestion, and unit cost of shipment. Expressed in miles of detour, the length of detour can be obtained from the National Bridge Inventory database. Level of congestion is expressed as the ratio between throughput on detour and throughput on the TCP. DIETT provides a default value for unit cost of shipment (per ton) which can be overwritten by users.

Increased business inventory costs associated with detour are estimated to account for the increased travel time en route and altered risk due to detour. The altered risk is evaluated using cargo value, inventory premium, and detour reliability factor (which may not be readily available and may need to use statewide average).

The DIETT program is recommended to be set up within CATS-JACE, a consequence management package called the Consequences Assessment Tool Set – Joint Assessment of Catastrophic Events. This shall enable the interaction within other security programs. The Commonwealth of Kentucky is already using CATS system.

It should be noted that the DIETT program considers only the commercial shipment business; this limits its application on impact assessment of broader transportation system. Some data items may not be easily obtained and limited spot validation (conducted for the state of Virginia) has revealed questionable quality of the data used in by the DIETT program.

Applications of Route Disruption Analysis

The results of either a quantitative or qualitative analysis of route disruption impacts may be utilized in numerous transportation planning and engineering applications. A few of these applications are discussed below.

Transportation Planning

Traditional highway planning typically concentrates on providing the most cost-effective method of providing mobility from one place to another during normal operations without consideration for the effects of closed or disrupted routes. It is always cheaper to have only one of a particular type of infrastructure or system, while building redundancy into the

system can be expensive and seen as "wasteful spending." However, the failure of that system can significantly hamper mobility during periods of significant route disruption. [2]

Overall, route disruptions have significant impacts on traffic flow over both the short and long term. These impacts are mainly represented by the changes of traffic patterns such the traffic demand changes over time, traffic mode choice changes over time, and traffic changes by time of day. The complex traffic behavior present transportation agencies with new challenges to incorporate route disruption in highway network planning.

Analysis of the overall of importance critical assets and the identification potential impacts due to route disruption can direct transportation planning activities to incorporate times of incidents, as well as normal operation, into the planning process. This can lead to a transportation system more effective at handling both normal operational conditions as well as during times of disruptions from short term disruptions due to major traffic crashes to long term disruptions due to natural disasters or terrorist attacks.

To integrate the route disruptions into transportation planning, useful suggestions that are closely related to route disruption are summarized as [11]:

1. Identifying high value assets, such as intermodal facilities, bridges, tunnels, and station. By integrating the route disruption analysis into infrastructure assessment, critical highway components can be identified.

2. Assessing potential disruptions to the system or assets.

3. Understanding the relative risk of high value infrastructure to disruption scenarios.

4. Quantifying the traffic consequences of disruptions.

5. Developing short-term and long-term countermeasures to address high impact scenarios.

6. Prioritizing countermeasures based on their estimated cost-effectiveness in reducing the consequences of potential route disruptions.

Srinivassan [9] elaborates on this new dimension of security in transportation planning in which route disruption and risk assessment analysis may be utilized. New questions that may need to be answered in the planning process include

7. What are the security implications of adding a facility or a lane on an existing facility?

8. How much reserve capacity is needed to meet emergency response needs under disruptive attacks?

9. Which network components nodes and links are more vulnerable?

10. Where and in what form should redundancies be provided to reduce local and global system impacts?

11

11. What would be the consequence of adding these redundancies and spare capacities on operational system performance?

Developing a methodology capable effectively evaluating the potential impacts of route disruption, which is sensitive to surrounding infrastructure and redundancy, will go a long way towards answering these questions. Such a methodology will allow for the evaluation of alternative scenarios and the incorporation of route disruption into the decision making process along with operational, safety and environmental concerns.

Infrastructure Security Assessment

Infrastructure assessment incorporates vulnerability and risk assessment for highway infrastructure leading to better protection of these components against criminal attack. Since the events of September 11, 2001, the safety and security of the nation's transportation infrastructure has drawn increasing attention [6,7].

Understanding the potential impacts of route disruptions for specific elements in the highway network, can aid in the allocation of resources to provide cost effective implementation of security measures at the most critical of assets.

Emergency/Security Response and Decision Making.

Providing and evaluation of transportation infrastructure and potential consequences of route disruption, can also provide additional information to emergency operations personnel who are tasked with allocating recovery and security resources during times of emergency. "Due to the current state of art, transportation managers and decision-makers are forced to rely on 'rules of thumb' and 'gut feel' in making these complex decisions that affect several lives and have tremendous socio-economic consequences. To make matters worse, these decisions must be made in a matter of few minutes, with limited information about the initiating events and possible current and future repercussions [8,9]." Identifying those routes which are most vital to maintaining mobility, safety and strategic importance will allow for decision makers to make better informed decisions leading to decreased repercussions during times of emergencies.

Methodology

As seen in the literature review, quantification of route disruption impacts on a statewide level is prohibitive in terms of data and time constraints, due to the countless number of potential route disruption causes and potential disruption scenarios. However, qualitative assessment methods employed by security agencies provide a cost effective means of identifying and assessing critical infrastructure elements. Qualitative assessment can be just as effective as quantitative assessment methods in allocating resources to mitigate potential impacts of route disruption. Due to these factors, a qualitative assessment method was identified as the most appropriate for this statewide analysis.

A multi-variate evaluation procedure was developed to assess the relative degree of impact associated with the disruption of each route segment in the study sample. This approach assesses each route segment against a specified set of criteria. The project team will then evaluated the performance of each route segment with regard to each criterion, assigning a relative "criterion score" of 1 to 5 using qualitative and quantitative techniques. A criterion weight was then assigned to each criterion by the Study Advisory committee depending on the perceived significance of each criterion. A "weighted score" was then determined from the product of the criterion score and the criterion weight. The final "Impact Assessment Score" was then calculated as the sum of all weighted scores across all applicable criteria for that element.

An example of this process is shown in **Tables 1 through 3**, below.

Table 1: Weights assigned to Criteria

Route Segments	ADT			Economic Impact			Impact Assess. Score
	Score	Weight	S x W	Score	Weight	S x W	
Route 1		4			5		
Route 2		4			5		
Route 3		4			5		
Route 4		4			5		

In the example above weights between 1 and 5 were assigned to each criteria, ADT and Economic Impact relative to the perceived importance of each factor with respect to route disruption impacts. In the example above a higher value was placed on Economic Impact (5) compared to ADT (4) indicating that Economic impact is more important to evaluating the impact of Route disruption than ADT.

Table 2: Routes scored with respect to Criteria

Route Segments	ADT			Economic Impact			Impact Assess. Score
	Score	Weight	S x W	Score	Weight	S x W	
Route 1	**5**	4		**2**	5		
Route 2	**4**	4		**3**	5		
Route 3	**3**	4		**4**	5		
Route 4	**5**	4		**5**	5		

Infrastructure elements are scored on a scale of 1 to 5 with respect to each of the criterion, with 1 identifying the highest value, i.e. highest ADT, or most economic impact.

Table 3: Weighted Scores and Impact Assessment Score Calculated

Route Segments	ADT			Economic Impact			Impact Assess. Score
	Score	Weight	S x W	Score	Weight	S x W	
Route 1	5	4	**20**	2	5	**10**	**30**
Route 2	4	4	**16**	3	5	**15**	**31**
Route 3	3	4	**12**	4	5	**20**	**32**
Route 4	5	4	**20**	5	5	**25**	**45**

The weighted scores of each route-criterion pair is determined and summed to derive the impact assessment score. In the example above, Route 4 *is determined to be the most critical asset as it ranks highest in both ADT and Economic Impact.*

Evaluation Criteria

The criteria that were used in this evaluation have been identified as "critical asset factors." Simply, these are functions of the highway infrastructure that have been identified as critical to carrying out the mission of the transportation system. As a starting point to developing these criteria, four primary functions of the highway system have been identified. These are:

- Defense

- Economic Support (Movement of Goods)

- Mobility (Movement of People)

Based upon these primary functions a preliminary list of criteria were developed by the project team and SAC chairperson within the constraints of available data identified in the literature review to assess the potential impact of a route during disruption. These criteria are both qualitative and quantitative in nature. Additionally, all criteria were developed based on readily available data sources, which allow for reduced data collection and analysis enabling for the consideration of a more criteria and infrastructure elements in the analysis.

Criteria were both qualitative and quantitative in nature, and concentrate around three primary areas (a) transportation impacts, (b) state and national strategic impacts, and (c) economic impacts. The full list of criteria and the applicable data sources are discussed below.

Strategic Importance. This criterion was established to evaluate the criticality of roadway segments for carrying out strategic functions of the government such as national military duties and providing emergency services. The identified metrics for this criterion were inclusion on the Strategic Highway Network (STRAHNET) and identification as a NHS Priority Corridor and BHS Intermodal Connectors. As all study routes are part of the Interstate Roadway system all are identified as part of STRAHNET and NHS Priority Corridors and intermodal connectors. Nonetheless these metrics could be used should the study sample be expanded to include lower class roadways. This criterion may be further expanded for regional and local analysis by analyzing designated evacuation routes and/or roadways critical for emergency services.

In the absence of stratified data based on these metrics, local bypass routes such as I-265 and I-471 were given a rating of 3, while primary interstate routes were assigned a full value of 5.

Economic Impact. This criterion aimed to identify the potential impact of a roadway closure on the economy. The number of heavy vehicles on the roadway was chosen as the metric to evaluate this criterion. Heavy vehicles volume was determined by multiplying the average heavy vehicle percentage by the Average Daily Traffic (ADT) on the roadway segment as reported in the HPMS database. The range of heavy vehicles was then stratified into 5 equal intervals and assigned a value of 1 to 5 respectively.

Functional Importance. Average Daily Traffic and county population served were used as metric of evaluating functional importance of the roadway system. Should the study sample

be expanded to include lower class roadways, inclusion of the functional classification would be useful for evaluating this criterion. The ranges of ADT and populations were stratified into 5 equal intervals and assigned a value of 1 to 5 respectively.

Critical Network Component. This criterion measures how many critical paths in a network share a given component. As an example a short segment of Interstate 75/64 near Lexington, KY serves both the critical path of I-64 running east-west and I-75 running north-south across the state; thus disruption of this shared or "critical" component would disrupt both I-75 and I-64. Roadway network connectivity was reviewed using GIS applications. Segments identified as having a shared component were assigned a rating of 5. All other segments were assigned a rating of 1.

