Final Report

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Updating and Improving Methodology for Prioritizing Highway Project Locations on the Strategic Intermodal System (SIS)

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METRIC CONVERSION CHART

SYMBOL	WHEN YOU KNOW	MULTIPLY BY	TO FIND	SYMBOL
LENGTH				
in	inches	25.400	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.610	kilometers	km
mm	millimeters	0.039	inches	in
m	meters	3.280	feet	ft
m	meters	1.090	yards	yd
km	kilometers	0.621	miles	mi
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
AREA				
in^2	square inches	645.200	square millimeters	mm^2
ft^2	square feet	0.093	square meters	m^2
yd^2	square yard	0.836	square meters	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.590	square kilometers	km^2
mm^2	square millimeters	0.0016	square inches	in^2
m^2	square meters	10.764	square feet	ft^2
m^2	square meters	1.195	square yards	yd^2
ha	hectares	2.470	acres	ac
km^2	square kilometers	0.386	square miles	mi^2
SYMBOL	**WHEN YOU KNOW**	**MULTIPLY BY**	**TO FIND**	**SYMBOL**
VOLUME				
fl oz	fluid ounces	29.570	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	cubic meters	m^3
yd^3	cubic yards	0.765	cubic meters	m^3
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	cubic meters	35.314	cubic feet	ft^3
m^3	cubic meters	1.307	cubic yards	yd^3
NOTE: volumes greater than 1,000 L shall be shown in m^3.				

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Ms. Yleana Baez and Mr. Kyle Purvis of the Intermodal Systems Development Office at the Florida Department of Transportation District One and Dr. Rax Jung, P.E. of the Florida's Turnpike Enterprise served as the Project Managers for this project.

16. Abstract

The Florida Department of Transportation (FDOT) District One developed the Congestion Management Process (CMP) system to prioritize low-cost, near-term highway improvements on the Strategic Intermodal System (SIS). The existing CMP system is designed to screen and prioritize all project locations based on seven performance measures that were adopted from FDOT's Strategic Investment Tool (SIT). The system also uses a simple scoring method to prioritize project locations. Since the development of the CMP in 2009, a number of new developments have taken place, including, but not limited to, the development of the 2060 Florida Transportation Plan (FTP), the publication of the Highway Safety Manual (HSM), and a new emphasis on freight transportation for economic development. At the same time, more advanced methods for identifying improvement locations and ranking projects have also become available. Accordingly, the main objective of this project is to research and update the existing performance measures and the project prioritization method in the CMP to better reflect the current conditions and strategic goals of FDOT. A second objective of the project is to develop visual mapping tools in the system.

The final updated list of performance measures includes number of excess fatalities, number of excess injuries, volume-to-capacity ratio, average annual daily traffic (AADT) per lane, truck volume per lane, truck percent, and delay. The Analytic Network Process (ANP), an advanced multi-criteria decision-making technique, is implemented to prioritize highway project locations. Unlike the simple scoring method, the ANP does not give undue weight to a specific performance measure, and it can account for the interdependencies that usually exist in the performance measures. Furthermore, the ANP facilitates pairwise comparison of the project locations with respect to each of the performance measures. The new updated CMP system calculates the performance measures and implements the ANP approach to prioritize roadway segments. The system also has the capability to create thematic maps of performance measures and other input variables.

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EXECUTIVE SUMMARY

The Florida Department of Transportation (FDOT) District One developed the Congestion Management Process (CMP) to prioritize low-cost, near-term highway improvements on its Strategic Intermodal System (SIS). The CMP is designed to screen and prioritize all project locations system-wide and is able to automatically generate a ranked list of project locations. The existing system screens locations based on the following seven performance measures, with their maximum scores in percentage given in parentheses:

1. Crash ratio (22%)
2. Fatal crash (9%)
3. Volume-to-capacity (v/c) ratio (31%)
4. Average Annual Daily Traffic (AADT) per lane (10%)
5. Truck volume per lane (13%)
6. Truck percent (6%)
7. Delay (9%)

Since the development of the CMP in 2009, a number of new developments have taken place, including, but not limited to, the development of the 2060 Florida Transportation Plan (FTP), the publication of the Highway Safety Manual (HSM), and a new emphasis on freight transportation for economic development. At the same time, more advanced methods for identifying improvement sites and ranking projects have become available. For example, the HSM includes more advanced methods that could be adopted in the CMP to better screen and prioritize highway locations for safety improvements. As such, there is a need to update the existing performance measures and the prioritization method to better reflect the current conditions and align more consistently with the Department's current strategic goals.

Accordingly, the objectives of this project are to research and update:

1. the existing performance measures to better reflect the current conditions and strategic goals of the Department;
2. the current ranking methodology, including the weighting strategy and the method of prioritization; and
3. the CMP system to incorporate the updated project prioritization process and include visualization and mapping capabilities in the system.

Performance Measures

Of the existing seven measures, AADT, v/c ratio, and delay are retained as they are common measures of mobility and level of service. Although these measures are related, they serve to capture highway locations of different conditions. Truck volume and truck percent are also retained in the revised list as they provide key measures of freight transportation, an emphasis area in the 2060 Florida Transportation Plan, Florida Freight Mobility and Trade Plan, as well as the Florida's SIS Strategic Plan. In the strategic area of safety and security, the two existing safety performance measures, crash ratio and fatal crash, are replaced with "number of excess fatalities" and "number of excess injuries," which are calculated using the empirical Bayes (EB) approach. The final updated list of performance measures includes:

1. Number of excess fatalities (per mile per year)
2. Number of excess injuries (per mile per year)
3. Volume-to-capacity ratio
4. Average annual daily traffic (AADT) per lane
5. Truck volume per lane
6. Truck percent
7. Delay

Prioritization Method

The existing prioritization method consists of the application of quantitative criteria followed by qualitative questionnaire. A simple scoring method is used to prioritize highway project locations based on the quantitative criteria. Each of the seven quantitative performance measures is first assigned a maximum score. The actual score of each measure is then determined based on site-specific characteristics. Finally, for each project location, scores from the seven measures are summed up to obtain the overall score which is then used in project prioritization. Top-ranked project locations are scrutinized through the qualitative criteria to determine the final location list for funding.

The Analytic Network Process (ANP), an advanced multi-criteria decision-making technique, was evaluated for potential adoption within the CMP application. The ANP breaks down a decision problem into logical order and addresses the interaction among the criteria, the alternatives, and the overall goal. It reduces the risk of undue weight of any one criterion on decision making, and can effectively consider subjective judgments in a systematic way. For these reasons, the ANP approach was implemented within the updated CMP system.

The Updated CMP System

The updated CMP system provides the following key functions:

- Upload various traffic-related data and crash records.
- Calculate performance measures from uploaded data.
- Determine the importance of each performance measure based on pairwise comparisons.
- Prioritize roadway segments by applying the ANP method with multiple performance measures.
- Create thematic maps of performance measures and other input variables on Google Maps.
- Evaluate potential projects and record project information.
- Manage user accounts and assign account privileges.

A detailed user's manual of the system was prepared and included in Appendix A.

The system requires crash and roadway segment data for each analysis year. The crash data consist of crash records for the District in a standard format used by FDOT's Unified Basemap Repository (UBR). The segment data include the standard Roadway Characteristics Inventory (RCI) file for four variables needed in the calculation of safety-related performance measures, and a Keyhole

Markup Language (KML) file that is converted from the shapefiles prepared by District One Consultants annually. The KML file contains data for capacity, vehicular volume, truck percent, level of service (LOS), and number of lanes. These data files are used to calculate the seven performance measures.

After the performance measure data are successfully calculated, the next step is to apply the ANP method. The relative importance of each performance measure is determined via pairwise comparisons of the performance measures. The final scores of each roadway segment are next calculated using the ANP method. The scores are then used to gauge a roadway segment's overall need for improvements. A list of roadway segments is then selected for further consideration for potential funding. Finally, the selected roadway segments are further analyzed to identify and "short-list" projects to be reviewed in detail regarding operational analysis, specific improvements, cost estimates, potential funding opportunities, etc.

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LIST OF ACRONYMS/ABBREVIATIONS

AADT	Average Annual Daily Traffic
AADTT	Average Annual Daily Truck Traffic
AASHTO	American Association of State Highway and Transportation Officials
AHP	Analytic Hierarchy Process
B/C	Benefit-cost
CI	Consistency Index
CMAQ	Congestion Mitigation and Air Quality
CMP	Congestion Management Process
CR	Consistency Ratio
CTP	Capital Transportation Program
DelDOT	Delaware Department of Transportation
DOT	Department of Transportation
EB	Empirical Bayes
EI	Environmental Impact
FAMPO	Fredericksburg Area Metropolitan Planning Organization
FDOT	Florida Department of Transportation
FHWA	Federal Highway Administration
FI	Fatal and Injury
FMTP	Freight Mobility and Trade Plan
FTA	Federal Transit Administration
FTP	Florida Transportation Plan
GCTP	Governor’s Commission on Transportation Policy
GIS	Geographic Information System
HRTPO	Hampton Roads Transportation Planning Organization
HSM	Highway Safety Manual
HSP	Highway System Plan
INDOT	Indiana Department of Transportation
ITS	Intelligent Transportation Systems
KHA	Kimley-Horn and Associates
KML	Keyhole Markup Language
LOS	Level of Service
LRTP	Long Range Transportation Plan
MoDOT	Missouri Department of Transportation
MPO	Metropolitan Planning Organization
MVM	Million Vehicle Miles
NB	Negative Binomial
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NPV	Net Present Value
PET	Project Evaluation Toolkit
PSI	Potential for Safety Improvement
RCI	Roadway Characteristics Inventory
RI	Random Consistency Index
RPO	Rural Planning Organization
RTM	Regression-to-the-mean

SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SIS	Strategic Intermodal System
SIT	Strategic Investment Tool
SMF	Strategic Mobility Formula
SPF	Safety Performance Function
STP	Surface Transportation Program
TAC	Technical Advisory Committee
TCC	Technical Coordinating Committee
TEA-21	Transportation Equity Act for the 21st Century
TIP	Transportation Improvement Program
TOPSIS	Technique for Order Preference by Similarity to an Ideal Solution
TRAC	Transportation Review Advisory Council
TTC	Texas Transportation Commission
TxDOT	Texas Department of Transportation
UBR	Unified Basemap Repository
UDOT	Utah Department of Transportation
UTP	Unified Transportation Program
v/c	Volume-to-capacity
VDOT	Virginia Department of Transportation
VTRC	Virginia Transportation Research Council
WisDOT	Wisconsin Department of Transportation
WSDOT	Washington State Department of Transportation
WSUAMPO	Winston-Salem Urban Area Metropolitan Planning Organization

CHAPTER 1
INTRODUCTION

1.1 Project Background

The Florida Department of Transportation (FDOT) District One first deployed the Congestion Management Process (CMP) in 2009 to prioritize low-cost, near-term highway improvements on its Strategic Intermodal System (SIS). The project prioritization method used in the CMP was modeled after the Strategic Investment Tool (SIT), which was developed by the Department's Systems Planning Office. The SIT is a project selection tool for capacity and safety improvements on the SIS. It includes a total of 24 prioritization measures across five categories, each corresponding to the five SIS goals, i.e., *Safety*, *Preservation*, *Mobility*, *Economic Competitiveness*, and *Quality of Life*. Of the 24 SIT performance measures, the following seven were adopted for implementation in the CMP: crash ratio, fatal crash, volume-to-capacity (v/c) ratio, average annual daily traffic (AADT), truck volume, truck percent, and delay.

Although the project prioritization methods implemented in the SIT and the CMP are similar, the SIT is designed to evaluate individual projects, while the CMP is designed to screen and prioritize all projects system-wide and is able to automatically generate a ranked list of project locations. Although the main function of the CMP is to screen segment locations that have significant safety and mobility issues, it also includes functions to record project-specific information, such as site characteristics and costs associated with specific improvements at potential improvement locations. Accordingly, the CMP is divided into two tiers: (1) screening for roadway segment locations with potential for improvement; and (2) prioritizing project improvement alternatives. Tier one is an automated process where critical locations are flagged for consideration and a "long-list" of candidate locations is generated. Tier two is mainly a manual process where the earlier identified "long-list" is reviewed to identify the "short-list" of potential candidate projects. In this step, the "short-list" projects are reviewed in detail regarding operational analysis, specific improvements, cost estimates, potential funding opportunities, etc.

Since the development of the SIT in 2008, and later, the CMP in 2009, a number of new developments have taken place, including, but not limited to, the development of the 2060 Florida Transportation Plan (FTP), the publication of the Highway Safety Manual (HSM), and a new emphasis on freight transportation for economic development. At the same time, more advanced methods for identifying improvement sites and ranking projects have become available. For example, the HSM, which has been adopted by the Department for full implementation, includes potentially more advanced methods that could be adopted for implementation in the CMP to better screen and prioritize highway locations for safety improvements. All of these developments require that the existing performance measures and the prioritization method be updated to better reflect the current conditions and align more consistently with the current strategic goals of the Department.

1.2 Project Objectives

The objectives of this project are to research and update:

1. the existing performance measures to better reflect the current conditions and strategic goals of the Department;
2. the current segment location ranking methodology, including the weighting strategy and the method of prioritization; and
3. the CMP system to incorporate the updated project prioritization process and include visualization and mapping capabilities in the system.

1.3 Report Organization

The rest of this report is organized as follows:

- Chapter 2 documents the project prioritization practices currently being used by the state Departments of Transportation (DOTs), Metropolitan Planning Organizations (MPOs), and other local transportation agencies. It also presents the FDOT policy goals, objectives, and performance measures.

- Chapter 3 discusses the performance measures that are currently being used within the FDOT District One's CMP system, the recommended revisions to the existing performance measures, and the development of new performance measures.

- Chapter 4 describes a new method adopted for implementation in the updated CMP system for prioritizing highway improvement locations.

- Chapter 5 focuses on the data preparation and processing efforts undertaken while implementing the new method. It also includes a brief discussion of the updated CMP system.

- Chapter 6 provides a summary of this research effort and the relevant findings and conclusions.