Availability of Alternate Route. The availability of alternate or by-pass routes as well as the ability of the designated by-pass route to handle the diverted traffic is critical in ensuring transportation operations can continue during a disruption. Detour routes for each interstate section were determined using the "Kentucky Detour Routes" document published by the Kentucky Transportation Center (www.ktc.uky.edu). This document identifies detour routes on the state maintained system for each interstate segment between exits. Using the HPMS database a maximum capacity for the detour routes was determined. Daily delay times were then determined using the BPR speed-capacity equation assuming the full volume of the detoured route was placed on the detour route. The range of delay times was then stratified into 5 equal intervals and assigned a value of 1 to 5 respectively.

Replacement Impacts. This criterion was intended to evaluate the reconstruction costs and reconstruction time, which may be associated with a route disruption. However, preliminary analysis indicated that these measures would be directly related to the mode of disruption, consideration of which is beyond the scope of this study. As such, this criterion was assigned a weight of zero (0) by the Study Advisory Committee.

A weighting system was then established to determine the significance and importance of each criterion identified above. Direct input from the SAC was used to develop these weights by rating each element on a scale of 1 to 5. The more points assigned to the criteria, the greater the importance. The points assigned by individual SAC members were then averaged for each of the criterion to establish the final weights for the criteria.

Table 4 contains the full list of study criteria and the final assigned weights.

Table 4: Evaluation Criteria

Criticality Component	Evaluation Criteria	Data Source	Criteria Weight
National/Military Strategic Importance	Identified as Component of Strategic Highway Network (STRAHNET) (Binary)	FHWA	4.3
	NHS Priority Corridor (Binary)	FHWA	
	NHS Intermodal Connector (Binary)	FHWA	
Economic Impact	Commercial Vehicle Data (Volume) (1 to 5)	HPMS	4
Functional Importance	ADT (1 to 5)	HPMS	4
	Population Served (100 Mile Radius) (1 to 5)	US Census	
Critical Network Component	Dependence of Regional Major "Paths" on Route Segment (1 to 5)	GIS Analysis	4
Availability of Alternate Route Exists	Access to Alternate Route (Scale of 0 to 5 based on functional classification of Alternate Route; 0 indicates no alternate route exists)	GIS Analysis	4.7

Sample Data Set

A stated previously the study routes to be evaluated were limited to interstate routes as these are the most heavily traveled routes in Kentucky. All major interstate routes were included in the sample including:

- Interstate 71

- Interstate 75

- Interstate 64

- Interstate 65

- Interstate 24

- Interstate 265

- Interstate 264

- Interstate 275

- Interstate 471

At first it was necessary to identify the infrastructure elements that will be studied with the route disruption analysis. Two alternatives were initially considered and presented to the Study Advisory Committee. The first proposed to analyze all structures within the interstate system including bridges, tunnels dams etc. These infrastructure elements were chosen as they: (a) are the most susceptible to catastrophic failure, and (b) require the most expensive and lengthy reconstruction, involving extended periods of disruption. The second approach proposed analyzing route segments based on the HPMS segments determined by the KYTC. This approach aligned the analysis based on the available datasets in order to reduce data collection efforts and to provide a process readily adaptable to new areas based on existing data sources. The second approach, based on HPMS segments, was chosen with the understanding that a manual review of the segments be conducted and segments be adjusted if necessary. This approach allows for future identification of structures should a segment be identified as most critical and also allows for expansion of the methodology to be useful for disruptions caused by methods other than structural failure of the roadway.

A total of 197 unique HPMS segment routes were included in the sample database. Directional analysis was not conducted.

Available inventory information for all infrastructure elements identified above on the study routes was obtained from the KYTC and other secondary data sources. The data was stored in a Geographic Information System (GIS) database. Utilization of the GIS database allowed for the application of existing information databases such as the Highway Performance Monitoring System (HPMS). This methodology also provided for spatial analysis of critical infrastructure and provided for integrated project mapping.

Study Results

Based upon the methodologies presented above the weighted criterion score was determined for each individual roadway segment. The Impact Assessment Score was then determined from the sum of the individual weighted criterion scores. **Table 4** shows the distribution of scores for each criterion. **Figure 1** shows a histogram for the Impact Assessment Scores. As can be seen from these exhibits, while there is a wide range of values across the many criteria evaluated, there are only 2 segments that are within the top quintile of Impact Assessment Scores. This represents a less than 1 percent of the entire sample. Those sections which are identified as having the highest Impact Assessment Score can be assumed to be the most critical elements of the roadway infrastructure and the most likely to cause the most significant impacts should disruption occur.

Figure 1: Impact Assessment Score Distribution

Frequency
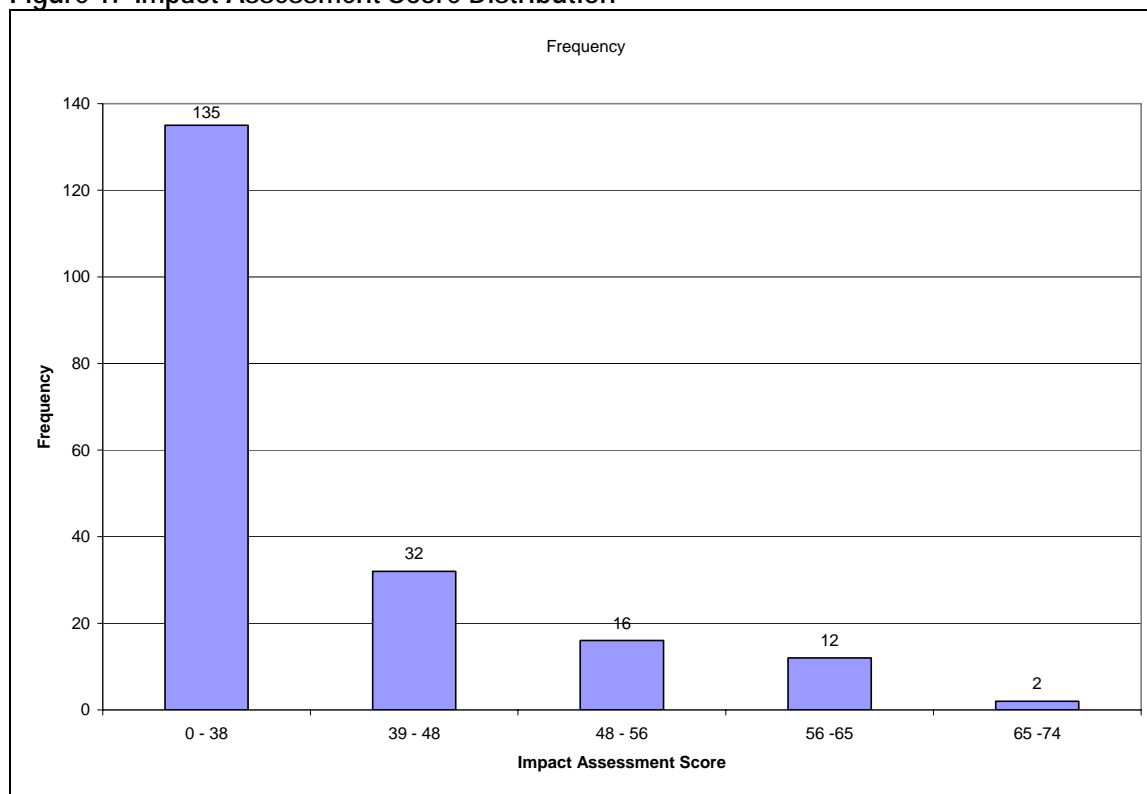
Table 5 identifies the 10 sections with the highest Impact Assessment Score. **Appendix A** provides the Impact Assessment score for each sample roadway segment. As expected those section with the highest Impact Assessment Scores are located within the urban centers of the state.

Table 5: Top 10 Impact Assessment Score

Rank	Route	Mile Pt	Strategic Importance	Economic Impact	ADT	Pop.	Critical Network Path	Alt. Route	Impact Assess. Score
1	I-75	110 - 113	5	5	2	2	5	1	74.3
2	I-75	113 - 115	5	3	2	2	5	1	66.3
3	I-264	14 - 15	3	1	5	5	1	5	64.3
4	I-264	12 - 14	3	2	5	5	1	4	63.7
5	I-75	115 - 120	5	2	2	2	5	1	62.3
6	I-264	19 - 20	3	2	4	5	1	4	61.7
7	I-264	15 - 16	3	1	5	5	1	4	59.7
8	I-264	16 - 17	3	1	5	5	1	4	59.7
9	I-65	128 - 131	3	1	5	5	1	4	59.7
10	I-264	9 - 0	3	2	5	5	1	3	59.0

Figures 2 through 6 show the ranking of the different segments against each individual criterion and for the total Impact Assessment Scores.

Legend

Segment Rating
- 1
- 2
- 3
- 4
- 5
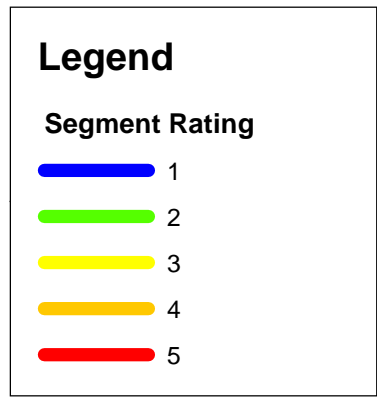
Inset: Louisville Metro Area
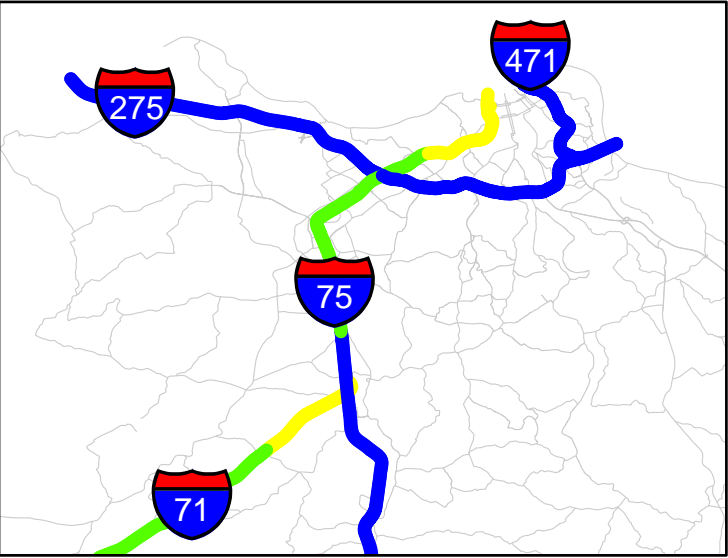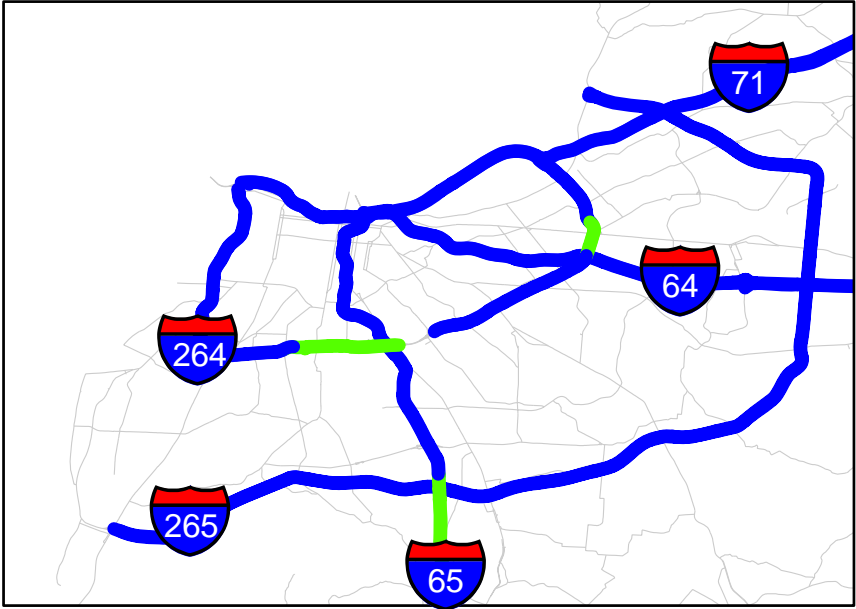
Inset: Northern Kentucky
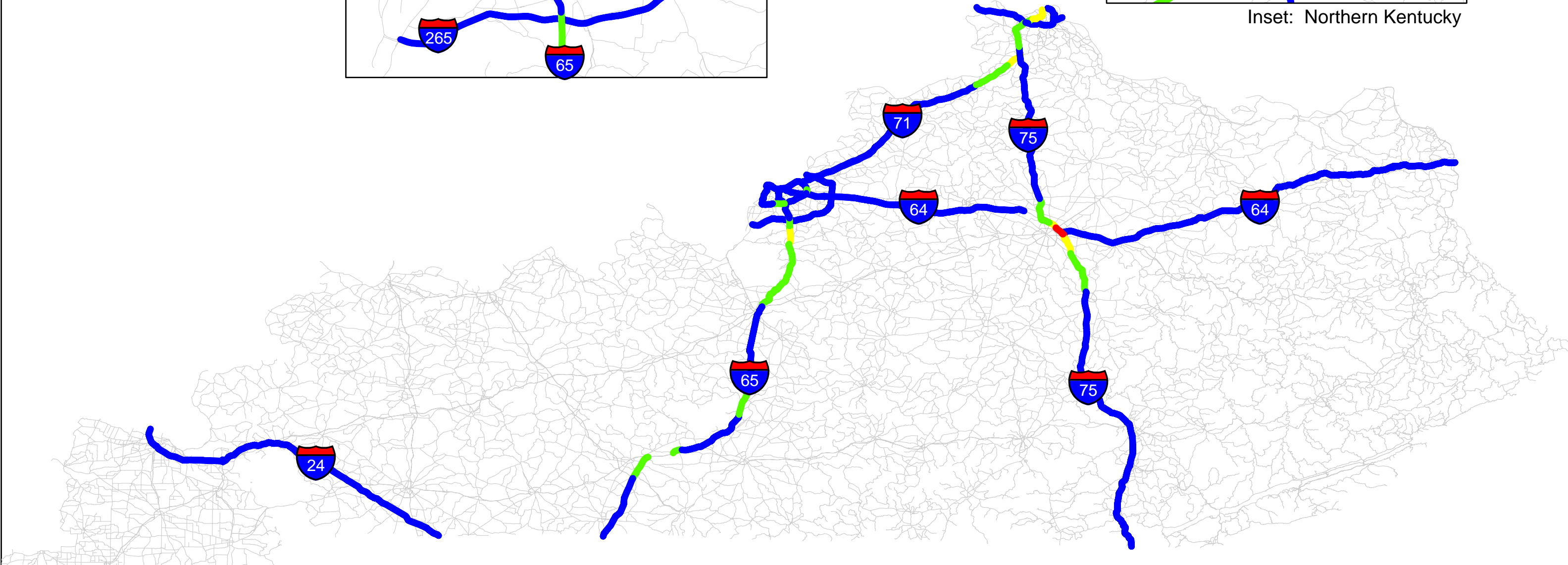
Figure 2
Economic Impact Ratings

Legend

Segment Rating
- 1 (blue)
- 2 (green)
- 3 (yellow)
- 4 (orange)
- 5 (red)
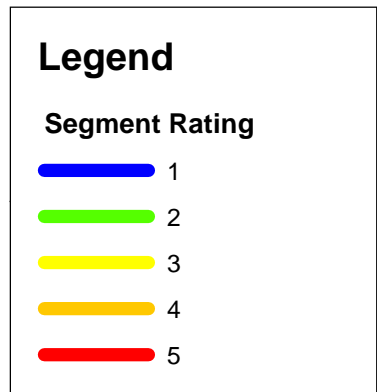
Inset: Louisville Metro Area
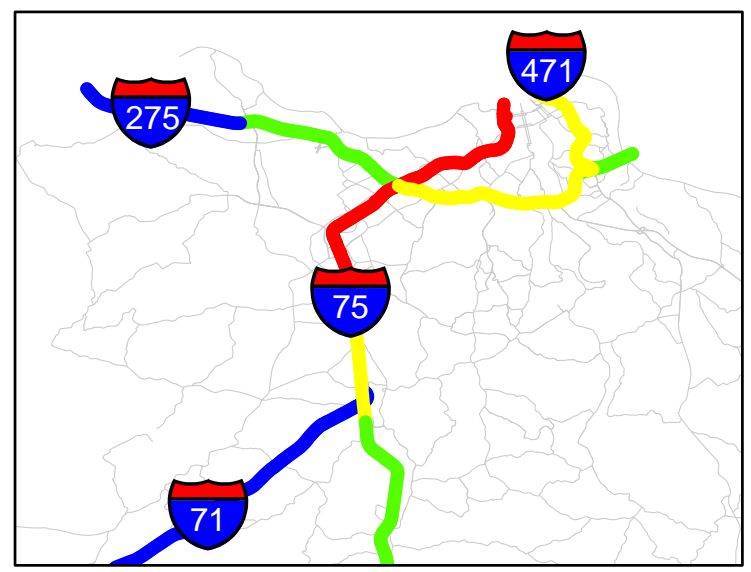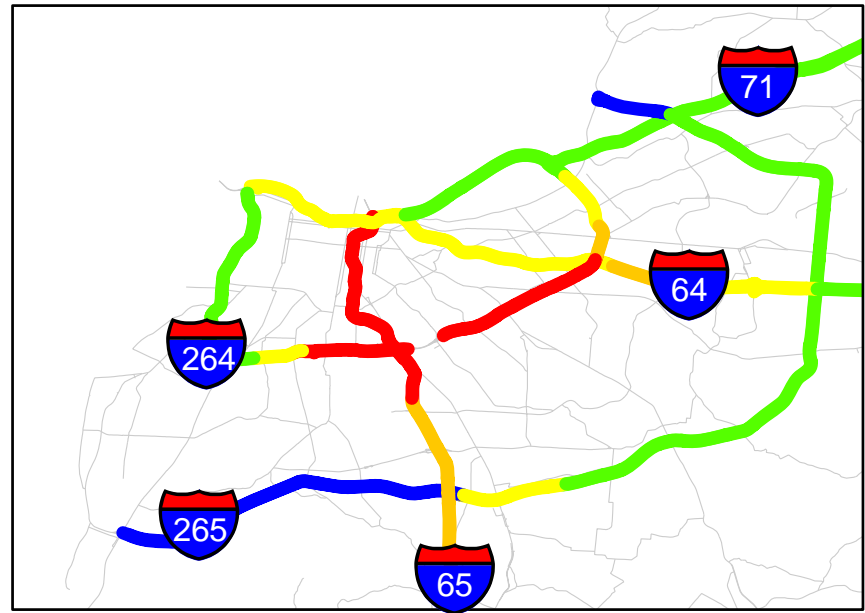
Inset: Northern Kentucky
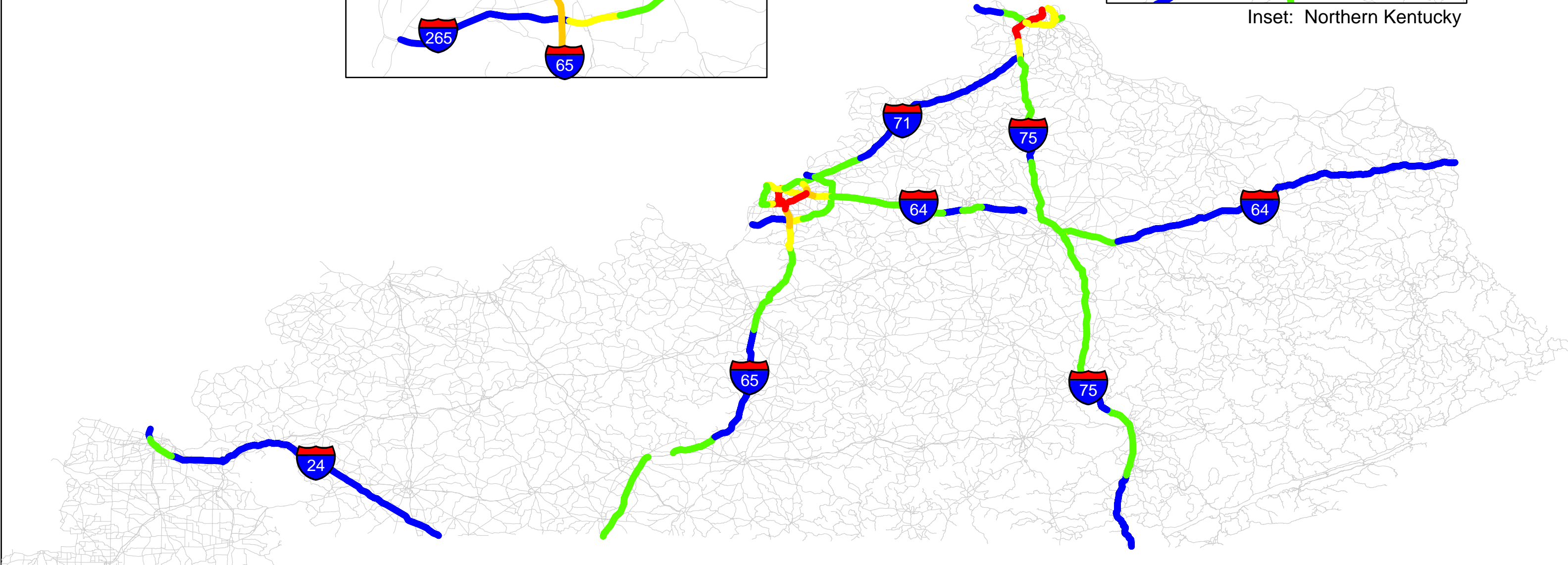
Figure 3
Functional Importance (ADT)