CHAPTER 2
STATE-OF-THE-PRACTICE REVIEW

This chapter provides a review of the state-of-the-practice in transportation project screening and decision making. The current FDOT policy goals and objectives are first summarized. Particularly, Florida's SIS Strategic Plan, the 2060 Florida Transportation Plan, and the Florida Freight Mobility and Trade Plan are discussed. In addition, the FDOT's implementation plan of the advanced safety applications including the HSM and *SafetyAnalyst* is also presented. Finally, the chapter summarizes the project prioritization practices at the state and local agencies from across the country.

2.1 FDOT Policy Goals and Objectives

This section presents the FDOT policy goals, objectives, and performance measures. Particularly, the following documents are reviewed:

- Florida's SIS Strategic Plan
- The 2060 Florida Transportation Plan
- Florida Freight Mobility and Trade Plan

As FDOT has adopted the HSM and *SafetyAnalyst* for statewide implementation, a discussion on these advanced safety analysis tools is also included in this section.

2.1.1 Florida's SIS Strategic Plan

The SIS is a statewide network of high priority transportation facilities, including the state's largest and most significant commercial service airports, spaceport, deep-water seaports, freight rail terminals, passenger rail and intercity bus terminals, rail corridors, waterways, and highways. These facilities carry more than 99% of all commercial air passengers and cargo, virtually all waterborne freight and cruise passengers, almost all rail freight, and 89% of all interregional rail and bus passengers. They also account for more than 70% of all truck traffic and 55% of total traffic on the State Highway System. The SIS introduced a new approach for planning transportation, focusing on the function of each element of the system as it supports three different types of trips: those between regions, states, and nations; those between communities within a single region; and those within communities (FDOT, 2010).

The framework for SIS designation policies and criteria reflects the following key principles:

- Emphasize interregional, interstate, and international travel and transport.
- Use objective measures of transportation activity reflecting national and industry standards.
- Consider the economic requirements of key Florida industries.
- Identify transportation facilities emerging in importance.
- Screen for responsible environmental stewardship.
- Proactively designate planned facilities.

The SIS objectives are:

- *Interregional Connectivity*: Enhance connectivity between Florida's economic regions and between Florida and other states and nations for both people and freight.

- *Intermodal Connectivity*: Provide for safe and efficient transfers for both people and freight between all transportation modes.

- *Efficiency*: Reduce delay and improve the reliability of travel and transport using SIS facilities.

- *Choices*: Expand modal alternatives to SIS highways for travel and transport between regions, states, and nations.

- *Economic Competitiveness*: Provide transportation systems to support statewide goals related to economic diversification and development.

- *Energy, Air Quality, and Climate*: Reduce growth rate in vehicle-miles traveled and associated energy consumption and emissions of air pollutants and greenhouse gases.

- *Emergency Management*: Help ensure Florida's transportation system can meet national defense and emergency response and evacuation needs.

2.1.2 The 2060 Florida Transportation Plan

The 2060 Florida Transportation Plan (FTP), published in 2011, calls for a fundamental change in how and where Florida invests in transportation. The FTP defines transportation goals, objectives, and strategies to make our economy more competitive, our communities more livable, and our environment more sustainable for future generations (FDOT, 2011a). The 2060 FTP includes six goal areas together with their respective performance indicators are listed below (FDOT, 2011a):

1. *Economic Competitiveness*: Invest in transportation systems to support a prosperous, globally competitive economy

    - Access from businesses to employees, customers, and suppliers within reasonable travel time.
    - Transportation costs as a percentage of household income or gross state product.
    - Jobs, income, and gross state product created by transportation investments.

2. *Community Livability*: Make transportation decisions to support and enhance livable communities

    - Number of counties participating in development and implementation of regional visions.
    - Community polling on livability issues including satisfaction with public transportation and other mobility options.

- Combined cost of housing and transportation as percentage of household income
- Travel time.
- Walkability indicators.

3. *Environmental Stewardship*: Make transportation decisions to promote responsible environmental stewardship

   - Critical lands, waters, and habitats enhanced and negative impacts avoided by transportation investments.
   - Energy consumption for transportation uses (total and per capita).
   - Transportation related air quality pollutants and greenhouse gas emissions (total and per capita).
   - Areas meeting federal air quality standards.

4. *Safety and Security*: Provide a safe and secure transportation system for all users

   - Incidents or crashes by mode (total and rates).
   - Fatalities and injuries by mode (total and rates).
   - Security incidents involving the transportation system.
   - Percentage of transportation facilities meeting federal or state security standards (where defined) by mode.
   - Emergency response and management measures (such as emergency response and planned evacuation times).

5. *Maintenance and Operations*: Maintain and operate Florida's transportation system proactively

   - Physical condition of infrastructure and equipment by mode (such as percent meeting standards).
   - Capacity utilization by mode.

6. *Mobility and Connectivity*: Improve mobility and connectivity for people and freight

   - Person miles traveled.
   - Highway vehicle miles traveled.
   - Percentage of travel using each mode for people and freight.
   - Accessibility to public transportation facilities.
   - Person and freight hours of delay.
   - Reliability of travel and delivery.

2.1.3 Freight Mobility and Trade Plan

The Freight Mobility and Trade Plan (FMTP), published in 2013, defines policies and investments that will enhance Florida's economic development efforts into the future. The Florida's freight network includes (FDOT, 2013a):

- all Florida facilities on the National Freight Network,
- all designated SIS facilities that are not purely passenger-oriented, and
- additional connectors to facilitate freight movement through the "last mile".

A project will be considered a freight project in Florida if it is on the Florida Freight Network and satisfies one of the following three components (FDOT, 2013a):

- *Freight Focused* - the primary purpose of the project is to address a specific freight transportation need.
- *Freight Related* - the primary purpose of the project is to address multiple transportation concerns, of which freight is one element.
- *Freight Impacted* - the primary purpose of the project is to address general transportation needs, however freight mobility may be positively affected.

The FMTP Policy Element document identified the following as the seven Florida freight policy objectives (FDOT, 2013b):

1. Capitalize on the freight transportation advantages of Florida through collaboration on economic development, trade, and logistics programs
2. Increase operational efficiency of goods movement
3. Minimize costs in the supply chain
4. Align public and private efforts for trade and logistics
5. Raise awareness and support for freight movement investments
6. Develop a balanced transportation planning and investment model that considers and integrates all forms of transportation
7. Transform the FDOT's organizational culture to include consideration of supply chain and freight movement issues

FDOT was looking to expand the multimodal mobility performance measures to include the following in the near future (FDOT, 2013a):

- Combination truck tonnage (daily)
- Combination truck ton miles traveled (daily)
- Truck Level of Service (LOS) (peak hour)
- Combination truck backhaul tonnage (daily)
- Aviation access - highway adequacy (LOS) (peak hour/peak period)
- Rail access - highway adequacy (LOS) (peak hour/peak period)
- Quality rail access (yearly)
- Seaport access - highway adequacy (LOS) (peak hour/peak period)

In addition to mobility performance measures listed in Table 2-1, FDOT regularly tracks and reports on maintenance and the state of good repair. The measures used and their associated objectives include:

- *Maintenance Rating* - Achieve a maintenance rating of at least 80 on the State Highway System.

- *Pavement Condition* - The percentage of lane miles on the State Highway System having a pavement condition rating of either excellent or good should be ≥ 80.
- *Bridges* - The percentage of bridge structures on the State Highway System having a condition rating of either excellent or good should be ≥ 80.

Table 2-1: Freight Mobility Performance Measures (Source: FDOT, 2013a)

Mode	Performance Measure	Mobility	Reporting Period	Methodology
Highway	Combination Truck Miles Traveled	Quantity	Daily	Determined using combination truck traffic volume and segment length.
	Truck Miles Traveled	Quantity	Daily	Determined using truck traffic volume and segment length.
	Travel Time Reliability	Quality	Peak Period	Freight travel time reliability is defined as the percentage of travel that is greater than 45 mph on freeways.
	Travel Time Variability	Quality	Peak Period	Freight travel time variability is defined as the 95th percentile travel time index (TTI_{95}).
	Combination Truck Hours of Delay	Quality	Daily	Combination truck hours of delay is based on combination truck speed. The free flow combination truck speed is assumed to be equal to the speed limit. Similar to vehicle hours of delay, delay is calculated as the product of directional hourly volume and the difference between travel time at "threshold" speeds (at LOS B) and travel time at the average speed.
	Combination Truck Average Travel Speed	Quality	Peak Hour	The calculation of combination truck average travel speed is identical to the methodology for (passenger) vehicle's average travel speed, except that combination trucks are assumed to have a lower free-flow speed. The free flow truck speed is assumed to be equal to the speed limit.
	Percent Miles Severely Congested	Utilization	Peak Hour	The freight percentage of miles severely congested is determined by summing the centerline miles of roadway operating at LOS F in the peak hour and then dividing by the total highway miles.
	Vehicles Per Lane Mile	Utilization	Peak Hour	Vehicles per lane mile (freight) is calculated as the summation of each roadway segment's peak hour vehicle miles traveled divided by the number of lane miles.
Aviation	Tonnage	Quantity	Yearly	All air cargo landed at public airports.
Rail	Tonnage	Quantity	Yearly	Tons of freight carried by rail mode originated or terminated in Florida.
Seaport	Tonnage	Quantity	Yearly	International and domestic waterborne tons of cargo handled at both public and private terminals in port areas of Florida.
	Twenty-foot Equivalent Units	Quantity	Yearly	International and domestic waterborne cargo handled at both public and private terminals in port areas of Florida.

The prioritization process consists of the following five steps:

1. Development of Florida freight project prioritization criteria
2. Rating of projects according to selected criteria
3. Incorporation of criterion importance weighting
4. Compilation of project scores and prioritization grouping
5. Evaluation of return on investment

Table 2-2 summarizes the prioritization criteria. More details on the project prioritization process are provided in the Freight Mobility and Trade Plan Investment Element document (FDOT, 2013a). Additionally, for each criterion listed in Table 2-2, this document includes specific details on the project scoring factors, the weighting used, and the freight project priority groups.

2.1.4 Advanced Safety Applications

Over the past several decades, traditional methods that primarily consist of crash frequencies and crash rates have been used to identify high crash locations. These traditional methods are known to have two major shortcomings. First, they do not account for the regression-to-the-mean effect (RTM) caused by the practice of selecting high crash locations (i.e., non-random selection of locations) for safety improvements. This bias may cause locations with high crashes that were due merely to random fluctuations in crash numbers to be erroneously selected for safety improvements, thus, reducing the cost-effectiveness of safety programs. Second, traditional methods identify high crash locations based strictly on the historical trends in crash data (i.e., past safety experience at a site). However, locations with the highest observed crash frequencies or crash rates do not necessarily hold the greatest potential for safety improvements. For example, a location with a high number of crashes may actually be considered “normal” if other locations with similar characteristics also experienced similar number of crashes. Thus, an investment at the location may not yield as much safety benefit and it would be better for the same investment to be made at another location that has a greater potential for crash reduction.

These shortcomings can be addressed through statistically advanced methods such as the empirical and full Bayes methods. The empirical Bayes (EB) method not only accounts for the RTM bias, but also identifies high crash locations based on the site’s expected safety performance and the site’s potential for safety improvement (PSI). Section 3.2 provides more details about the RTM effect and the EB method.

The HSM and *SafetyAnalyst* are two major safety analysis applications that employ the rigorous EB method to identify and evaluate safety improvement projects. These two applications are the culmination of a decade long research of several national, state, and regional agencies. FDOT has been a proponent of these two applications since their development phase. Florida was one of the 13 lead states that started implementing the new HSM, and one of the 27 states that participated in the development of *SafetyAnalyst.*

Highway Safety Manual

The HSM is published by the American Association of State Highway and Transportation Officials (AASHTO) in 2010. The manual “presents tools and methodologies for consideration of ‘safety’ across the range of highway activities: planning, programming, project development, construction, operations, and maintenance” (AASHTO, 2010). The HSM is a comprehensive document that focuses on all the steps in the roadway safety management process (i.e., network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and safety effectiveness evaluation).

Table 2-2: Florida Freight Project Prioritization Criteria (FDOT, 2013a)

FMTP Objectives	Criteria Name	Prioritization Criteria
FMTP Objective 1	Targeted Industry	Project addresses a specific transportation challenge for an Enterprise Florida identified targeted industry
	Freight Hub Access	Project improves access to/from an existing or developing freight hub
	Intermodal Logistics Center (ILC) Exports	Project improves ILC's export capabilities/capacity
	Unique Niche	Project supports/strengthens the unique niche of a seaport, airport, spaceport, rail freight terminal, or ILC
	Identified Market Need	Project is in response to an identified market need
FMTP Objective 2	Florida Freight Network	Project is on a facility designate as the Florida Freight Network
	Freight Bottleneck	Project eliminated a freight bottleneck
	Dedicated Freight Facility	Project provides a dedicated freight facility or freight shuttle that restores capacity for freight movement
	Intelligent Transportation Systems (ITS)	Project uses ITS technology to improve system operations
	Truck Parking	Project improves truck parking situation
	Rest Stop Safety and Security	Project improves safety and security at rest-stops/layover areas/other facilities
	Marine Highways	Project simulates use of marine highways/short-sea shipping
FMTP Objective 3	Empty Backhaul	Project reduces empty backhaul movements to cut shipping costs
	Alternative Fuels Access	Project improves access to Compressed Natural Gas (CNG)/Liquefied Natural Gas (LNG) or other alternative fuels
	Supply Chain Costs	Project minimizes costs through the entire supply chain to support manufacturing
FMTP Objective 4	Private Funding Amount	Project private funding
FMTP Objective 6	Local Freight Plans	Project is in a local freight plan
	Statewide Modal Plans	Project is consistent with the statewide modal plan
FMTP Objective 7	Emerging freight facilities	Project supports an emerging freight facility
	Benefits	Project benefits to tax payers
	Intermodal Logistics Center Exports	Project provides significant intermodal benefits
Best Practices	Cost	Project total cost
	Non-FDOT Funding Status	Funding status
	Timing and Readiness	Project timing and readiness
	TIP/STIP	TIP/STIP Inclusion
	Dependency	Dependency

As part of the National Cooperative Highway Research Program (NCHRP) Project 17-50, FDOT was one of the 13 lead states that started implementing the new HSM. Florida is also the first state to finalize its implementation plan and begin implementation. Figure 2-1 provides the timeline of the Department's HSM implementation plan. Although this information is slightly dated, it gives the broader perspective of the Department's direction in adopting the manual.