Legend

Segment Rating
- 1 (blue)
- 2 (green)
- 3 (yellow)
- 4 (orange)
- 5 (red)

Inset: Louisville Metro Area
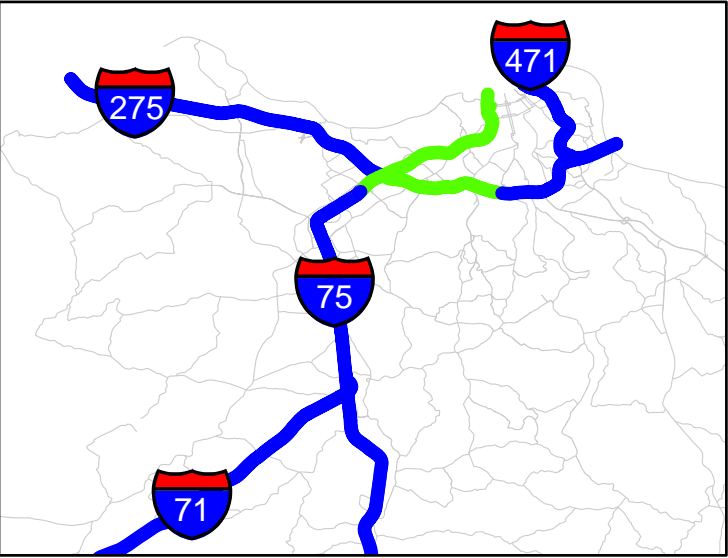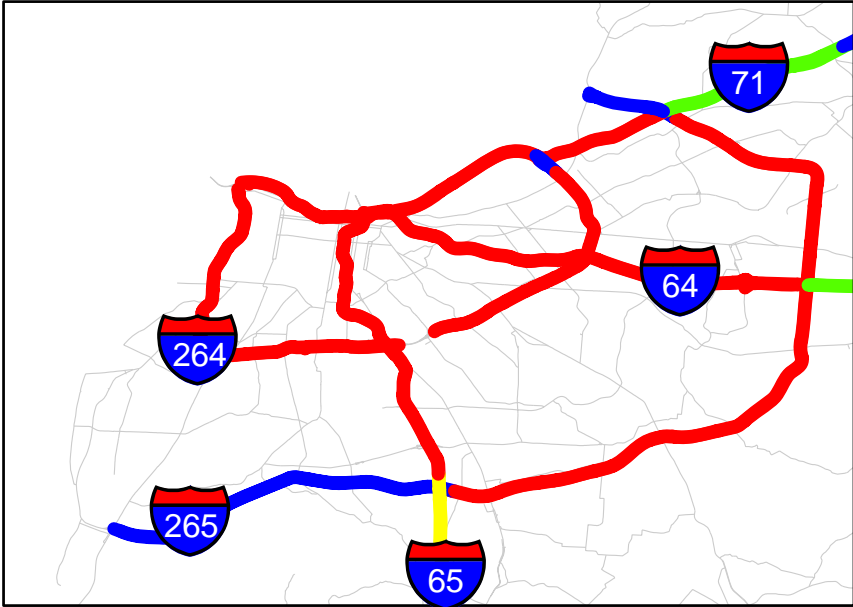
Inset: Northern Kentucky
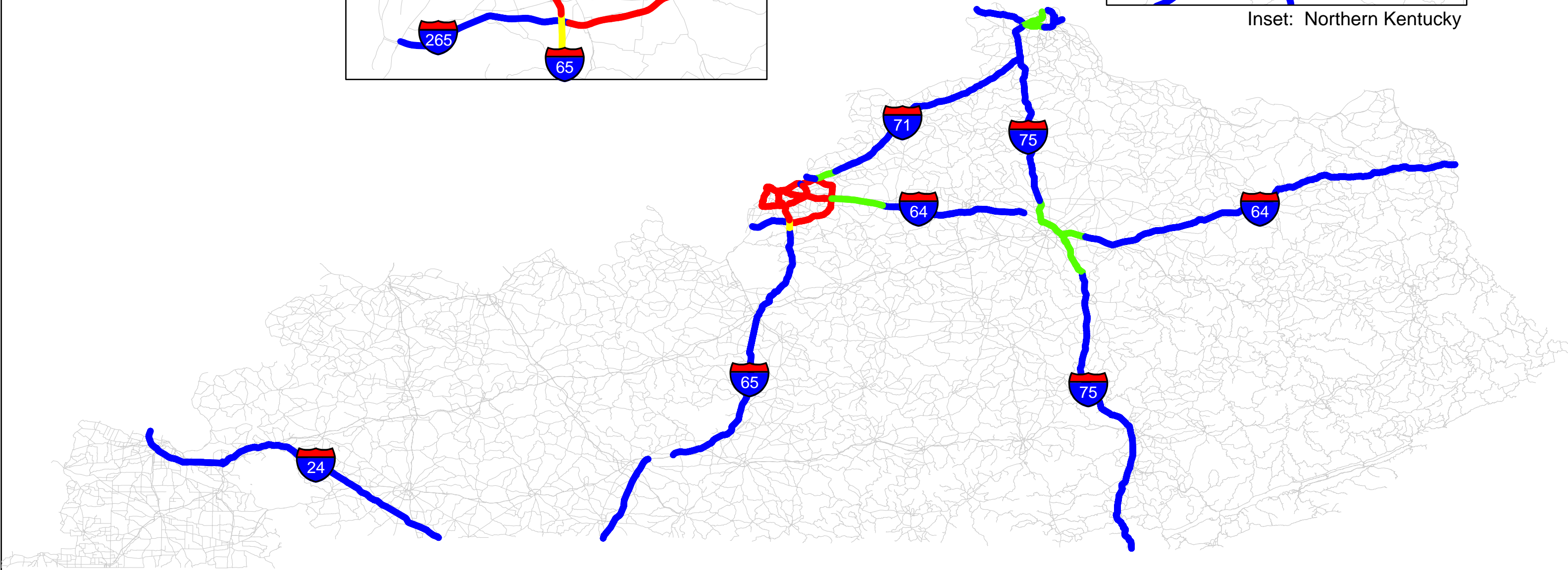
Figure 4
Functional Importance (Pop.)

Legend

Segment Rating

- ——— 1
- ——— 2
- ——— 3
- ——— 4
- ——— 5
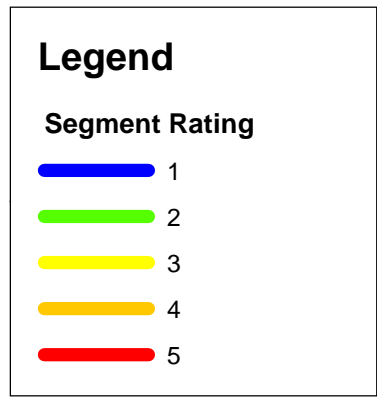
Inset: Louisville Metro Area
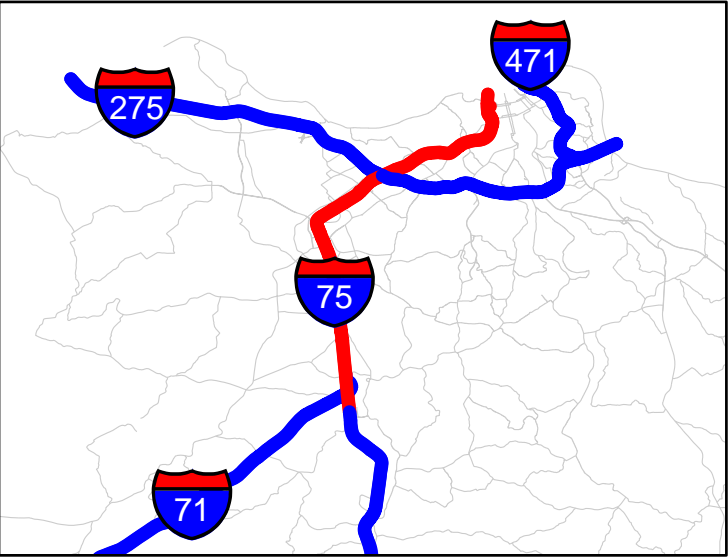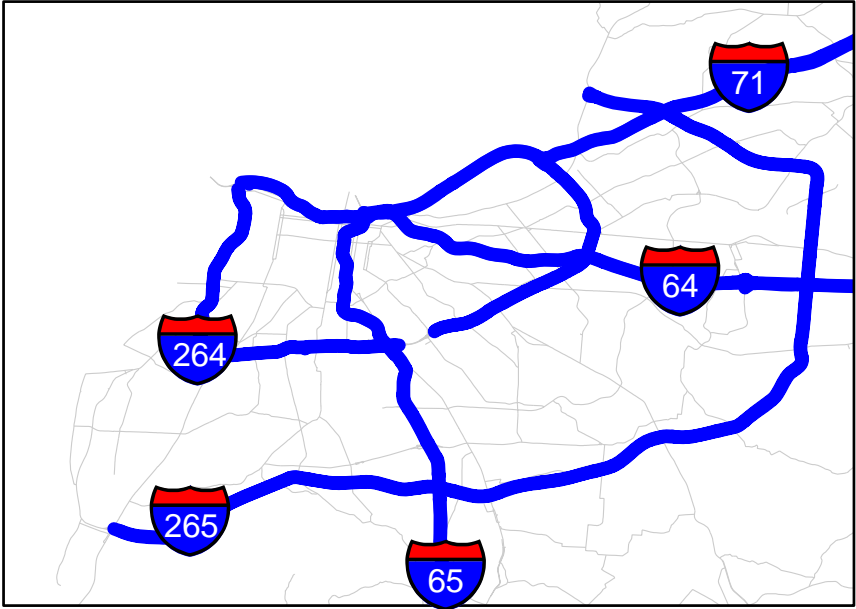
Inset: Northern Kentucky
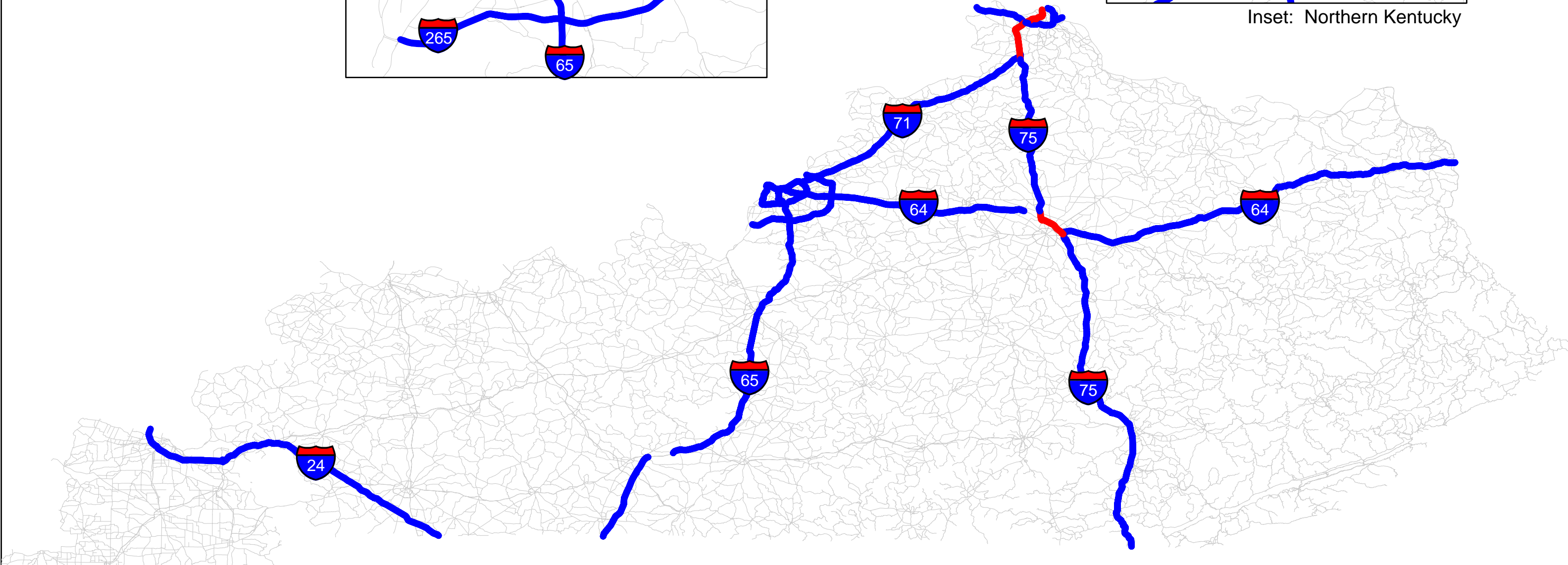
Figure 5
Critical Network Component

Legend

Segment Rating
1
2
3
4
5

Inset: Louisville Metro Area
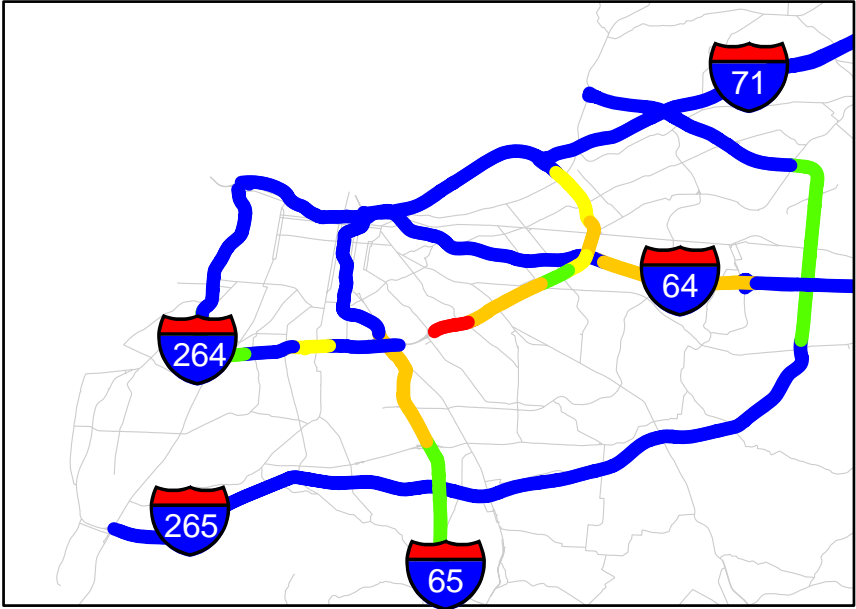
Inset: Northern Kentucky
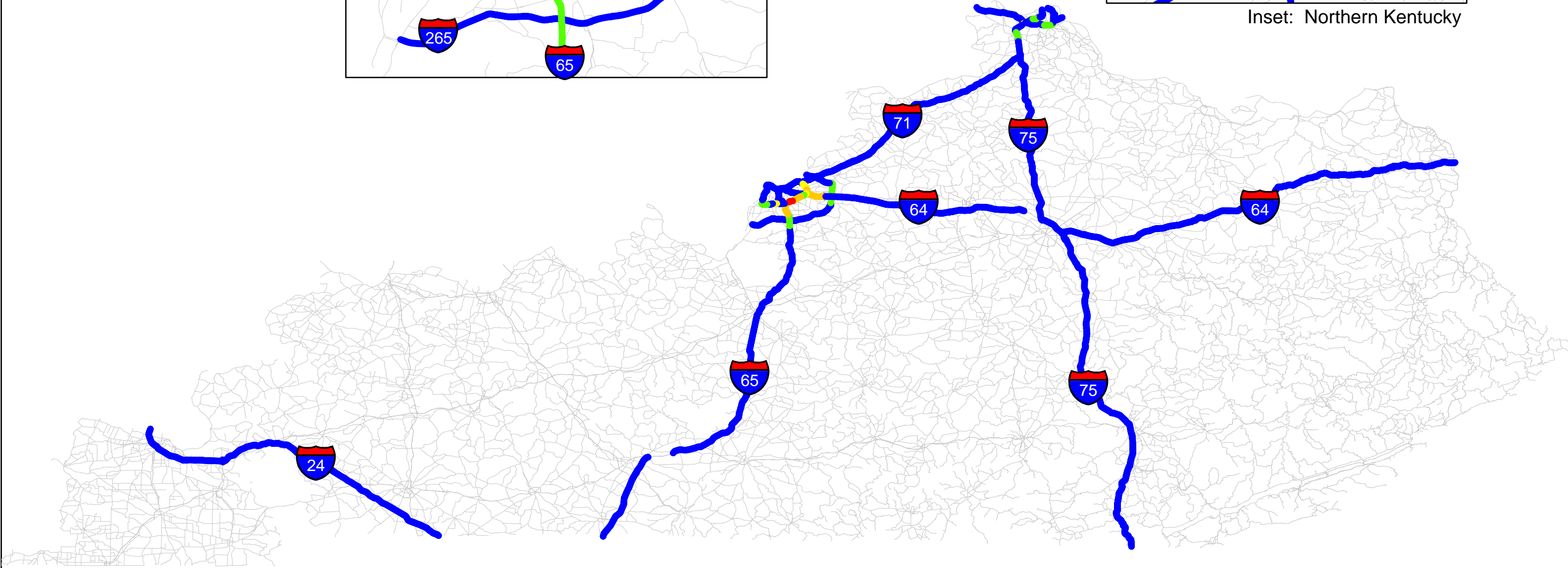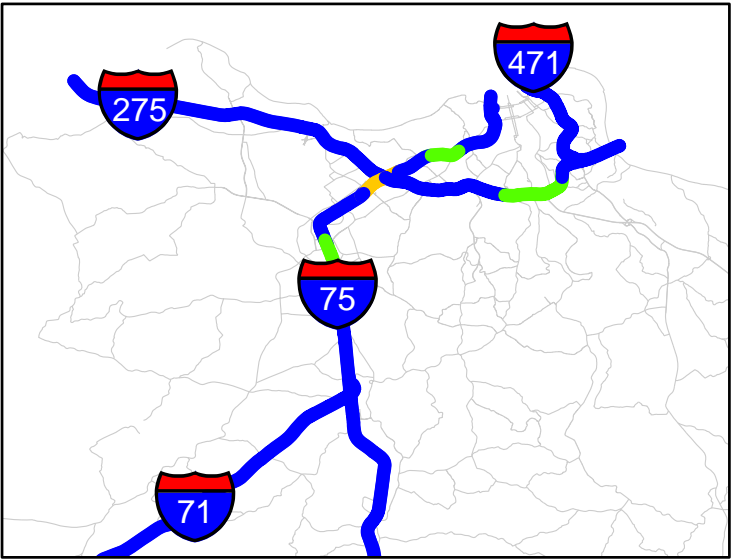
Figure 6
Alternate Route Availability

Legend

Segment Rating
- 1 (blue)
- 2 (green)
- 3 (yellow)
- 4 (orange)
- 5 (red)