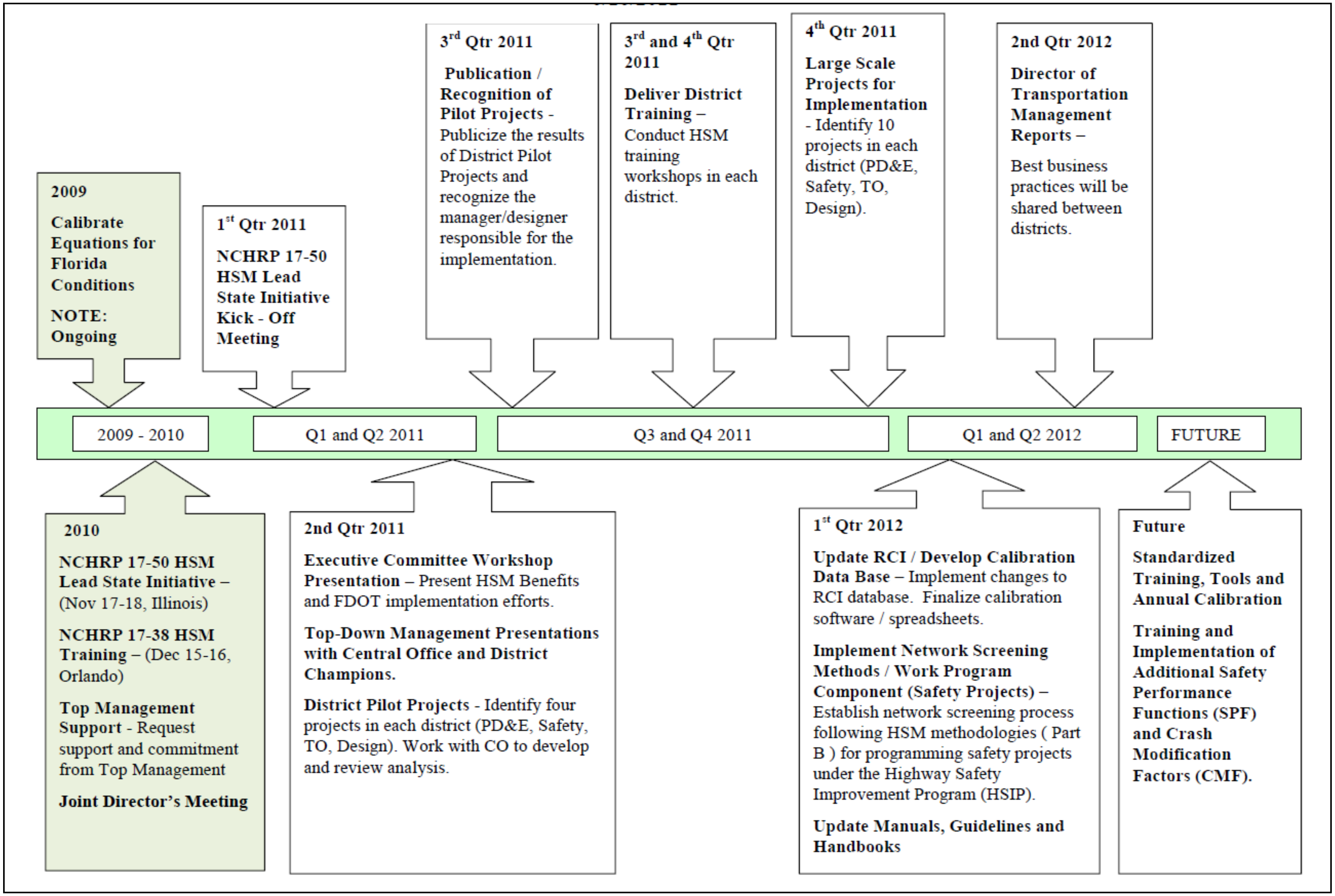

Figure 2-1: FDOT HSM Implementation Plan Timeline (Source: FDOT, 2011b)

SafetyAnalyst

SafetyAnalyst was developed as a cooperative effort by Federal Highway Administration (FHWA) and participating state and local agencies. *SafetyAnalyst* "provides state-of-the-art analytical tools for use in the decision-making process to identify and manage a system-wide program of site-specific improvements to enhance highway safety by cost-effective means" (AASHTO, 2014). It integrates all the steps in the roadway safety management process (i.e., network screening, diagnosis, countermeasure selection, economic appraisal, project prioritization, and safety effectiveness evaluation). *SafetyAnalyst* automates the advanced EB analysis procedures, requiring agencies to only need minimum statistical knowledge. One of the major hurdles in deploying *SafetyAnalyst* is its stringent data requirements. Problems with data availability and data compatibility have steered some agencies' implementation efforts of *SafetyAnalyst* while deterring others from its adoption. First, significant effort is required to convert the local data into the strict data format required by *SafetyAnalyst*. Second, the process to assemble the data elements that are not readily available in the agencies' databases could be resource intensive.

FDOT has been working toward deploying *SafetyAnalyst* for Florida for both state and local roads. As part of the implementation efforts, FDOT has developed a software tool to automatically convert Florida's state road data to the data format required by *SafetyAnalyst.* FDOT is also planning to conduct statewide hands-on workshops to train the district officials on using *SafetyAnalyst.* FDOT plans to take full advantage of the new capabilities of *SafetyAnalyst* to enhance the safety improvement programs in the state not only for the on-system roads, but also the off-system roads that are critical to the overall performance of the state's highway system. By deploying *SafetyAnalyst,* Florida can, for the first time, have a standard system to consistently conduct safety analysis across the state.

2.2 State Departments of Transportation

This section discusses the project prioritization practices that are either currently being applied or being considered for adoption by 12 DOTs from the states of Delaware, Florida, Indiana, Missouri, North Carolina, Ohio, Oregon, Texas, Utah, Virginia, Washington, and Wisconsin. A majority of these state DOTs were found to prioritize projects, rather than highway project locations. This is in contrast to the FDOT District One's practice of dividing the process into two tiers: (a) screening for highway project locations with potential for improvement; and (b) prioritizing projects. Nonetheless, the approaches used by the state DOTs to prioritize projects are to a large extent applicable to screening highway project locations.

2.2.1 Delaware

The Delaware Department of Transportation (DelDOT) developed seven broad criteria to enhance the project prioritization process for their six-year (2015-2020) Capital Transportation Program (CTP) (DelDOT, 2014).

Performance Measures

The project prioritization process includes the following seven criteria. The percentage in parentheses gives each criterion's corresponding weight.

1. Safety (33%)
2. System operating effectiveness (24.8%)
3. Multi-modal mobility/flexibility/access (15.6%)
4. Revenue generation/economic development/jobs and commerce (7.9%)
5. Impact on the public/social disruption/economic justice (7.2%)
6. Environmental impact/stewardship (6.5%)
7. System preservation (5%)

Project Prioritization Methodology

DelDOT's prioritization method is based on total score calculated from the criteria identified earlier. Each of the seven criteria is evaluated based on multiple factors that have different weights, rating scales, and corresponding values. The scores are calculated for all the factors associated with each criterion. The weight of each criterion is then applied to obtain the final score used to prioritize projects. Table 2-3 summarizes DelDOT's project prioritization method.

2.2.2 Florida

FDOT District One developed CMP to prioritize low-cost near-term highway improvements for Florida's SIS network. The project prioritization method used in CMP was modeled after the SIT, which was developed by the Department's System Planning Office. Although the SIT and the CMP are both Web-based systems and the project prioritization methods implemented in both are similar, the SIT is designed to evaluate specific projects one at a time, while the CMP is designed to screen and prioritize all projects system-wide, and is able to automatically generate a ranked list of project locations (FDOT, 2008).

Performance Measures

Both quantitative and qualitative factors are considered in prioritizing the potential CMP project locations. The CMP was found to accommodate only three of the five SIS goals (*Safety*, *Preservation*, and *Mobility*) through the following seven quantitative measures:

1. Crash ratio
2. Fatal crash
3. v/c ratio
4. AADT per lane
5. Truck volume per lane
6. Truck percent
7. Delay

The remaining two SIS goals, *Economic Competitiveness* and *Quality of Life*, are addressed through a series of qualitative questions, which are considered later in the project selection process (FDOT, 2008). More detailed discussion on the seven quantitative performance measures is provided in Chapter 3.

Table 2-3: DelDOT's Project Prioritization Criteria (Source: DelDOT, 2014)

Criteria (Weighting %)	Objective of the Criteria	Factors	Rating Scale/Name	Value
Safety (33%)	To assess a project's extent to address identified safety issues and improves safety	Identified in a safety program (80%)	0	0.00
			0.1	0.20
			10	1.00
		Addresses strategies in the strategic highway safety plan (20%)	One or more strategies	1.00
			No strategy	0.00
System Operating Effectiveness (24.8%)	To assess a project's extent to meet operating objectives as described in the state strategy and in regional or local community plans	Existing level of service (LOS) (50%)	LOS F	1.00
			LOS E	0.80
			LOS D	0.50
			LOS C	0.25
			LOS B	0.00
			LOS A	0.00
			N/A	0.00
		Congestion management (50%)	Congestion corridor	1.00
			Locally congested area	0.75
			No significant congestion	0.00
Multi-Modal Mobility/ Flexibility/ Access (15.6%)	To assess a project's extent to address transportation choices and to allow additional connectivity to existing system		Significant improvement	1.00
			Moderate improvement	0.50
			No effect	0.00
			Detrimental	0.00
Revenue Generation/Economic Development/Jobs and Commerce (7.9%)	To assess a project's potential to generate revenue or to support economic development and benefit commerce	In a transportation improvement district (TID) (33%)	Located in a TID	1.00
			Not located in a TID	0.00
		Cost-sharing support (33%)	0	0.00
			20	0.50
			50	0.70
			100	1.00
		Freight corridor (33%)	Any freight corridor	1.00
			Located in a secondary corridor	0.75
			Not located in a freight corridor	0.00
Impact on the Public/Social Disruption/ Economic Justice (7.2%)	To assess a project's extent to support investment in existing communities and to provide community enhancements such as sidewalks, safe routes to school, etc.		Positive impact	1.00
			No impact	0.25
			Detrimental impact	0.00
Environmental Impact/Stewardship (6.5%)	To assess a project's extent to mitigate the threat or damage to the environment, including air quality		Positive impact	1.00
			No impact	0.50
			Minor negative impact	0.20
			Major negative impact	0.00
System Preservation (5%)	To assess a project's extent to contribute towards system preservation and is identified through an existing preservation program		Identified preservation need	1.00
			Not identified as a preservation need	0.00

Project Prioritization Methodology

The prioritization methodology consists of the application of quantitative criteria followed by qualitative questionnaire. Each of the seven quantitative performance measures is assigned a maximum score which is also directly adopted from SIT. The actual score of each measure is then determined based on site-specific characteristics. Finally, for each project location, scores from the seven measures are summed up to obtain the overall score which is then used in project prioritization. Top-ranked project locations are scrutinized through the qualitative criteria to determine the final location list for funding (FDOT, 2008).

2.2.3 Indiana

The Indiana Department of Transportation (INDOT) used a scoring methodology to prioritize projects towards their Major Moves program as part of INDOT 2030 Long Range Transportation Plan (LRTP). Projects included in the Major New Capacity component of the Major Moves program are analyzed, scored, and ranked systematically. The ranked projects are then assigned to construction years based on their scores and INDOT's protocols and policies (INDOT, 2007; IPOC, 2005).

Performance Measures

The following three broad goals are considered as primary criteria for prioritization. The percentage in parentheses gives each criterion's corresponding weight.

1. Transportation efficiency (50%)
2. Safety (25%)
3. Economic development and customer input (25%)

The most significant component, transportation efficiency, is related to some form of direct transportation preservation or enhancement criteria. Safety, the second component, focuses on improving the safety of the transportation system. The impact of economic development and customer input constitutes the remaining 25% of the project score. However, INDOT considers economic points only when direct, demonstrable economic impacts from the transportation project could be identified. Note that the 50-25-25 split occurs among the available total potential points. A bonus point category is considered for scoring and it is based on earmarks (public/private/or local participating funds) and urban revitalization.

Project Prioritization Methodology

Projects are scored based on the earlier discussed criteria. Note that each of the criteria is associated with a set of factors. Table 2-4 summarizes INDOT's scoring method for project prioritization.

Table 2-4: INDOT's Project Prioritization Criteria (Source: INDOT, 2007)

Goal	Factors	Maximum Score
Transportation Efficiency	Cost Effectiveness Index – A measure of the Benefit-cost Ratio and Net Present Value of the investment	20
	Corridor Completion – A measure of a project's ability to complete statewide connectivity targets	2
	Road Classification – A measure of a highway's importance	5
	Congestion Relief (Mobility) – A measure of the Truck and Vehicle AADT, Volume-to-capacity Ratio, and Change in LOS from the improvement	15
	Adjacent State or Relinquishment Agreement – A measure of interstate connectivity	3
	Percent Complete in Development	5
Safety	A measure of the Crash Frequency/Density, Crash Severity, and Fatality Rate Ratio	25
Economic Development	Jobs Created or Retained	10
	Economic Distress and Cost Effectiveness	5
Customer Input	Local Planning Agency Input – Priorities established by planning organizations	4
	Legislative and Elected Officials – Priorities of the local officials	3
	Other – A measure of the input of citizens either through their legislative representative or via direct documented comments to the agency	3
Bonus Point Categories:		
Earmarks	Public/Private/or Local Participating Funds	100
Urban Revitalization		10
	Total Possible Points	**210**

2.2.4 Missouri

Missouri Department of Transportation's (MoDOT) project prioritization policy recognizes "the need for a balance between taking care of the current transportation system and expanding the system to accommodate anticipated future demand. As a result, transportation funding is divided accordingly" (MoDOT, 2006). The nature of this balance is adjusted through the distribution of transportation funds among the following categories:

- safety,
- taking care of the system,
- regional and emerging needs,
- major projects, and
- interstates and major bridges

MoDOT works with MPOs, regional planning commissions, local officials, and the general public to rank projects in each category. Within each category, projects are again divided into three sub-categories:

- *High*: resources are focused on addressing these projects first.
- *Medium*: these projects may be addressed when additional resources become available.
- *Low*: these projects will not be addressed at this time.