Inset: Louisville Metro Area
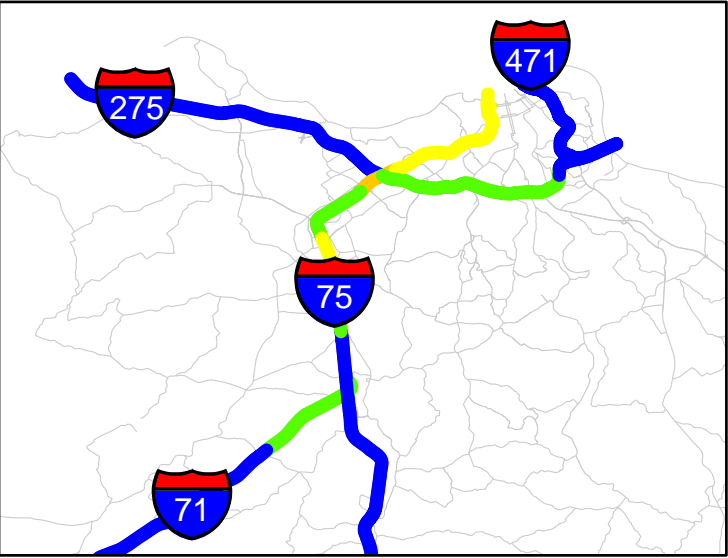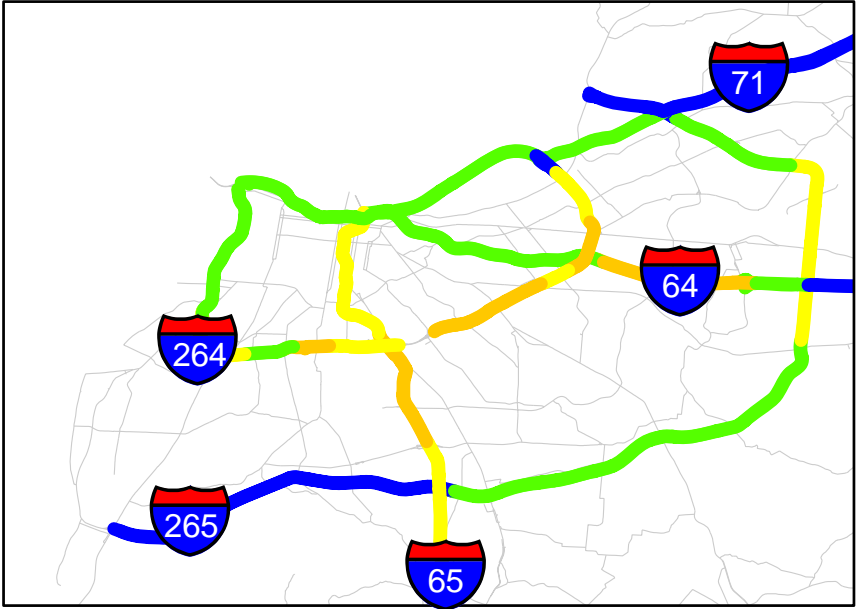
Inset: Northern Kentucky
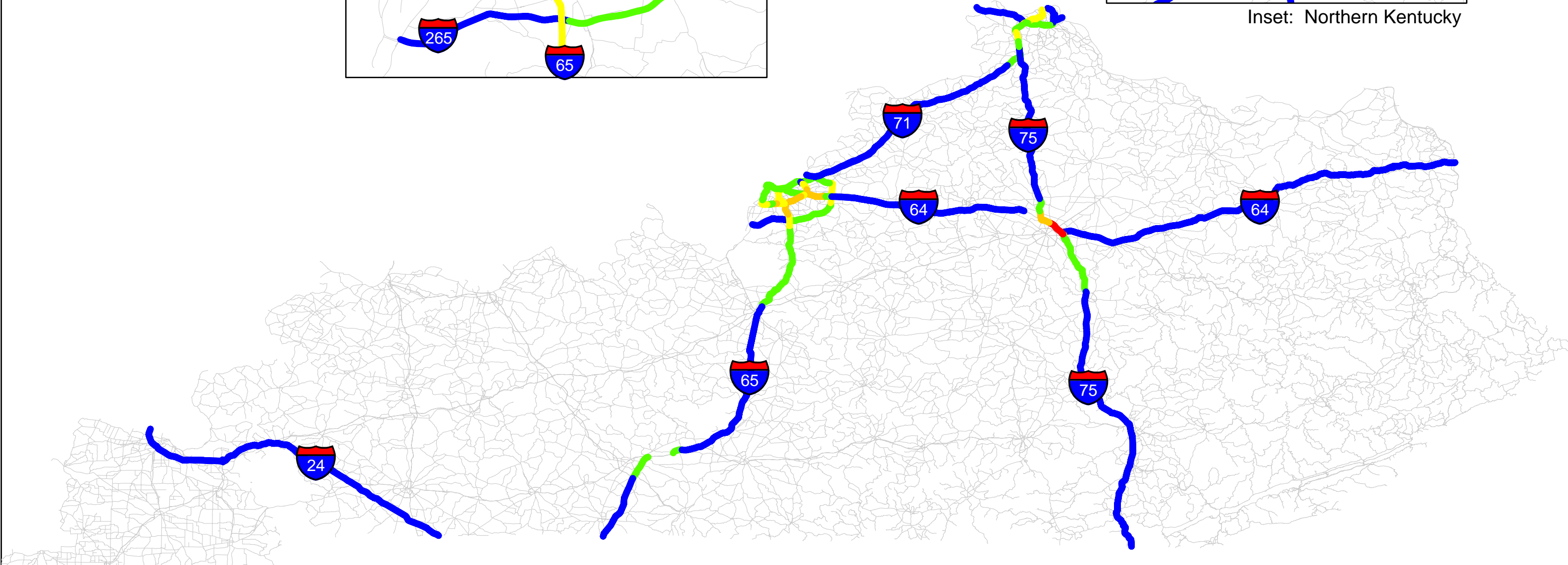
Figure 7
Impact Assessment Score

Conclusion and Recommendations

Based upon the literature review and analysis presented the following conclusions and recommendations are made.

- During times of significant route disruptions, the presence of redundant transportation facilities can significantly defer mobility and transportation related impacts.

- In heavily populated urban areas, the presence of alternative modes of transportation can significantly aid in maintaining mobility by providing modes of transportation dependent on separate infrastructure. Additionally high occupancy transit modes have higher person trip capacities than single occupancy vehicles, which is increasingly important when infrastructure is disrupted or reduced.

- Due to the countless number of potential route disruption causes and potential disruption scenarios, quantification of route disruption impacts on a statewide level is prohibitive in terms of data and time constraints.

- Qualitative assessment methods employed by security agencies provide a cost effective means of identifying and assessing critical infrastructure elements. Qualitative assessment can be just as effective as quantitative assessment methods in allocating resources to mitigate potential impacts of route disruption.

- The methodology set forth in this analysis can be expanded and applied to lower class roadways as well as used for regional security and redundancy planning. This is possible through the use of readily available data sources and adaptable measures of effectiveness.

- Route disruption analysis can be implemented in long range planning by providing redundancy to maintain mobility in times of short term and long term route disruptions. Additionally route disruption analysis can be used in long range security planning as well as security and emergency response activities to provide better informed decision making.

- Based upon the method presented a definite stratification of roadway Impact Assessment Scores is presented. This leads to the identification of less than 1 percent of roadway segments as being in the top quintile. This stratification allows for a ready identification of the most critical routes and allocation of planning, protection and security resources to the most critical elements of these segments.

References

1. Haimes, Y., J. Lambert, and B. Horowitz. (2005) Assessing and management risk of terrorism to Virginia's interdependent transportation systems. Final contract report VTRC 05-CR6

2. FHWA (2004). Effects of catastrophic events on transportation system management and operations, comparative analysis. Federal Highway Administration, DOT-VNTSC-FHWA-04-03, Washington D.C.

3. AASHTO. (2002) *A guide to updating highway emergency response plan for terrorist incidents.* American Association of State Highway and Transportation Officials, Washington D.C.

4. Giuliano, G., and J. Golob. (1998). *Impacts of the Northridge earthquake on transit and highway use.* Journal of Transportation and Statistics, Vol. 1, Number 2, May 1998.

5. Mcnally, M., S. Mattingly, R. Komerska, and A. Nickerson. (1996) *Impacts of the Northridge earthquake on traffic network performance.* Final report UCI-ITS-TS-WP-96-2, University of California, CA.

6. SAIC (2002). *A Guide to Highway Vulnerability Assessment for Critical Asset Identification and Protection.* American Association of State Highway and Transportation Officials. Vienna, VA.

7. PB Consult and SAIC (2004). *State of New Mexico Terrorism Risk Management Process Guide.* New Mexico Surety task Force. New Mexico Office of Homeland Security.

8. Xia, J., and M. Chen (2005). *A Framework for Risk Assessment of Highway Network.* Presented at the 84th Meeting of Transportation Research Board, Washington, D.C.

9. Srinivassan, K. Transportation Network Vulnerability Assessment: A Quantitative Framework. Vanderbilt University, Nashville, TN.

10. Friedman, D., M. Monteith, D. Kay, C. Couts, J. Trombly, D. Bratvold, and I. Hischman (2006) *Disruption Impact Estimating Tool – Transportation (DIETT): A Tool for Prioritizing High-Value Transportation Choke Points*, Surface Transportation Security, NCHRP Report 525 Volume 11, Transportation Research Board.

11. Dornan D. and M. Maier (2005). *Incorporating security into the transportation planning process.* NCHRP Report 525, Washington, D.C.