The high-priority project list is fiscally constrained to five years of funding and is not a commitment for construction. Therefore, each time when projects are prioritized, existing projects that have not been programmed for construction are reevaluated (MoDOT, 2006).

Performance Measures

MoDOT developed their project prioritization criteria based on the state's transportation goals. Each group in MoDOT's funding distribution has a separate process. Table 2-5 presents a summary of MoDOT's prioritization criteria for "Taking Care of the System Projects" funding category. The table includes the prioritization criteria, their weights, associated factors, and the maximum attainable points in each of the associated factors. Note that the district factors/flexible points may be used to capture unique items that are important to an individual region or can be allocated among existing factors.

Table 2-5: MoDOT's Prioritization Criteria for Taking Care of the System Projects (Source: Metropolitan Planning Council, n.d.)

Criteria	Weight		Factors	Points
	Minimum	Maximum		
Access to opportunity	0%	20%	Elimination of bike/pedestrian barriers	25
			Vehicle ownership	25
			District factors/flexible points	50
Congestion relief	0%	20%	Level of service	75
			District factors/flexible points	25
Economic competitiveness	0%	20%	Strategic economic corridor	30
			Level of economic distress	20
			District factors/flexible points	50
Efficient movement of freight	0%	20%	Truck volume	90
			District factors/flexible points	10
Quality of communities	0%	20%	District factors/flexible points	100
Environmental protection	0%	20%	Environmental index	50
			District factors/flexible points	50
Safety	5%	25%	Safety index	70
			Safety concern	10
			Safety enhancements	10
			District factors/flexible points	10
For roadway: taking care of the system	75%	95%	Pavement smoothness	30
			Pavement condition	20
			Functional classification	10
			Daily usage (all vehicles)	10
			Truck usage	10
			Substandard roadway features	10
			District factors/flexible points	10
For bridge: taking care of the system	75%	95%	Bridge condition	40
			Exceptional bridge	10
			Functional classification	10
			Daily usage (all vehicles)	10
			Truck usage	10
			Substandard bridge features	10
			District factors/flexible points	10

Project Prioritization Methodology

The MoDOT's project prioritization methodology includes the following steps (Metropolitan Planning Council, n.d.):

- Projects are separated based on five funding categories, i.e., safety, taking care of the system, regional and emerging needs, major projects/system expansion, and interstates.
- The weights of each transportation goal, i.e., prioritization criteria for each funding category, is then determined. The total weight for a funding category should be equal to 100%.
- The appropriate factors along with their point values for each prioritization criteria are determined next. The total allowable points under each criterion should be equal to 100.
- MoDOT districts provide scores for objective factors based on data.
- MoDOT districts along with their planning partners determine the ratings for subjective factors.
- The total scores are then calculated for each criterion from associated factors, followed by multiplying by the weight of the criterion. Finally, all the weighted scores are added to determine the total score.

2.2.5 North Carolina

The North Carolina Department of Transportation (NCDOT) categorizes similar projects together as the first step in their project prioritization policy. Wasserman (2012) of NCDOT Strategic Planning Office presented the following ten prioritization buckets (i.e., categories):

1. aviation,
2. bike and pedestrian,
3. transit,
4. ferry,
5. rail,
6. mobility – highway,
7. safety – highway,
8. bridges – highway,
9. pavement – highway, and
10. modernization – highway.

Similar projects are then compared with each other using a scoring methodology based on the combination of quantitative data and local inputs. For highway projects, the quantitative data includes congestion, benefit-cost (B/C) ratio, expected economic impact, safety, pavement condition, lane width, shoulder width, multimodal issues, and connectivity. Local inputs are derived from MPOs, Rural Planning Organizations (RPOs), and NCDOT divisions. After similar projects are prioritized, the NCDOT involves public and partner participants in discussions leading to funding allocation decisions. The final step of the department's prioritization process is to apply financial and scheduling constraints to determine investment strategies. The constraints include Federal and State regulations as well as taking into consideration the project development process and construction sequencing (NCDOT, 2014b; NCDOT, 2014c).

Performance Measures

The NCDOT Transportation Board approved the quantitative scoring criteria, measures, and weights for the Strategic Mobility Formula (SMF), which was a new way to prioritize and fund transportation projects (NCDOT, 2014a). The performance measures identified by NCDOT are given below. For each performance measure, the parameters, the formula, and the weights are provided when available.

- Congestion
  - Parameter: AADT.
  - Formula:

$$Congestion\ score = \left(\left(\frac{Existing\ Traffic\ Volume}{Roadway\ Capacity\ Ratio} \times 100\right) \times 60\%\right) + \left(\frac{Existing\ Traffic\ Volume}{1{,}000} \times 40\%\right)$$

  - Weight of congestion for statewide mobility projects, regional impact, and division needs is 30%, 25%, and 20%, respectively.

- Benefit-cost based on travel time criteria
  - Parameters: travel time savings, project cost.
  - Formula:

$$Benefit/Cost = \frac{Travel\ time\ savings\ over\ 30\ years\ in\ dollars}{Project\ cost\ to\ NCDOT}$$

  - Weight of benefit-cost for statewide mobility projects, regional impact, and division needs is 30%, 25%, and 20%, respectively.

- Economic Competitiveness
  - Parameters: jobs, value added in dollars.
  - Formula:

$$Economic\ competitiveness\ index = A \times 50\% + B \times 50\%$$

    where A is the number of long term jobs created, and B is the value added in dollars based on productivity change in NCDOT division economy.
  - Weight of economic competitiveness for statewide mobility projects is 10%.

- Safety Score
  - Parameters: critical crash rates, density, severity.
  - Formula:

    For segments:

$$Safety\ Score = Crash\ Density \times 33\% + Severity\ Index \times 33\% + Critical\ Crash\ Rate \times 33\%$$

    For intersections:

$$Safety\ Score = Crash\ Frequency \times 50\% + Severity\ Index \times 50\%$$

  - Weight of safety score for statewide mobility projects, regional impact, and division needs is 10%.

- Pavement Score
  - Parameters: pavement condition rating.

- Lane Width
  - Parameters: existing width, standard width.
  - Formula: The greater the difference between the DOT design standard lane width and the existing lane width, the higher points the project receives. Each foot difference between the standard lane width and the existing lane width yields 25 points, and a difference of ≥ 4 ft yields 100 points.
  - Weight of lane width is not used in statewide default criteria. However, it is used as an alternate criterion for NCDOT Divisions 1 and 4 as 10% for regional impact and division needs projects.

- Shoulder Width
  - Parameters: existing width, standard width.
  - Formula: The greater the difference between existing paved shoulder width and DOT design standard paved shoulder width, the higher points the project receives. Similar to the case of lane width, each foot difference between the standard shoulder width and the existing shoulder width yields 25 points, and a difference of ≥ 4 ft yields 100 points.
  - Weight of shoulder width is not used in statewide default criteria. However, it is used as an alternate criterion for NCDOT Divisions 1 and 4 as 10% for regional impact and division needs projects.

- Multimodal (includes freight and military routes)
  - Parameters: military route, transportation terminals, trucks
  - Formula:

$$\text{Multimodal Index} = \left((A\times 100)\times 25\%\right)+\left((B\times 100)\times 25\%\right)+\left(\left(\frac{C}{100}\right)\times 50\%\right)$$

    where A is v/c ratio for strategic highway network, B is v/c ratio for transportation terminal routes, and C is truck volume.
  - Weight of multimodality for statewide mobility projects is 20%.

- Accessibility/Connectivity
  - It includes three components of the scoring criteria:
    - county tier designation (20%),
    - upgrade roadway function (40%), and
    - commuting times by census tracts (40%).
  - Parameters: county tier, facility type upgrade, commuting times.
  - Formula:

    <u>For county tier designation</u>: For projects in Tier 1 county, for volumes ≤ 20,000 vpd, the score is calculated as volume/200. For higher volumes, the score is 100 points. For projects in Tier 2 county, for volumes ≤ 20,000 vpd, the score is calculated as volume/300. For higher volumes, the score is 67 points. For projects in Tier 3 county, for volumes ≤ 20,000 vpd, the score is calculated as volume/600. For higher volumes, the score is 33 points.

    <u>For upgrading roadway function</u>: The eligibility is based on combination of existing facility type and proposed facility type. If projects are eligible, the score is calculated as volume/200.

For commuting times by census tracts: This component is applicable when commute time is greater than 20 minutes. If commute time is > 40, the score will be 100 points. For commute times > 20 minutes and ≤ 40 minutes, the score is calculated by multiplying the excess of 20 minute commute time by 5.

- Weight of accessibility on regional impact projects is 10%.

Project Prioritization Methodology

Similar projects are classified together taking funding category into consideration. Proper quantitative criteria along with measures and weights are then applied to calculate the scores. All criteria are measured on a 0-100 point scale. Local inputs are then incorporated according to NCDOT guidelines. Finally, the projects are prioritized based on the calculated total scores. Table 2-6 presents a summary of NCDOT's highway scoring criteria and weights used to prioritize projects.

Table 2-6: NCDOT's Highway Scoring Criteria and Weights (Source: NCDOT, 2014c)

Funding Category	Quantitative Data	Weight	Local Input	
			Division Rank	MPO/RPO Rank
Statewide Mobility	Benefit-cost [Travel Time]	30%	N/A	N/A
	Congestion	30%		
	Economic Competitiveness	10%		
	Safety	10%		
	Multimodal [Freight + Military]	20%		
Regional Impact	Benefit-cost [Travel Time]	25%	15%	15%
	Congestion	25%		
	Safety	10%		
	Accessibility/Connectivity	10%		
Division Needs	Benefit-cost [Travel Time]	20%	25%	25%
	Congestion	20%		
	Safety	10%		

2.2.6 Ohio

The Ohio Department of Transportation (Ohio DOT) adopted a scoring methodology for their major new capacity projects. The selection process of these projects operates under the purview of the Transportation Review Advisory Council (TRAC) of Ohio. The TRAC's policy is to provide equal consideration to all modes of transportation during project prioritization. TRAC has thus devised scoring criteria to include all modes of transportation so that modal benefits can be compared equally across modes (Ohio DOT, 2013).

Performance Measures

Ohio DOT's prioritization process includes the following four criteria, with the total points for each criterion given in the parentheses:

1. Transportation factors (55)
2. Economic performance factors (15)
3. Local investments (15)
4. Project funding plan (15)

Each of the criteria is associated with a number of factors and sub-factors. The criteria are designed in such a way that they are able to provide equal consideration for all transportation modes. Table 2-7 presents a summary of Ohio DOT's scoring criteria for project prioritization.

Table 2-7: Ohio DOT's Project Prioritization Criteria (Source: Ohio DOT, 2013)

Prioritization Criteria	Evaluation Factors	Evaluation Sub-Factors			Points
		Transportation Mode			
		Road	Transit	Freight	
Transportation	Traffic	V/C Ratio	Existing Peak Hour Ridership/Capacity	Existing Freight Volume/Capacity	10
		Safety	Proposed Peak Hour Capacity Increase	Proposed Freight Capacity Increase	10
		ADTT	VMT Reduction	Cost/Truck Reduction	5
	Benefit and Cost	Benefit-cost	Cost/VMT Reduction	Cost/Truck Reduction	10
	Air Quality	Emission Reduction			5
	Functional Class				10
	Intermodal Connectivity				5
Economic Performance	Existing Jobs within the Project Area				5
	Estimated Jobs Created				3
	Estimated Gross State Product Generated				2
	Considering Factors of Economic Distress				2.5
	Economic Distress in Relation to the Estimated Economic Performance				2.5
Local Investments	Percentage of Acres Served by Local Streets				15
	Percentage of Acres Served by Local Water and Sewer				
	Percentage of Acres Served by Local Electricity				
	Thousand Square Feet of Light Industrial Buildings within the Project Area				
	Thousand Square Feet of Heavy Industrial Buildings within the Project Area				
	Thousand Square Feet of Warehouse Buildings within the Project Area				
	Thousand Square Feet of Commercial Buildings within the Project Area				
	Thousand Square Feet of Institutional Buildings within the Project Area				
	Percentage of Road Routes Served by Fixed Transit Routes				
	Percentage of Square Footage of Existing Buildings Currently Vacant				
	Estimated Dollar Value of Committed or Recent Public Investment (within 5 years) in New, Non-project Infrastructure and Services				
	Estimates of Private Investments in Existing Private Facilities (within 5 years)				
Project Funding Plan	Local Funding Investments for the Phase(s) being Requested				8
	Local Funding Investments for Future Phase(s)				4
	Number of Non-ODOT Funding Sources				3

Project Prioritization Methodology

Projects are scored and ranked based on the factors and associated sub-factors. Ohio DOT is responsible for conducting the technical analyses of the projects. They also provide the TRAC with recommended scores. TRAC staff reviews various transportation components of a project and awards a draft score. The sufficiency and accuracy of the scores are verified during the hearing and public comment process.

TRAC's prioritization process is a means to ranking projects. However, it does not guarantee that projects will always be funded according to their ranking. Moreover, Ohio DOT does not have a formal process to cover unique or non-traditional transportation projects such as transit stations or intelligent transportation systems. Therefore, Ohio DOT evaluates such projects based on costs, consistency with local transportation plans, the stated preference of local officials in comparison with other local requests, the projects' effect on the movement of people and goods, the projects' ability to advance other transportation goals, the estimated volume of usage and comparison of that usage to other transportation projects' ability to transport goods and people (Ohio DOT, 2013).

2.2.7 Oregon

Franklin and Niemeier (1998) prepared a prioritization process for multimodal mobility improvement projects for Oregon Department of Transportation. The process involved two phases. In the first phase, the projects are evaluated based on the following seven factors:

1. land use conformity,
2. environmental resource impacts,
3. cost-efficiency (calculated as the ratio of a project's net present value to its total costs),
4. economic development,
5. modal integration,
6. community support, and
7. accessibility.

The project worksheets for this phase consist of a screening sheet and seven scoring sheets for each of the seven criteria. The screening sheet is used to eliminate projects that failed to meet the modal integration and community support criteria. The ranking algorithm, Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS), initially developed by WSDOT, is employed in the second phase to evaluate scores and rank projects. The policy goals of Oregon DOT and WSDOT are different, and hence, the criteria used by Oregon DOT in TOPSIS are different from those used by WSDOT.

Performance Measures

As mentioned earlier, the Oregon DOT's project prioritization is based on the following seven performance measures:

- *Land Use Conformity*: Two sub-categories, compatibility with local land use plans and growth management, are used. Compatibility with local land use plans refers to "reaffirming local and regional government's ability to determine relevant local land use issues". Growth management refers to "giving weight to the state's compelling interest of compact densities" (Franklin and Niemeier, 1998).

- *Environmental Resource Impacts*: This category includes 'natural' resources such as water, flora and fauna, and 'cultural' resources such as historical landmarks, archeological sources, and scenic byways (Franklin and Niemeier, 1998).

- *Cost Efficiency*: It is the ratio of a project's net present value to its total costs. It is also known as net present value (NPV) to project cost ratio.

- *Economic Development*: The Oregon DOT's Technical Advisory Committee (TAC) considers the following three criteria for this measure: the surrounding regions distress, support to a regional transportation strategy, and direct distress measured by Oregon DOT.

- *Modal Integration*: Two indices of multi-modalism, connectivity offered by the project and expansion of mode choice are considered.

- *Community Support*: The Oregon DOT's TAC believed community interest for a project would be reflected in the rank that the project would receive in regional/local prioritization process. Therefore, each region would be allotted points to evaluate the projects that would reflect the degree of regional support.

- *Accessibility*: Accessibility measures the ease of travel to destinations on transportation systems. The minimum level of service concept developed in the Oregon Transportation Plan and basic standards for minimum tolerable conditions are considered for this criterion.

Project Prioritization Methodology

Franklin and Niemeier (1998) suggested new performance measures to be used with the TOPSIS-6 algorithm to determine the final ranking. A Delphi analysis is used to demonstrate a consensus-oriented process for determining how criteria weights could be assigned. The TOPSIS-6 algorithm includes the following six steps (Franklin and Niemeier, 1998):

- *Step 1: Determining Project Scores:* Each project is evaluated based on the predefined performance measures. An evaluation matrix is then formed. In the matrix, the rows are defined by the projects to be ranked and the columns contain the scores according to performance measures.

- *Step 2: Normalizing Scores:* The normalization step uses a vector normalization method in which each project's score within a criterion is divided by the root-sum-of-squares of the scores of all projects in that criterion. Equation 2-1 illustrates this concept. Normalization is used to eliminate the units of criteria scores so that criteria can be compared.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad (2\text{-}1)$$

where,

x_{ij} = criterion score for a project,
$\sum_{i=1}^{m} x_{ij}^2$ = sum of squares of criterion scores for all projects, and
r_{ij} = criterion normalized score for a project.

- *Step 3: Weighting Scores:* This step uses weighting factors determined based on the perceived importance of each of the criteria. The weighting factors are a set of percentages that add up to 100%, with the most important criterion receiving the highest weighting factor. In this step, all the normalized scores in each criterion are multiplied by the weighting factor for that corresponding criterion.

- *Step 4: Determining Ideal Projects:* To evaluate projects on the basis of all criteria, two theoretical 'Ideal' projects representing the best and worst projects possible are defined to act as benchmarks against which the submitted projects are compared. These best and worst projects are known as the 'Ideal Positive' and 'Ideal Negative' projects, respectively. The Ideal Positive project's score in each criterion is established by finding the best score in that criterion from the submitted projects and giving that score to the Ideal Positive project; similarly, the worst score out of the submitted projects' scores is given to the Ideal Negative project. The actual scores of the Ideal Positive and Negative projects depend on the group of projects being evaluated, and are recalculated each time a new set of projects is evaluated (Franklin and Niemeier, 1998).

- *Step 5: Ranking Projects:* In this step, each project's diagonal distances from the defined positive and negative ideal projects are obtained through an extended version of Pythagorean Theorem shown in Equations 2-2 and 2-3.

$$S_{A1}^{*} = \sqrt{\left(X_1^{*} - X_{1,A1}\right)^2 + \left(X_2^{*} - X_{2,A1}\right)^2 + \cdots + \left(X_m^{*} - X_{m,A1}\right)^2} = \sqrt{\sum_{i=1}^{m}\left(X_i^{*} - X_{i,A1}\right)^2} \quad (2\text{-}2)$$

$$S_{A1}^{-} = \sqrt{\left(X_1^{-} - X_{1,A1}\right)^2 + \left(X_2^{-} - X_{2,A1}\right)^2 + \cdots + \left(X_m^{-} - X_{m,A1}\right)^2} = \sqrt{\sum_{i=1}^{m}\left(X_i^{-} - X_{i,A1}\right)^2} \quad (2\text{-}3)$$

where,

S^{*}_{A1}	=	distance of Project A_1 from ideal positive project,
S^{-}_{A1}	=	distance of Project A_1 from ideal negative project,
$X_{i,A1}$	=	score of Project A_1 in criterion i,
X^{*}_{I}	=	score of ideal positive project in criterion i,
X^{-}_{I}	=	score of ideal negative project in criterion i, and
M	=	number of criteria.

The 'Priority Index' is then calculated for each project, as defined in Equation 2-4. The index is calculated by dividing the project's distance from the ideal negative project by the sum of the distances between the project and each of the ideal projects. It indicates the ranking of the projects. A project with a high priority index will have a higher rank in the prioritization list.

$$PI = \frac{S^{-}}{S^{*} + S^{-}} \quad (2\text{-}4)$$

- *Step 6: Selecting Projects for Funding:* In this step, funding is allocated to the ranked list of projects, one project at a time, starting with the highest-ranked project, until all available funds are exhausted (Franklin and Niemeier, 1998).

It is noted that TOPSIS-6 and TOPSIS-8 were developed by WSDOT to prioritize mobility improvement projects in Washington State. Franklin and Niemeier (1998) evaluated various aspects of TOPSIS-6 and TOPSIS-8 with respect to Oregon State and concluded that it was not possible to transfer TOPSIS-8 directly from Washington State to Oregon due to the different scoring methods used in the two states. Therefore, it was suggested that the concepts similar to those in TOPSIS-8 be adapted in Oregon DOT's algorithm. Detailed discussions on TOPSIS-6 and TOPSIS-8 can be found in Franklin and Niemeier (1998).

2.2.8 Texas

Texas' strategic plan for 2007-2011 highway projects included the following goals and objectives (Metropolitan Planning Council, n.d.):

- Reliable mobility – ensure that people and goods move efficiently
- Improved safety – reduce roadway fatalities
- Responsible systems preservation – maintain and improve existing roads and bridges
- Streamlined project delivery – complete projects faster
- Economic vitality – attract and retain businesses and industry

Performance Measures

The evaluation criteria of Texas strategic plan for 2007-2011 highway projects include (Metropolitan Planning Council, n.d.):

- reduce congestion,
- enhance safety,
- expand economic opportunity,
- improve air quality,
- increase the value of transportation assets,
- address local, regional or statewide transportation issues, and
- provide a short-term, mid-term, or long-term solution.

Project Prioritization Methodology

The Texas Department of Transportation (TxDOT) receives the identified transportation needs or proposals from communities, state or federal level. Project sponsors also approach TxDOT district offices or local MPOs for support and approval. TxDOT district staff formulates funding strategy for the proposed projects. Projects viability and environmental implications, alternative solutions, cost estimates, public input and support, are considered prior to project selection. The Texas Transportation Commission (TTC) and local officials make the selection decision. A large portion of the budget is allocated to projects through the Unified Transportation Program (UTP). The allocation criteria and standards for different kinds of projects are established by TTC (Metropolitan Planning Council, n.d.).

Project Evaluation Toolkit (PET)

The University of Texas at Austin developed the Project Evaluation Toolkit (PET) under research projects sponsored by TxDOT. PET is a spreadsheet tool that evaluates operational strategies for transport project and policy impact evaluation. PET has been developed to anticipate long-term project impacts (including traveler welfare, emissions, safety, and travel time reliability), evaluate and compare multiple scenarios using NPVs, B/C ratios, etc., and enable optimal allocation of limited resources. The toolkit emphasizes multi-criteria evaluation for project metrics, along with sensitivity analysis, budget allocation across competing projects, and other tools for project planners (Kockelman *et al.*, 2012).

The following project impacts can be assessed within PET (The University of Texas at Austin, 2014):

- traveler welfare (consisting of operating costs and changes in travel time),
- travel time reliability (based on the valuation of travel time variance),
- crash counts (by severity),
- emissions (14 pollutant species),
- tolling revenues,
- fuel use, and
- link-level volumes and speeds by time of day.

PET supports the following transportation project types:

- capacity expansion and grade separation,
- tolling (pricing can vary by mode, user class, and time of day),
- shoulder lane use,
- reversible lanes,
- ramp metering,
- transit route and headway changes,
- work zone phasing/scheduling,
- traffic safety projects,
- advanced traveler information systems,
- variable speed limits (speed harmonization),
- incident management, and
- changes to parking and other fixed trip costs.

2.2.9 Utah

A two-tiered framework of project prioritization was developed for the Utah Department of Transportation (UDOT). The two tiers are sequentially coordinated. The projects scoring in the top third in Tier I are considered for evaluation in the Tier II process. Projects in the Tier I phase are screened based on engineering parameters. Tier II is a more in-depth phase and it evaluates the projects based on congestion, economics, environmental impacts, and safety. The Tier II process yields a list of ranked projects (Schultz and McGee, 2009). Figure 2-2 illustrates the entire two-tiered framework developed for UDOT.

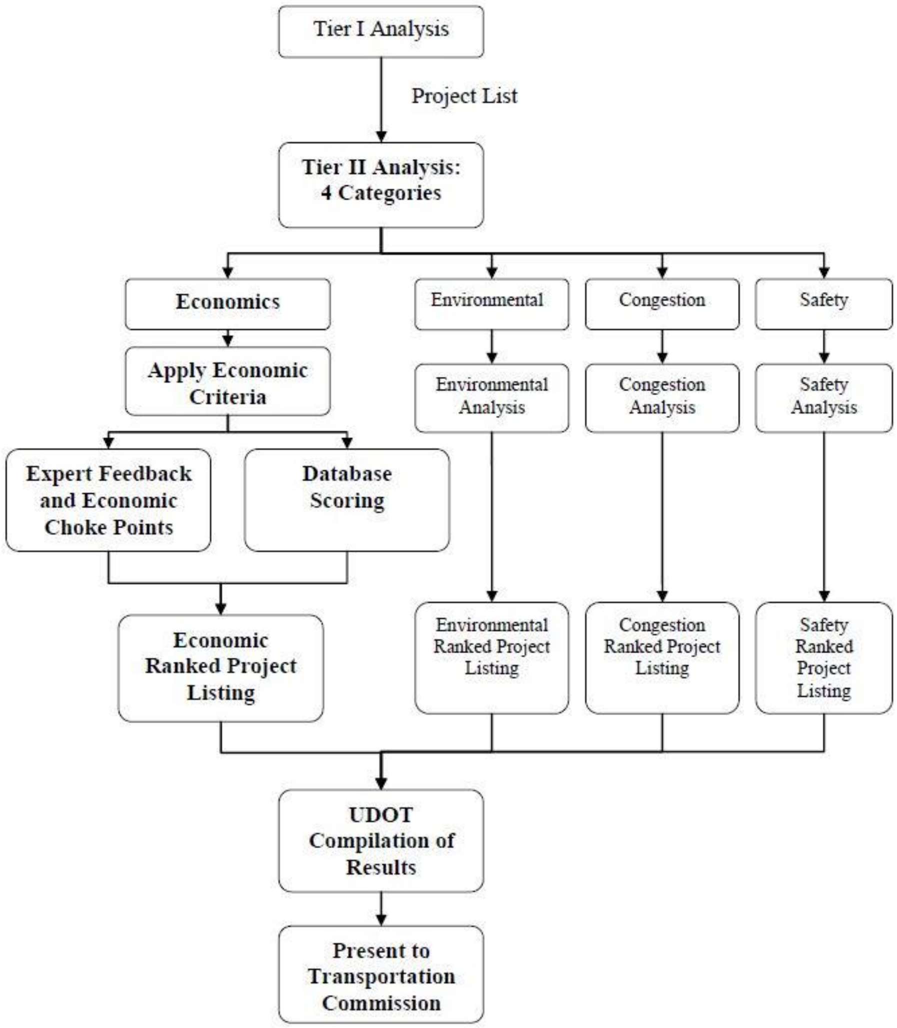

Figure 2-2: UDOT's Project Prioritization Framework (Source: Schultz and McGee, 2009)

Performance Measures

The standard indices, i.e., the criteria used for the Tier I process are:

- AADT,
- truck AADT,
- v/c ratio,
- v/c ratio improvement,
- safety index,
- functional class,
- transportation growth,
- vehicle-hours-saved,
- B/C ratio,
- adjacent interchange v/c ratio, and
- average adjacent interchange distance.

The evaluation criteria for the Tier II process include economics, environmental impacts, congestion, and safety.

Project Prioritization Methodology

Projects are classified into four types – widening existing facilities, constructing new facilities, constructing new interchanges on existing freeways, and upgrading existing at-grade signalized intersections. Table 2-8 presents a summary of UDOT's scoring criteria for the Tier I process by project type. As identified in the table, each project type uses only few indices to calculate the final score.