Appendix A
Interstate System Rankings

Rank	Route	Milepoint	ADT	Delay	Trucks	Population	STRAT	ECON	ADT	POP	NET	DELAY	IAScore
1	I-75	110 - 113	69008	6232.856	65024	260512	5	5	2	2	5	1	74.33333
2	I-75	113 - 115	68832	13805.37	50146	260512	5	3	2	2	5	1	66.33333
3	I-264	14 - 15	160865	153705.2	12869	693604	3	1	5	5	1	5	64.33333
4	I-264	12 - 14	174955	136680	18850	693604	3	2	5	5	1	4	63.66667
5	I-75	115 - 120	60479	1711.838	16359	260512	5	2	2	2	5	1	62.33333
6	I-264	19 - 20	114434	123964.4	16021	693604	3	2	4	5	1	4	61.66667
7	I-264	15 - 16	160865	98861.35	12869	693604	3	1	5	5	1	4	59.66667
8	I-264	16 - 17	160865	90929.35	12869	693604	3	1	5	5	1	4	59.66667
9	I-65	128 - 131	147929	108546.8	11834	693604	3	1	5	5	1	4	59.66667
10	I-264	9 - 0	152324	73653.3	18279	693604	3	2	5	5	1	3	59
11	I-264	9 - 0	152324	73653.3	18279	693604	3	2	5	5	1	3	59
12	I-64	1 - 15	116685	70222.66	14002	693604	3	1	4	5	1	4	57.66667
13	I-65	127 - 128	137314	93790.9	11619	693604	3	1	4	5	1	4	57.66667
14	I-75	184 - 185	169868	74762.93	20384	151464	3	2	5	2	5	4	57.66667
15	I-64	15 - 17	104211	128850.6	12505	693604	3	1	3	5	1	4	55.66667
16	I-264	18 - 19	160865	175360.9	12869	693604	3	1	5	5	1	3	55
17	I-264	10 - 11	152324	51050.3	18279	693604	3	2	5	5	1	2	54.33333
18	I-64	69 - 115	25555	19936.99	7073	9812	5	1	1	1	5	1	54.33333
19	I-75	186 - 188	152858	47785.52	38215	151464	3	3	5	2	5	2	52.33333
20	I-75	109 - 110	73059	2611.496	72328	260512	3	5	3	2	1	1	51.66667
21	I-264	20 - 22	71800	88302.59	10052	693604	3	1	3	5	1	3	51
22	I-264	17 - 18	160865	50016.77	12869	693604	3	1	5	5	1	2	50.33333
23	I-65	121 - 125	118788	65309.27	17583	535512	3	2	4	4	1	2	50.33333
24	I-264	11 - 12	160973	22769.93	19317	693604	3	2	5	5	1	1	49.66667
25	I-75	110 - 113	69008	6232.856	65024	260512	3	5	2	2	1	1	49.66667
26	I-65	125 - 127	126698	68491.53	11403	693604	3	1	4	5	1	2	48.33333
27	I-75	188 - 189	144747	15623.22	30397	151464	3	3	5	2	5	1	47.66667
28	I-75	189 - 191	144747	19077.78	30397	151464	3	3	5	2	5	1	47.66667
29	I-75	191 - 192	144747	6830.916	30397	151464	3	3	5	2	5	1	47.66667
30	I-75	192 - OH	144747	7496.427	30397	151464	3	3	5	2	5	1	47.66667
31	I-75	178 - 180	141805	45467.34	25525	85991	3	2	5	1	5	2	46.33333
32	I-65	131 - 137	147929	17247	11834	693604	3	1	5	5	1	1	45.66667
33	I-264	5 - 8	57371	41316.42	6884	693604	3	1	2	5	1	2	44.33333
34	I-265	23 - 25	62539	41156.45	7505	693604	3	1	2	5	1	2	44.33333
35	I-265	25 - 27	65020	61115.43	9404	693604	3	1	2	5	1	2	44.33333
36	I-265	27 - 30	54027	38728.17	10806	693604	3	1	2	5	1	2	44.33333
37	I-75	185 - 186	161215	30920.75	24314	151464	3	2	5	2	5	1	43.66667

Rank	Route	Milepoint	ADT	Delay	Trucks	Population	STRAT	ECON	ADT	POP	NET	DELAY	IAScore
38	I-264	8 - 9	96731	28060.86	11608	693604	3	1	3	5	1	1	41.66667
39	I-265	10 - 12	83861	32300.06	10063	693604	3	1	3	5	1	1	41.66667
40	I-265	12 - 14	72100	25981.21	8011	693604	3	1	3	5	1	1	41.66667
41	I-64	1 - 12	94752	17247	12872	693604	3	1	3	5	1	1	41.66667
42	I-64	17 - 19	80367	17247	10373	693604	3	1	3	5	1	1	41.66667
43	I-64	17 - 19	80367	17247	10373	693604	3	1	3	5	1	1	41.66667
44	I-65	117 - 121	89780	16518.26	34116	61236	3	3	3	1	1	1	41.66667
45	I-75	104 - 109	63770	16157.11	38259	260512	3	3	2	2	1	1	41.66667
46	I-75	104 - 109	63770	16157.11	38259	260512	3	3	2	2	1	1	41.66667
47	I-75	180 - 181	141805	20254.26	25525	85991	3	2	5	1	5	1	41.66667
48	I-75	181 - 182	141805	24749.27	25525	85991	3	2	5	1	5	1	41.66667
49	I-75	182 - 184	152246	28890.39	23942	107815	3	2	5	1	5	1	41.66667
50	I-264	1 - 2	43995	636.0863	5279	693604	3	1	2	5	1	1	39.66667
51	I-264	2 - 3	53840	17247	6461	693604	3	1	2	5	1	1	39.66667
52	I-264	3 - 4	53840	1155.632	6461	693604	3	1	2	5	1	1	39.66667
53	I-264	4 - 5	53840	2664.839	6461	693604	3	1	2	5	1	1	39.66667
54	I-265	14 - 15	64165	6797.368	6417	693604	3	1	2	5	1	1	39.66667
55	I-265	15 - 17	64165	16231.21	6417	693604	3	1	2	5	1	1	39.66667
56	I-265	17 - 19	64165	9749.275	6417	693604	3	1	2	5	1	1	39.66667
57	I-265	19 - 23	62327	15346.7	6838	693604	3	1	2	5	1	1	39.66667
58	I-265	30 - 33	51077	10425.27	10216	693604	3	1	2	5	1	1	39.66667
59	I-265	33 - 34	54653	10322.4	10931	693604	3	1	2	5	1	1	39.66667
60	I-71	1 - 2	65774	17247	3946	693604	3	1	2	5	1	1	39.66667
61	I-71	2 - 5	65840	14451.31	3950	693604	3	1	2	5	1	1	39.66667
62	I-71	5 - 9	69504	29727.99	11816	693604	3	1	2	5	1	1	39.66667
63	I-275	76 - 77	76492	47039.6	9179	88616	3	1	3	1	1	2	38.33333
64	I-275	77 - 79	90807	37545.8	10897	130515	3	1	3	1	1	2	38.33333
65	I-65	116 - 117	74863	7300.102	28448	61236	3	2	3	1	1	1	37.66667
66	I-71	72 - 77	29793	8906.356	29793	85991	3	3	1	1	1	1	37.66667
67	I-71	72 - 77	29793	8906.356	29793	85991	3	3	1	1	1	1	37.66667
68	I-75	120 - 125	56696	7279.865	15308	146787	3	2	2	2	1	1	37.66667
69	I-75	175 - 178	102931	20347.08	25733	85991	3	2	3	1	5	1	37.66667
70	I-75	97 - 99	58919	16896.98	15908	197299	3	2	2	2	1	1	37.66667
71	I-75	99 - 104	57577	2994.7	15546	260512	3	2	2	2	1	1	37.66667
72	I-275	79 - 80	97965	30617.05	11756	151464	3	1	3	2	1	1	35.66667
73	I-275	80 - 82	97965	16450.85	11756	151464	3	1	3	2	1	1	35.66667
74	I-275	80 - 82	97965	16450.85	11756	151464	3	1	3	2	1	1	35.66667

Rank	Route	Milepoint	ADT	Delay	Trucks	Population	STRAT	ECON	ADT	POP	NET	DELAY	IAScore
75	I-275	82 - 83	103203	3201.062	12384	151464	3	1	3	2	1	1	35.66667
76	I-275	83 - 84	103203	30015.04	12384	151464	3	1	3	2	1	1	35.66667
77	I-65	105 - 112	56136	3037.912	21332	61236	3	2	2	1	1	1	35.66667
78	I-65	112 - 116	56136	1620.657	21332	61236	3	2	2	1	1	1	35.66667
79	I-65	20 - 22	43884	23551.72	17115	92522	3	2	2	1	1	1	35.66667
80	I-65	22 - 28	47771	20644.57	18855	92522	3	2	2	1	1	1	35.66667
81	I-65	28 - 38	44817	4014.712	18375	92522	3	2	2	1	1	1	35.66667
82	I-65	36 - 38	44817	358.2004	18375	92522	3	2	2	1	1	1	35.66667
83	I-65	94 - 105	51794	3560.972	16455	80999	3	2	2	1	1	1	35.66667
84	I-65	94 - 105	51794	3560.972	16455	80999	3	2	2	1	1	1	35.66667
85	I-75	90 - 95	61603	4179.472	16633	70872	3	2	2	1	1	1	35.66667
86	I-75	95 - 97	61603	552.7493	16633	70872	3	2	2	1	1	1	35.66667
87	I-275	74 - 76	76492	35.08513	9179	88616	3	1	3	1	1	1	33.66667
88	I-471	1 - 2	96980	13438.3	7758	88616	3	1	3	1	1	1	33.66667
89	I-471	2 - 3	96980	12968.44	7758	88616	3	1	3	1	1	1	33.66667
90	I-471	3 - 4	96980	6975.044	7758	88616	3	1	3	1	1	1	33.66667
91	I-471	4 - 5	96980	7897.255	7758	88616	3	1	3	1	1	1	33.66667
92	I-471	5 - OH	96980	17247	7758	88616	3	1	3	1	1	1	33.66667
93	I-64	19 - 32	51123	15692.78	10590	209408	3	1	2	2	1	1	33.66667
94	I-64	81 - 87	36858	1827.692	5529	260512	3	1	2	2	1	1	33.66667
95	I-65	58 - 65	33515	2016.473	16087	17445	3	2	1	1	1	1	33.66667
96	I-65	65 - 71	33581	333.6554	16455	17445	3	2	1	1	1	1	33.66667
97	I-71	62 - 72	29302	336.3265	22411	59951	3	2	1	1	1	1	33.66667
98	I-71	9 - 14	55101	10880.81	13224	261987	3	1	2	2	1	1	33.66667
99	I-75	171 - 175	75490	6841.295	13836	85991	3	1	3	1	5	1	33.66667
100	I-24	3 - 4	37595	4043.918	7143	65514	3	1	2	1	1	1	31.66667
101	I-24	4 - 7	37595	8458.872	7143	65514	3	1	2	1	1	1	31.66667
102	I-24	7 - 11	37972	9706.495	7215	65514	3	1	2	1	1	1	31.66667
103	I-264	22 - 23	47360	5991.59	6630	9812	3	1	2	1	1	1	31.66667
104	I-265	34 - 35	50207	9750.817	10041	9812	3	1	2	1	1	1	31.66667
105	I-275	4 - 7	35832	2665.978	6808	85991	3	1	2	1	1	1	31.66667
106	I-275	84 - 4	67671	7446.871	6688	107815	3	1	2	1	1	1	31.66667
107	I-275	OH - 74	55699	17247	6684	88616	3	1	2	1	1	1	31.66667
108	I-64	32 - 35	42287	10326.22	8880	33337	3	1	2	1	1	1	31.66667
109	I-64	35 - 43	42287	4618.177	8880	33337	3	1	2	1	1	1	31.66667
110	I-64	35 - 43	42287	4618.177	8880	33337	3	1	2	1	1	1	31.66667
111	I-64	43 - 48	41714	921.6837	10628	44100	3	1	2	1	1	1	31.66667