Table 2-8: UDOT's Scoring Indices by Project Type in Tier I Phase (Source: Schultz and McGee, 2009)

Scoring Index	Project Type			
	Widening Existing Facilities	Constructing New Facilities	Constructing New Interchange on Existing Freeway	Upgrading Existing Signalized At-grade Intersection
AADT	•	•	•	•
Truck AADT	•	•		
v/c	•	•		
v/c Improvement		•		•
Safety	•			
Functional Class	•			
Transportation Growth	•			
Vehicle-Hours-Saved			•	•
B/C			•	•
Adjacent Interchange v/c			•	
Avg. Adjacent Interchange Distance			•	

The projects scoring in the top third in Tier I are then considered for evaluation in the Tier II process, and are evaluated once again based on economics, environmental impacts, congestion, and safety criteria. As there is not a universal method for economic analysis, a Policy Delphi method requiring subjective judgment is employed to develop the economic development criteria and the framework. The method includes four steps, i.e., exploration of the subject, finding how the group views the issues, exploring the disagreements, and performing the final evaluation. Four aggregate criteria including sub-criteria, and one bonus criterion are identified through the Policy Delphi method. Table 2-9 summarizes these criteria.

2.2.10 Virginia

The Virginia Transportation Research Council (VTRC) developed a project prioritization template for Virginia Department of Transportation (VDOT). The objective was to help VDOT decide which capital improvement project should be undertaken first. The template is based on 14 performance measures which accommodate the criteria from the Transportation Equity Act for the 21st Century (TEA-21) and the Governor's Commission on Transportation Policy (GCTP) in Virginia (Miller *et al.*, 2002).

Table 2-9: UDOT's Project Prioritization Criteria for Economic Analysis (Source: Schultz and McGee, 2009)

Criteria	Sub-criteria	Points
Population and Education	Population within a 20-mile radius of the project	10
	Education within a 40-mile radius of the project	10
Existing Infrastructure (evaluated by proximity to the roadway project)	Electrical power (transmission lines)	5
	Railway mainline/spur	5
	Culinary water	5
	Freeway interchange	5
	Industrial level sewer	5
	Advanced communications	5
Economic Attractiveness	Recent economic success of area	10
	Economic hot spots	10
	Size (cost) of the project	10
	Expert feedback	10
Tourism	Evaluated by proximity to a tourist attraction (Non-urbanized[1] area radius is 50 miles and urbanized[2] area radius is 10 miles) as well as achievement of state goals and the roadway project classification	10
Bonus: Economic Choke Points	Evaluated based on the priority given by the UDOT region or district	10

[1] non-urbanized: areas with a population of less than 50,000; [2] urbanized: areas with a population of more than 50,000.

Performance Measures

Table 2-10 summarizes the 14 performance measures along with their corresponding TEA-21 planning factors and GCTP factors.

Table 2-10: VDOT's Project Prioritization Performance Measures (Miller *et al.*, 2002)

TEA-21 Planning Factor	GCTP Factor	Performance Measure
Connectivity	Innovation	1. Intermodal connectivity
Economic development	Economic development	2. Freight mobility
		3. Relative unemployment rate
Efficiency	Quantitative measures of use	4. AADT (truck and auto)
		5. Relative priority in the local, MPO, or PDC plan or TIP
Environmental	Land use and environmental considerations	6. Community support/consistency with local and MPO plans
		7. Environmental approval readiness
		8. Growth management
Accessibility and mobility	Quantitative measures of use	9. v/c ratio
Safety	Safety	10. Accident rate
		11. Geometric deficiencies such as width, grade, or alignment
System preservation	None	12. Bridge deficiencies
		13. Surface rehabilitation
Efficiency	Innovation	14. Total estimated cost

Project Prioritization Methodology

Scoring method is adopted to rank the projects. Each performance measure is given the same weight, i.e., 10 points, so that the highest total points a project could get is 140. Note that the selected performance measures were tailored from a list of approximately 75 measures covering a broad range of priorities (e.g., environmental, congestion relief, and safety), data needs (AADT, costs, and land use plans), and measures of objectivity. The final selection of the 14 performance measures was influenced by data availability at VDOT, objective or systematic determination of a performance measure, link with TEA-21 planning factors, elimination of overlapping measures within the larger measure list, etc. VTRC recommended that VDOT might vary the weights; change the scoring criteria; add or delete performance measures; reduce or increase the number of performance measures; and change the computational methods or data source based on the feedback from stakeholders and technical staff (Miller *et al.*, 2002). For detailed scoring template please refer to Miller *et al.* (2002).

2.2.11 Washington State

Washington State Department of Transportation (WSDOT) prioritizes the highway mobility projects every two years with the goal to produce maximum benefits from transportation improvements. Washington State's Highway System Plan (HSP) serves as the screening criteria for mobility projects. The HSP is the state highway component of the Washington State Multimodal Transportation Plan, which is the state's overall transportation plan that includes an analysis of facilities the state owns and those in which the state has an interest. Projects not contained in the system plan are ineligible for further prioritization (WSDOT, 2014; Dowling Associates, Inc., 2000).

Performance Measures

Table 2-11 lists the seven criteria along with their relative weights that were used for 1995-1997 biennial mobility project evaluation. The criteria, scoring procedures, and weights were established with the input from state transportation officials and WSDOT personnel. Each of the seven criteria is briefly described below (Dowling Associates, Inc., 2000).

Project Prioritization Methodology

WSDOT uses the TOPSIS algorithm to rank and prioritize the highway mobility projects. After screening and scoring in the seven criteria, an evaluation matrix is created. In the matrix, the rows define the projects to be ranked and the columns contain the scores according to seven criteria. The algorithm allows projects with dissimilar criteria to be easily evaluated. The premise of TOPSIS includes (Dowling Associates, Inc., 2000):

- normalization of the scores from an evaluation matrix into dimensionless units;
- multiplication of each score by their relative assigned weights;
- formulation of a theoretical 'ideal-best' project and a theoretical 'ideal-worst' project;
- prioritization of projects by calculating their relative distances between the ideal solutions.

It is noted that the theoretical ‘ideal-best’ project is determined by combining all of the best scores in each of the separate criteria and the ‘ideal-worst’ project is determined by combining all of the worst scores in each of the criteria (Dowling Associates, Inc., 2000).

Table 2-11: WSDOT’s Mobility Project Evaluation Criteria and Weights for 1995-1997 (Source: Dowling Associates, Inc., 2000)

Criteria	Weights
1. Cost-efficiency: measured by the benefit-cost ratio, which was the present value of the monetized project benefits divided by the project costs.	65%
2. Community support: addresses financial participation, endorsement, and opposition by local governments, local organizations, and private groups or individuals as well as potential disruption of neighborhoods and displacement of homes, businesses, or farm land.	14%
3. Wetlands: assesses the intrusion of proposed projects upon classified wetlands and associated buffer areas in accordance with federal, state, and local regulations 4. Water quality and permitting: assesses potential impact on the acreage of impervious surface area within 2,000 ft of any water body. 5. Noise: assesses the potential noise impacts for a proposed project. Points are accrued on the basis of a calculated ‘risk factor’, which is based on the number of lanes for the proposed project, as well as the number of noise receptors and their proximity to that project.	8%
6. Modal integration: assesses the level of modal integration supported by a proposed project in accordance with Washington State policy goals.	7%
7. Land use: assesses the support that proposed projects provide for Washington State mobility and land-use management objectives.	6%
Total	100%

2.2.12 Wisconsin

Wisconsin Department of Transportation (WisDOT) along with Wisconsin’s MPOs, municipalities, and regions identify the emerging needs and highway and bridge projects of transportation. WisDOT then reviews the proposals and develops a list of candidate projects for the transportation project commission’s (TPC) evaluation. The projects also filter through environmental and engineering studies by TPC and WisDOT before the prioritization process (Metropolitan Planning Council, n.d.).

Performance Measures

Table 2-12 presents WisDOT’s prioritization criteria, objectives, factors, and associated weights for highway and bridge projects.

Project Prioritization Methodology

The basic steps of WisDOT’s prioritization process for highway and bridge projects include (Metropolitan Planning Council, n.d.):

1. TPC holds hearing to receive public comment on the candidate projects,
2. WisDOT analyzes each candidate project using objective criteria and weighted measures, and
3. WisDOT ranks each candidate project based on the final score.

Table 2-12: WisDOT's Prioritization Criteria of Highway and Bridge Projects (Source: Metropolitan Planning Council, n.d.)

Criteria (Weighting %)	Objectives of the Criteria (Weighting %)	Factors Addressed	% Weight
Economic measure (40%)	Identify competitiveness of existing business (50%)	Reduction in travel costs vs. construction costs	15%
		Business that will benefit	5%
	Identify attractiveness for new business (25%)	Economic growth potential	5%
		Unique reasons why project will attract new business	5%
	Identify routes that provide connections (25%)	Part of corridors 2020 or national highway system (NHS) network	10%
Traffic flow measure (20%)	Identify traffic flow problems (100%)	Level of service	20%
Safety measure (20%)	Identify crash problems (100%)	Crash rate	20%
		Severity proportion	
		Pedestrian and bicycle considerations	
Environmental measure (10%)	Identify affected natural and physical resources (50%)	Natural resources	2.5%
		Physical resources	2.5%
	Identify socio-economic and cultural resources (50%)	Socio-economic resources	2.5%
		Cultural resources	2.5%
Community input measure (10%)	Identify community input (100%)	Public support or opposition	5%
		Relationship to adopted plans	5%

2.3 MPOs and Local Transportation Agencies

This section summarizes the project prioritization methodologies that are currently being applied by the following MPOs and local transportation agencies:

1. Boston Region Metropolitan Planning Organization, Massachusetts
2. Broward Metropolitan Planning Organization, Florida
3. Fredericksburg Area Metropolitan Planning Organization, Virginia
4. Hampton Roads Transportation Planning Organization, Virginia
5. Metrolinx, Ontario, Canada
6. Nashville Area Metropolitan Planning Organization, Tennessee
7. North Central Pennsylvania, Pennsylvania
8. Winston-Salem Urban Area Metropolitan Planning Organization, North Carolina

2.3.1 Boston Region Metropolitan Planning Organization, Massachusetts

The Boston Region MPO updates the Transportation Improvement Program (TIP) annually. Transportation projects and strategies that Boston Region plans to take into consideration for the next four years are identified in the TIP. A transportation improvement project must be included in the TIP before it receives federal funds for implementation (Boston Region MPO, 2013).

Table 2-13 provides Boston Region MPO's TIP evaluation criteria, sub-criteria, and corresponding weights. The MPO uses TIP evaluation criteria to prioritize projects. The project evaluation framework has six policy criteria and 35 sub-criteria. The staff uses evaluation scoring and project readiness to prepare a first-tier list of projects. Staff recommendation, public review, and other information are also considered to determine the final list.

2.3.2 Broward Metropolitan Planning Organization, Florida

Intermodal transportation solution was considered for Broward MPO's 2035 LRTP. Broward's project prioritization policy starts with prioritizing premium transit projects which in turn help rank the mobility hubs, followed by pedestrian/bicycle/greenway projects and roadway projects. The later projects are selected in such a way that they could ensure necessary connectivity to and from the prior projects. Quantitative and qualitative performance measures are considered depending on evaluation criteria. Point values are assigned for the performance indicators. Projects with higher points got higher priorities in the ranking (Jacobs, 2009).

Broward MPO's 2035 LRTP vision, mission, and goals, and SAFETEA-LU planning factors are considered for developing the evaluation criteria for each mode, i.e., for each type of project category. The following project categories are identified:

- premium transit projects,
- mobility hubs projects,
- bicycle/pedestrian/greenway projects,
- roadways,
- intelligent transportation system (ITS),
- freight/airport/seaport, and
- safety and security projects.

Each category has its own performance measures. For example, a link-level analysis using the Southeast Florida Regional Planning Model, version 6.5 was conducted for the premium transit projects. Logical termini locations were also considered. Table 2-14 lists the factors that are used to further rank the premium transit projects.

The performance measures use both quantitative and qualitative data. However, most measures are quantitative and use figures from transportation and ridership forecasting models, U.S. Census data, project cost estimates, and other quantifiable data. The projects are given point values (0, 1, 2, or 3) based on their performance for each criterion. A project receiving higher points signified that it is a better project than those which got lower points for that particular criterion.

A four-tiered scoring system is developed for quantitative data. The data are first normalized by taking the raw data and dividing into quartiles. Then point values are assigned based on which quartile the project falls into. If a project falls within the first quartile, it is given zero points; if it falls between the first and the second quartile, it is given one point; if it falls between the second and the third quartile, it is given two points; and finally, if it falls between the third and the fourth quartile, it is given three points. Qualitative data are not normalized and relative scores are assigned. Once points are assigned to all the criteria, the points are added to determine the cumulative project score. This score is then used to rank or prioritize projects. Note that the Freight/Seaport/Airport and ITS projects are not prioritized in this manner; priorities are determined by the implementing agencies.