Rank	Route	Milepoint	ADT	Delay	Trucks	Population	STRAT	ECON	ADT	POP	NET	DELAY	IAScore
112	I-64	53 - 58	38659	7178.354	10438	47687	3	1	2	1	1	1	31.66667
113	I-64	87 - 94	37415	3749.921	8996	89986	3	1	2	1	1	1	31.66667
114	I-64	87 - 94	37415	3749.921	8996	89986	3	1	2	1	1	1	31.66667
115	I-64	94 - 96	43700	6041.044	5244	33144	3	1	2	1	1	1	31.66667
116	I-65	2 - 6	37733	2374.906	8678	16405	3	1	2	1	1	1	31.66667
117	I-65	38 - 48	38060	14031.98	12340	53724	3	1	2	1	1	1	31.66667
118	I-65	6 - 20	40588	8481.98	13701	67150	3	1	2	1	1	1	31.66667
119	I-65	86 - 91	38964	818.5491	9741	94174	3	1	2	1	1	1	31.66667
120	I-65	91 - 94	52616	4679.886	13399	94174	3	1	2	1	1	1	31.66667
121	I-65	TN - 2	41634	824.0303	10992	16405	3	1	2	1	1	1	31.66667
122	I-71	14 - 17	57706	4247.741	13272	46178	3	1	2	1	1	1	31.66667
123	I-71	17 - 18	55658	2393.546	12801	46178	3	1	2	1	1	1	31.66667
124	I-71	18 - 22	55658	5835.615	12801	46178	3	1	2	1	1	1	31.66667
125	I-75	125 - 126	43351	265.4225	7111	33061	3	1	2	1	1	1	31.66667
126	I-75	126 - 129	38959	4613.892	6018	33061	3	1	2	1	1	1	31.66667
127	I-75	129 - 136	35050	515.346	9300	33061	3	1	2	1	1	1	31.66667
128	I-75	144 - 154	40556	1368.242	10950	22384	3	1	2	1	1	1	31.66667
129	I-75	154 - 159	40556	5483.805	10950	22384	3	1	2	1	1	1	31.66667
130	I-75	159 - 166	40556	3465.166	10950	22384	3	1	2	1	1	1	31.66667
131	I-75	166 - 171	52429	2316.156	11534	107815	3	1	2	1	1	1	31.66667
132	I-75	25 - 29	35846	5051.219	5462	42605	3	1	2	1	1	1	31.66667
133	I-75	29 - 38	39615	13310.39	9108	52715	3	1	2	1	1	1	31.66667
134	I-75	38 - 41	42359	3761.17	5083	52715	3	1	2	1	1	1	31.66667
135	I-75	41 - 49	35648	3337.45	9625	52715	3	1	2	1	1	1	31.66667
136	I-75	62 - 76	40967	2076.476	11737	52775	3	1	2	1	1	1	31.66667
137	I-75	76 - 77	44453	4258.06	12447	70872	3	1	2	1	1	1	31.66667
138	I-75	77 - 87	46693	24226.46	13074	70872	3	1	2	1	1	1	31.66667
139	I-75	87 - 90	50385	8544.382	13984	70872	3	1	2	1	1	1	31.66667
140	I-24	11 - 16	31400	4868.078	7536	65514	3	1	1	1	1	1	29.66667
141	I-24	16 - 25	26060	969.8329	7721	41921	3	1	1	1	1	1	29.66667
142	I-24	25 - 27	25690	120.1544	7964	30125	3	1	1	1	1	1	29.66667
143	I-24	27 - 31	25805	369.7389	8000	19965	3	1	1	1	1	1	29.66667
144	I-24	31 - 40	25820	435.9078	8004	8573	3	1	1	1	1	1	29.66667
145	I-24	40 - 45	19150	216.2232	5550	8080	3	1	1	1	1	1	29.66667
146	I-24	45 - 56	14779	56.10877	3990	9503	3	1	1	1	1	1	29.66667
147	I-24	56 - 65	15069	498.7569	4069	12713	3	1	1	1	1	1	29.66667
148	I-24	65 - 73	15739	132.7794	5745	57348	3	1	1	1	1	1	29.66667

Rank	Route	Milepoint	ADT	Delay	Trucks	Population	STRAT	ECON	ADT	POP	NET	DELAY	IAScore
149	I-24	73 - 86	17982	119.2692	5937	72265	3	1	1	1	1	1	29.66667
150	I-24	86 - 89	29298	800.1295	7325	72265	3	1	1	1	1	1	29.66667
151	I-24	89 - TN	33900	17247	8475	72265	3	1	1	1	1	1	29.66667
152	I-24	IL - _3	31599	1381.275	7114	65514	3	1	1	1	1	1	29.66667
153	I-265	0 - 3	0	729.9108	0	9812	3	1	1	1	1	1	29.66667
154	I-265	3 - 6	0	262.8861	0	9812	3	1	1	1	1	1	29.66667
155	I-265	35 - 37	0	1265.52	0	9812	3	1	1	1	1	1	29.66667
156	I-265	6 - 8	0	151.4381	0	9812	3	1	1	1	1	1	29.66667
157	I-265	8 - 10	33600	4672.346	4032	9812	3	1	1	1	1	1	29.66667
158	I-275	11 - IN	33500	17247	6365	85991	3	1	1	1	1	1	29.66667
159	I-275	7 - 11	33700	1808.034	6403	85991	3	1	1	1	1	1	29.66667
160	I-64	101 - 110	24185	469.7912	5809	24672	3	1	1	1	1	1	29.66667
161	I-64	110 - 113	21643	411.6378	5844	22554	3	1	1	1	1	1	29.66667
162	I-64	113 - 121	20024	370.72	5407	16820	3	1	1	1	1	1	29.66667
163	I-64	121 - 123	18478	238.0255	4989	11085	3	1	1	1	1	1	29.66667
164	I-64	123 - 133	16371	306.0888	3501	18424	3	1	1	1	1	1	29.66667
165	I-64	133 - 137	15317	3646.595	2757	22094	3	1	1	1	1	1	29.66667
166	I-64	137 - 156	14619	4118.738	2962	23464	3	1	1	1	1	1	29.66667
167	I-64	137 - 156	14619	4118.738	2962	23464	3	1	1	1	1	1	29.66667
168	I-64	156 - 161	14584	299.3355	3775	26889	3	1	1	1	1	1	29.66667
169	I-64	161 - 172	16294	120.6376	4074	26889	3	1	1	1	1	1	29.66667
170	I-64	172 - 181	18525	427.786	4632	33421	3	1	1	1	1	1	29.66667
171	I-64	181 - 185	18966	387.8452	4742	49752	3	1	1	1	1	1	29.66667
172	I-64	185 - 191	23982	124.1013	5996	49752	3	1	1	1	1	1	29.66667
173	I-64	191 - WV	25164	1032.821	6291	49752	3	1	1	1	1	1	29.66667
174	I-64	48 - 53	31921	1214.132	8619	9812	3	1	1	1	1	1	29.66667
175	I-64	48 - 53	31921	1214.132	8619	9812	3	1	1	1	1	1	29.66667
176	I-64	58 - 65	34280	2986.997	9256	26705	3	1	1	1	1	1	29.66667
177	I-64	65 - 69	30125	455.3352	8134	30598	3	1	1	1	1	1	29.66667
178	I-64	96 - 101	30015	854.0128	4502	33144	3	1	1	1	1	1	29.66667
179	I-65	48 - 53	30957	481.899	7739	38033	3	1	1	1	1	1	29.66667
180	I-65	53 - 58	33202	154.7674	14243	21563	3	1	1	1	1	1	29.66667
181	I-65	71 - 76	34482	17.83947	11074	14730	3	1	1	1	1	1	29.66667
182	I-65	76 - 81	34311	416.2628	8461	67240	3	1	1	1	1	1	29.66667
183	I-65	76 - 81	34311	416.2628	8461	67240	3	1	1	1	1	1	29.66667
184	I-65	81 - 86	30222	320.3318	7556	9812	3	1	1	1	1	1	29.66667
185	I-65	81 - 86	30222	320.3318	7556	9812	3	1	1	1	1	1	29.66667

Rank	Route	Milepoint	ADT	Delay	Trucks	Population	STRAT	ECON	ADT	POP	NET	DELAY	IAScore
186	I-71	22 - 28	34119	1540.738	12794	25433	3	1	1	1	1	1	29.66667
187	I-71	28 - 34	28800	1223.453	12384	15060	3	1	1	1	1	1	29.66667
188	I-71	34 - 43	27549	398.4503	9269	11711	3	1	1	1	1	1	29.66667
189	I-71	43 - 44	25971	1792.894	7012	10155	3	1	1	1	1	1	29.66667
190	I-71	44 - 57	27849	4665.397	7519	8327	3	1	1	1	1	1	29.66667
191	I-71	57 - 62	28319	1196.328	7646	7870	3	1	1	1	1	1	29.66667
192	I-75	11 - 15	29194	1876.811	7883	35865	3	1	1	1	1	1	29.66667
193	I-75	136 - 144	32800	79.74112	8528	27723	3	1	1	1	1	1	29.66667
194	I-75	15 - 25	29740	1334.659	7155	35865	3	1	1	1	1	1	29.66667
195	I-75	49 - 59	33765	423.0247	9117	28626	3	1	1	1	1	1	29.66667
196	I-75	59 - 62	31500	2076.915	8505	16582	3	1	1	1	1	1	29.66667
197	I-75	TN - 11	23733	772.4944	6408	35865	3	1	1	1	1	1	29.66667