Table 2-13: Boston Region MPO's TIP Evaluation Criteria, Sub-criteria and Weights (Source: Boston Region MPO, 2013)

Criteria	Sub-criteria	Score points)
System Preservation, Modernization, and Efficiency	Pavement condition	6
	Signal equipment condition	6
	Traffic signals operational condition	6
	Congestion management process	6
	Intermodal accommodations/connections to transit	6
	ITS strategies other than traffic signal operations	6
Livability and Economic Benefit	Consistency with complete street policies	4
	Multimodal access to activity center	3
	Reduction of auto dependency	8
	Serving a targeted development site	6
	Consistency with compact growth strategies	5
	Quality of life	3
Mobility	Existing peak hour level of service	3
	Addresses an MPO or State identified freight movement issue	3
	Addresses proponent identified primary mobility need	3
	Addresses MPO identified primary mobility need	3
	Congestion reduction	6
	Transit reliability	7
Environment and Climate Change	Air quality	5
	CO_2 reduction	5
	Executive Office of Energy and Environmental Affairs (EOEEA) certified 'Green Community'	4
	Reduction in VMT/VHT	7
	Addresses identified environmental impacts	4
Environmental Justice	Improvement of transit for an EJ population	3
	Consistency with complete streets policies in an EJ area	4
	Addresses an MPO identified EJ transportation issue	3
Safety and Security	Improvement in emergency response	2
	Ability to respond to extreme conditions	6
	Injury value using Commonwealth's listing for Estimated Property Damage Only (EPDO) or injury value information	3
	Addresses proponent identified primary safety need	3
	Addresses MPO identified primary safety need	3
	Addresses freight related safety issue	3
	Bicycle safety	3
	Pedestrian safety	3
	Safety at the at grade railroad crossing	3

Table 2-14: Broward MPO's Evaluation Criteria for Premium Transit Projects (Source: Jacobs, 2009)

Evaluation Criteria	Measure	Maximum Achievable Point
Travel Market Size	Trip density within 1/4 mile of transit project (2035)	3
Cost Effectiveness	Capital cost per rider	3
Contributes to Efficiency of Transit System users	Number of connections to premium transit routes	3
Ability to Leverage New Funding Sources (i.e. sales tax, user tax, VMT tax, New Starts)	Cost Effectiveness Index (CEI) (Annualized capital and O&M cost normalized by ridership)	3
Tax Incremental Financing Opportunities	Area (in acres) of CRA/TOD/TOC/Higher Density Mixed Use designation within half-mile of transit project	3
Service to Transit Dependents	Transit dependent population (zero-auto households) within 1/4 mile of transit project	3
Reduction in Greenhouse Gases	Reduction in carbon-dioxide emission per year	3
Reduction in Single Occupancy Vehicle Travel or VMT	Passenger miles	3

2.3.3 Fredericksburg Area Metropolitan Planning Organization (FAMPO), Virginia

The Fredericksburg Area Metropolitan Planning Organization (FAMPO) developed a methodology to prioritize projects identified as part of its regional LRTP. The following factors are evaluated in the prioritization process (KHA, Inc., 2008):

- congestion,
- economic opportunities,
- safety,
- security,
- public support,
- environmental impacts,
- funding, local matches, and prior funding commitments,
- cost,
- benefit-cost ratio,
- regional connectivity,
- gap closure,
- deliverability/readiness,
- freight mobility,
- emergency evacuation,
- improve mobility for disadvantaged,
- sustainability,
- local priority, and
- remaining life cycle and existing conditions.

Table 2-15 presents the proposed recommended factors, sub-factors, and point values for the evaluation of projects. FAMPO's project ranking process includes the following steps (KHA, Inc., 2008):

- *Step 1*: Application of prioritization factors.
- *Step 2*: Addition of total points within each individual factor category.
- *Step 3*: Addition of total points of all factor categories.
- *Step 4*: Prioritization of projects, including:
  - organizing projects into urban and rural category,
  - organizing projects into interstate, arterial, collector, local, and bridge (divided into replacement and rehabilitation/maintenance type) category,
  - ranking categorized projects from highest to lowest scores, and
  - separate projects for individual jurisdictions within categories (optional).
- *Step 5*: Revision of information.
- *Step 6*: Prioritization of projects based on highest scores.
- *Step 7*: Final revision by staffs, TAC, and board to identify acceptable exceptions.

Table 2-15: FAMPO's Project Evaluation Factors and Points (Source: KHA, Inc., 2008)

Major Factors	Sub-factors	Points
Congestion Relief	Congestion: Level of current and future congestion	14
	Continuity and Connectivity: Improvement to route continuity and the connectivity of the overall transportation network	7
	Major Users: Service to major activity centers	4
	Freight Use: Substantial service to freight movement or facility servicing substantial freight movements	5
	Total	**30**
Safety and Security	Geometric Impact on Existing Roadways: Improvement to geometric deficiencies such as horizontal and vertical alignment, lane width, or shoulder conditions	18
	Vehicle Crash Reduction: Potential to reduce crash history	6
	Bike/Pedestrian Safety: Contributor to improved safety for pedestrians/bicyclists	4
	Homeland Security: Strategic project that improves Homeland Security	2
	Total	**30**
Environmental Impacts	Natural Environment: Impact on wetlands, ecosystems, air, and water quality	8
	Neighborhood: Impact on neighborhoods, communities, and historic and archaeological sites	8
	Total	**16**
Public/Community Support	Existing Plans: Adherence to existing street and highway, master, regional, and local modal plans	4
	Community Support: Strong governmental or community support or continuity with local goals and initiatives and consistency of request by local jurisdictions	4
	Total	**8**
Funding/ Implementation Considerations	Feasibility: Reasonable cost, efficient, resourceful, having positive long-term economic impacts	3
	Project Ready: Project ready to go except for funding	4
	Interagency Cooperation: Importance to other agencies or jurisdictions or related to joint initiatives involving multiple jurisdictions or agencies	1
	Total	**8**
Smart Growth/Mobility	Growth Areas: Promotion of sensible, sustainable growth	4
	Intermodal: Enhancement of intermodal access	4
	Total	**8**
	Grand Total	**100**

2.3.4 Hampton Roads Transportation Planning Organization (HRTPO), Virginia

The Hampton Roads Transportation Planning Organization (HRTPO) with the support of VDOT and Kimley-Horn and Associates (KHA) initiated the development of a program prioritization tool for regional transportation investments in Hampton Roads (Pickard *et al.*, 2010). Projects' technical merits and regional benefits along with funding constraints are considered in the prioritization process. The methodology evaluates transportation projects based on their utility, economic vitality, and viability.

The HRTPO Board approved the methodology in 2010 and directed the HRTPO staff to apply it for the evaluation of candidate transportation projects for the 2034 LRTP. The basic components for evaluation are similar for all transportation projects, and include project utility, project viability, and economic vitality. However, the criteria and sub-criteria differ based on project category. Table 2-16 presents the criteria and sub-criteria along with weights for highway projects.

Table 2-16: HRTPO's Highway Projects Prioritization Criteria and Sub-criteria (Source: Pickard *et al.*, 2010)

<table>
<tr><th colspan="3">Criteria and Sub-criteria</th><th>Weight</th></tr>
<tr><td rowspan="11">Project Utility</td><td rowspan="3">Congestion Level</td><td>% Reduction in existing and future v/c ratios</td><td>10</td></tr>
<tr><td>Existing v/c ratio</td><td>10</td></tr>
<tr><td>Impact to nearby roadways</td><td>10</td></tr>
<tr><td>System Continuity and Connectivity</td><td>Degree of regional impact</td><td>25</td></tr>
<tr><td rowspan="2">Safety and Security</td><td>Critical crash ratio</td><td>8</td></tr>
<tr><td>Improvements to incident management or evacuation routes</td><td>7</td></tr>
<tr><td colspan="2">Cost Effectiveness (Cost/VMT)</td><td>15</td></tr>
<tr><td colspan="2">Land Use/Future Development Compatibility</td><td>10</td></tr>
<tr><td rowspan="2">Modal Enhancements</td><td>Enhancement of other categories</td><td>3</td></tr>
<tr><td>Improvement to vehicular access</td><td>2</td></tr>
<tr><td colspan="2">Project Utility Total</td><td>100</td></tr>
<tr><td rowspan="10">Economic Vitality</td><td colspan="2">Total Reduction in Travel Time</td><td>30</td></tr>
<tr><td rowspan="2">Labor Market Access</td><td>Increased travel time reliability</td><td>10</td></tr>
<tr><td>Increased access for major employment centers</td><td>10</td></tr>
<tr><td rowspan="4">Addresses the Needs of Basic Sector Industries</td><td>Increased access to tourist destinations</td><td>10</td></tr>
<tr><td>Increased access for defense installations</td><td>6</td></tr>
<tr><td>Increased access for defense installations - STRAHNET</td><td>4</td></tr>
<tr><td>Increased access to port facilities</td><td>10</td></tr>
<tr><td rowspan="2">Increases Opportunity</td><td>Provision of new or increased access</td><td>10</td></tr>
<tr><td>Support for plans of future growth</td><td>10</td></tr>
<tr><td></td><td>Economic Vitality Total</td><td>100</td></tr>
<tr><td rowspan="8">Project Viability</td><td>Funding</td><td>Percentage of funding committed</td><td>50</td></tr>
<tr><td rowspan="6">Process/Project Readiness</td><td>Prior commitment (is project in LRTP)</td><td>10</td></tr>
<tr><td>Percentage of project design completed</td><td>10</td></tr>
<tr><td>Environmental documents completeness</td><td>15</td></tr>
<tr><td>Environmental decisions obtained</td><td>5</td></tr>
<tr><td>ROW obtained and utilities coordinated</td><td>5</td></tr>
<tr><td>Additional environmental permits obtained</td><td>5</td></tr>
<tr><td></td><td>Project Viability Total</td><td>100</td></tr>
</table>

The following five project categories were identified:

1. highways,
2. interchange,
3. intermodal,
4. bridge and tunnel, and
5. transit.

Each project according to its category is scored based on the three evaluation components. The component scores are summed up to get a final score, which is then used to prioritize the projects (Pickard *et al.*, 2010).

2.3.5 Metrolinx, Ontario, Canada

Metrolinx (2013) established a combination of both quantitative and qualitative evaluation criteria to assess '*The Big Move*' priorities in order to rank them in a sequential way for capital investment focusing on highest benefits. Environment, economy, and quality of life are their three basic principles for prioritization process. The primary evaluation criteria encompassed these principles along with measurement of deliverability and constructability in benefit-cost terminologies. Ten different metrics (i.e., indicators) are embedded under the three principles for primary evaluation. The secondary evaluation criteria considered the strategic fit as an opportunity for qualitative considerations not captured by the primary quantitative criteria. A number of key issues are used for the framework of strategic fit phase. The GO and Rapid Transit projects are prioritized currently. Table 2-17 provides Metrolinx's primary evaluation criteria, sub-criteria, and corresponding indicators.

Table 2-17: Metrolinx's Primary Evaluation Criteria, Sub-criteria, and Indicators (Source: Metrolinx, 2013)

Criteria	Sub-criteria	Indicator
A High Quality of Life	Building Communities	Change in the density of population and employment projected for the area
	Transit Ridership	Total weekday boarding forecasted
	Social Need	Youth/senior/low income population within 500m of an RT corridor or 2km of a GO station
	Regional Connectivity/ Destinations	Number of connections to other RT services/mobility hubs/post-secondary institutions/hospitals
A Thriving, Sustainable and Protected Environment	GHG Emissions Reduction	Tonnes saved annually based on VKT
	New Transit Riders	Projected total new weekday boardings
A Strong, Prosperous and Competitive Economy	Economic Impacts	Direct and indirect wages and GDP benefits (post construction) over the first 30 years of operation
	Capital Cost per Rider	Capital cost per new rider
	Operating Revenue/Cost Ratio	Net new operating revenue/cost ratio
	Benefit-cost Ratio	Transportation user benefits (travel time, safety, operating savings based on vehicle kilometers travelled (VKT), capital cost, and estimated incremental operating cost

For each indicator in Table 2-17, projects are scored on a scale of 1 to 5 based on the range of indicator values of the competing projects. Benefit-cost analysis provides the indicator values for each of the project. A composite score for each of the criteria is deduced by averaging the individual sub-criteria scores. The GO and rapid transit projects are evaluated separately due to differences in the projects' natures. Once the primary evaluation is completed, each project is analyzed for the issues of deliverability and constructability. Finally, the strategic fit of the projects is evaluated through the following subjective criteria:

- leveraging other investments and initiatives,
- project readiness,
- funding, and
- completing the network throughout whole region

2.3.6 Nashville Area Metropolitan Planning Organization, Tennessee

The Nashville Area MPO developed a comprehensive process to evaluate projects that are consistent with the MPO's program development guiding principles, regional goals, and major objectives. The MPO's selection process is mainly focused on the identification of high-scoring projects eligible for MPO-managed funds which included those from the FHWA Surface Transportation Program (STP), FHWA Congestion Mitigation and Air Quality (CMAQ), and FTA Section 5307 Urban Transit grant funds. Projects that are more suitable for state-managed funds are evaluated and scored primarily so that those priorities could be communicated to the Tennessee Department of Transportation. The projects with local or state funding commitments or prior federal funding commitments are given priority for funding in the new work program (Nashville Area MPO, 2013).

Table 2-18 provides Nashville Area MPO's project prioritization criteria and corresponding maximum achievable points. Nashville Area MPO uses the evaluation criteria listed in this table to prioritize the projects. The project evaluation framework has eight evaluation criteria and each criterion is associated with a number of sub-criteria. A project receiving higher points gets the higher priority.

Table 2-18: Nashville Area MPO's Prioritization Criteria and Corresponding Points (Source: Nashville Area MPO, 2013)

Evaluation Criteria	Points
System Preservation and Enhancement	15
Quality Growth, Sustainable Development, and Economic Prosperity	15
Multi-Modal Options	15
Congestion Management	10
Safety and Security	10
Freight and Goods Movement	10
Health and Environment	10
Project History (State and Local Support)	15

2.3.7 North Central Pennsylvania, Pennsylvania

North Central Pennsylvania stressed the project prioritization process in its 2007-2035 LRTP. A two-step process for evaluating candidate transportation projects was initiated. In the first step, the projects are categorized into the following six major types:

1. Highway restoration
2. New capacity
3. State bridges greater than eight feet in length
4. Local bridges greater than 20 feet in length
5. Safety
6. Transportation enhancements

Each of these project types is associated with different criteria and corresponding weighting and the projects within each type are rated accordingly. In the second step, all competing projects are evaluated based on a set of common overall transportation criteria. Finally, the scores from the first step are summed up with the scores from the second step to obtain a total final score that is then used to prioritize projects (PennDOT, 2010).

Each categorized project further has different performance measures, scoring scales, and weights. For example, a new capacity project would have the following prioritization criteria together with the corresponding weights given in parentheses:

- Network/accessibility (19%)
- Project effectiveness (22%)
- Business retention and growth (30%)
- Truck percent (8%)
- Cost factors (21%)

North Central Pennsylvania identified 14 different elements that would serve as the overall transportation criteria for the purpose of performing the pairwise comparison and weightings in the second step. These criteria were clustered into five basic groups. Table 2-19 presents the overall prioritization criteria and their corresponding weights.

The prioritization method used by North Central Pennsylvania is based on the total score calculated from the two aforementioned steps. In the first step, based on project type, the proper rating of a criterion is first determined. The rating is then multiplied by the corresponding criterion weight, followed by summing up the values of all criteria to come up with a final score for the first step. In the second step, the same approach is used with the exception that each criterion has different elements. Therefore, the rating is first multiplied by element weight, followed by summing up the entire element related values (multiplied by element weight) under each criterion. The weight of each criterion is then integrated in scoring to calculate the final score for the second step. Finally, the scores from both steps are summed up to obtain the final score for the prioritization process.

Table 2-19: North Central Pennsylvania's Overall Transportation Criteria (Source: PennDOT, 2010)

Project Criteria		Rating	Guidelines	Weighting Child	Weighting Parent
Safety	Safety	0	Project does not effectively address safety issues in the area	N/A	36%
		10	Project includes one of the top 25 safety projects identified in the region through PennDOT's C-DART database		
Job Creation and Community Benefits	Community Benefits	0	Does not have positive community benefits	30%	23%
		5	Project impacts confined to local community		
		10	Project has broad & positive multi-municipal/regional impact		
	Permanent Job Creation	0	No impact on total employment or employment potential	70%	
		5	Will ensure creation of new jobs		
		10	Will retain/preserve jobs		
Transportation Planning and Project Support	Supported by LRTP	0	Project is not related to, nor part of, the LRTP	34%	14%
		5	Supports an LRTP project		
		10	Project is included in LRTP		
	County/ Municipal Comprehen-sive Plan	0	Project is not included in any county or municipal comprehensive plan	31%	
		5	Project is part of one county or municipal comprehensive plan		
		10	Project is part of more than one county/municipal plan		
	Public/ Private Sector Involvement	0	No private sector/municipal money available	19%	
		3	Private sector/municipal involvement of 1-10% of project share		
		7	Private sector/municipal involvement of 11-19% of project share		
		10	Private sector/municipal involvement ≥ 20% of project share		
	Leadership & Political Support	0	Project has no leadership or political support	16%	
		5	Project has some leadership and political support		
		10	Project has defined leadership and strong political support		
Project Location Factors	Maximizes Existing Infra-structure	0	Project requires development of new transportation infrastructure	52%	12%
		5	Project improves existing transportation infrastructure		
		10	Project maximizes the use of existing transportation infrastructure		
	Environ-mental	0	Project is expected to have significant environmental impacts	19%	
		5	Project environmental impacts can be mitigated at reasonable cost		
		10	Project has no expected environmental impacts		
	Land Use	0	Project could negatively impact the land use of the area or community character	29%	
		5	Project will have minimal impacts on land use		
		10	Project will have no impact or make positive improvement to the area's land use and community character		
Transportation Benefits	Intermodal Benefit	0	No intermodal potential	25%	16%
		5	Facilitates transfer or intermodal potential between 1-2 modes		
		10	Connects >2 modes/services		
	Vehicle Trip Reduction	0	No trip reduction	23%	
		5	Project will result in some trip reduction		
		10	Project will encourage the reduction of trips/ discourage SOV use		
	Promotes Other Modes	0	Does not promote the use of multiple modes	27%	
		10	Promotes the use of multiple modes		
	Freight	0	Does not facilitate the movement of freight	24%	
		10	Enhances the operational performance and/or safety of freight carriers		

2.3.8 Winston-Salem Urban Area Metropolitan Planning Organization (WSUAMPO), North Carolina

Winston-Salem Urban Area Metropolitan Planning Organization (WSUAMPO) developed a prioritization process which is data-driven and responsive to local needs. The prioritization method intends to evaluate and prioritize all modes of transportation. However, bicycle and pedestrian projects are not incorporated due to different fund allocation principles (WSUAMPO, n.d.).

Table 2-20 lists the criteria and the corresponding indicators and weights used by WSUAMPO. The prioritization methodology takes local input into consideration along with quantitative and qualitative criteria. The MPO staff score all projects through the prioritization criteria and rank the projects according to different modes of transportation. The highest-ranked projects in each mode are then allowed to receive a maximum of 100 points as local inputs. Winston-Salem Urban Area TAC makes the final decision regarding point assignment based on public comments and recommendations from the Winston-Salem Urban Area Technical Coordinating Committee (TCC).

Table 2-20: WSUAMPO's Project Prioritization Criteria (Source: WSUAMPO, n.d.)

Criteria		Indicators	Maximum Achievable Points
Quantitative	Safety	• Crash density • Crash severity • Critical crash rate • Crash frequency • Severity index	10
	Congestion	• v/c ratio	10
	Freight	• Access to airports, freight distribution facilities, or major commercial/industrial districts • Freight movement to regional and national economic centers	10
	Environmental Justice	• More transportation options for the minority and low-income people • Stimulation to economic development or redevelopment investments • Little or no impact to existing homes and business	10
	Economic Development	• Access to existing employment centers • Access to land zoned or identified in development guides • Access to future employment	10
	Accessibility	• Access to and/or accommodating various modes of travel • Transit stops	10
Qualitative		• Public input • Consistency with planned growth and development areas • Adherence to Complete Streets Policy • Promotion of community goals and objectives • Existing local commitment to funding	40

2.4 Summary

This chapter focused on reviewing and assembling information on the project prioritization methods. Specifically, the following FDOT policy documents and implementation plans were reviewed summarized:

- Florida’s SIS Strategic Plan
- 2060 Florida Transportation Plan
- Implementation of the HSM and *SafetyAnalyst*
- Florida Freight Mobility and Trade Plan

Additionally, the project prioritization methods that are currently being adopted by the following state and local agencies are discussed. The states included:

1. Delaware
2. Florida
3. Indiana
4. Missouri
5. North Carolina
6. Ohio
7. Oregon
8. Texas
9. Utah
10. Virginia
11. Washington State
12. Wisconsin

The local agencies included:

1. Boston Region Metropolitan Planning Organization, Massachusetts
2. Broward Metropolitan Planning Organization, Florida
3. Fredericksburg Area Metropolitan Planning Organization, Virginia
4. Hampton Roads Transportation Planning Organization, Virginia
5. Metrolinx, Ontario, Canada
6. Nashville Area Metropolitan Planning Organization, Tennessee
7. North Central Pennsylvania, Pennsylvania
8. Winston-Salem Urban Area Metropolitan Planning Organization, North Carolina

Table 2-21 presents a summary of the 12 state DOTs’ project evaluation criteria, and prioritization methodology according to project types. Table 2-22 lists the performance measures considered by the eight local agencies. All eight local agencies adopted the scoring methodology to prioritize projects.

Based on the review of the FDOT policy documents and the state-of-the-practice prioritization methods, the quantifiable performance measures that could potentially be considered in the CMP system are identified. Table 2-23 lists these performance measures. The table also provides the FDOT goals addressed by each criterion.

Table 2-21: Summary of the State DOTs' Performance Measures and Project Prioritization Methods

State	Project Type	Performance Measures	Prioritization Method
Delaware	Capital Transportation Program	• Safety • System operating effectiveness • Multi-modal mobility/flexibility/access • Revenue generation/economic development/jobs and commerce • Impact on the public/social disruption/economic justice • Environmental impact/stewardship • System preservation	Rating Scale
Florida	Low-cost Near-term Highway Improvements for Strategic Intermodal System	• Crash ratio • Fatal crash • v/c ratio • AADT • Truck volume • Truck % • Delay	Scoring
Indiana	New Construction and Major Preservation Program	• Transportation efficiency • Safety • Economic development and customer input • Public/private or local participating fund, and urban revitalization	Scoring
Missouri	Taking Care of the System Projects	• Access to opportunity • Congestion relief • Economic competitiveness • Efficient movement of freight • Quality of communities • Environmental protection • Safety • Taking care of the system	Scoring
North Carolina	Highway Projects	• Congestion • B/C ratio • Economic competitiveness • Safety • Pavement condition • Lane width • Shoulder width • Multimodal issues • Connectivity	Scoring
Ohio	Major New Capacity Projects	• Transportation factors (v/c ratio, safety, ADTT, B/C, etc.) • Economic performance • Local investments • Project funding plan	Scoring
Oregon	Multimodal Mobility Improvement Projects	• Land use conformity • Environmental resource impacts • Cost-efficiency • Economic development • Modal integration • Community support • Accessibility	TOPSIS

Table 2-21: Summary of the State DOTs' Performance Measures and Project Prioritization Methods (Cont'd)

State	Project Type	Performance Measures	Prioritization Method
Texas	Highway Projects	• Congestion • Safety • Economic opportunity • Air quality • Value of transportation assets • Local, regional or statewide transportation issues • Short-term, mid-term or long-term solution	Scoring
Utah	Long Range Transportation Plan Roadway Projects	*Tier I* • AADT • Truck AADT • v/c ratio • v/c ratio improvement • Safety • Functional class • Transportation growth • Vehicle-hours-saved • B/C ratio • Adjacent interchange v/c ratio • Average adjacent interchange distance *Tier II* • Economics • Environmental impacts • Congestion • Safety	Scoring
Virginia	Capital Improvement Projects	• Intermodal connectivity • Freight mobility • Relative unemployment rate • AADT (truck and auto) • Relative priority in the local, MPO, or PDC plan or TIP • Community support/consistency with local & MPO plans • Environmental approval readiness • Growth management • v/c ratio • Accident rate • Geometric deficiencies such as width, grade, or alignment • Bridge deficiencies • Surface rehabilitation • Total estimated cost	Scoring
Washington State	Highway Mobility Projects	• Cost-efficiency • Community Support • Environment (wetlands, water quality & permitting, noise) • Modal integration • Land use	TOPSIS
Wisconsin	Highway and Bridge Projects	• Economic • Traffic flow • Safety • Environment • Community input	Scoring

Table 2-22: Summary of the Local Agencies' Performance Measures

MPO/Agency	Project Type	Performance Measures

North Central Pennsylvania	LRTP	• Safety
		• Job Creation and Community Benefit
		  ○ Community benefit
		  ○ Permanent job creation/retainage
		• Transportation Planning and Project Support
		  ○ Supported by LRTP
		  ○ Community/municipal comprehensive plan
		  ○ Public/private sector involvement
		  ○ Leadership and political support
		• Project Location Factors
		  ○ Maximizes existing infrastructure
		  ○ Environment
		  ○ Land use
		• Transportation Benefits
		  ○ Intermodal benefit
		  ○ Vehicle trip reduction
		  ○ Promotes other modes
		  ○ Freight

HRTPO	Regional Transportation Investment	• Project Utility
		  ○ Congestion
		  ○ System continuity and connectivity
		  ○ Safety and security
		  ○ Cost effectiveness
		  ○ Land use/future development compatibility
		  ○ Modal enhancements
		• Economic Viability
		  ○ Reduction in travel time
		  ○ Labor market access
		  ○ Needs of basic sector industries
		  ○ Opportunity
		• Project Vitality
		  ○ Funding
		  ○ Process/project readiness

Broward MPO	Premium Transit Projects	• Travel Market Size • Cost Effectiveness • Efficiency of Transit System Users • Ability to Leverage New Funding Sources • Tax Incremental Financing Opportunities • Service to Transit Dependents • Reduction in Greenhouse Gases • Reduction in Single Occupancy Vehicle Travel
WSUAMPO	TIP	• Safety • Congestion • Freight • Environmental Justice • Economic Development • Accessibility • Qualitative judgment

Table 2-22: Summary of the Local Agencies' Performance Measures (Cont'd)

MPO/Agency	Project Type	Performance Measures
Boston Region MPO	TIP	• System Preservation, Modernization, and Efficiency • Livability and Economic Benefit • Mobility • Environment and Climate Change • Environmental Justice • Safety and Security

FAMPO	LRTP	• Congestion Relief
		  ○ Congestion
		  ○ Continuity and connectivity
		  ○ Major users
		  ○ Freight use
		• Safety and Security
		  ○ Geometric impact
		  ○ Vehicle crash reduction
		  ○ Bike/pedestrian safety
		  ○ Homeland security
		• Environmental Impacts
		  ○ Natural environment
		  ○ Neighborhood
		• Public/Community Support
		  ○ Existing plans
		  ○ Community support
		• Funding/Implementation Considerations
		  ○ Feasibility
		  ○ Project readiness
		  ○ Interagency cooperation
		• Smart Growth/Mobility
		  ○ Growth areas
		  ○ Intermodal

Nashville Area MPO	TIP	• System Preservation and Enhancement • Quality Growth, Sustainable Development, and Economic Prosperity • Multi-Modal Option • Congestion Management • Safety and Security • Freight and Goods Movement • Health and Environment • Project History (State and Local Support)

Metrolinx	Transit Projects	• High Quality of Life
		  ○ Building communities
		  ○ Transit ridership
		  ○ Social need
		  ○ Regional connectivity/destinations
		• Sustainable and Protected Environment
		  ○ GHG emission reduction
		  ○ New transit riders
		• Strong, Prosperous, and Competitive Economy
		  ○ Economic impact
		  ○ Capital cost per rider
		  ○ Operating revenue/cost ratio
		  ○ Benefit-cost ratio

Table 2-23: Summary of Performance Measures

Criteria	Performance Measure	Goals Addressed
Safety	• Crash Frequency • Crash Rate • Critical Crash Rate • Severity Index • Fatality Rate • Crash Density • Excess Expected Crash Frequency	• Safety and Security
System Operating Effectiveness (i.e., Congestion)	• LOS • AADT • v/c • Cost/VMT	• Community Livability • Mobility and Connectivity • Maintenance and Operations
Transportation Efficiency	• B/C • NPV	• Economic Competitiveness • Community Livability • Environmental Stewardship • Safety and Security • Maintenance and Operations • Mobility and Connectivity
Freight	• Truck Volume • Truck Percent • Reduction in Truck Miles Traveled	• Community Livability • Mobility and Connectivity • Maintenance and Operations
Transit	• Ridership/Capacity • VMT Reduction	• Mobility and Connectivity • Maintenance and Operation

CHAPTER 3
PERFORMANCE MEASURES

This chapter focuses on the performance measures used in the CMP for the screening of project locations. It first discusses the performance measures that are currently being used in the CMP. Based on the results from the state-of-the-practice review presented in the previous chapter, modifications to the existing performance measures are then recommended for implementation in the CMP.

3.1 Existing Performance Measures

The SIT developed by the Department's Systems Planning Office includes a total of 24 prioritization measures across five categories, each corresponding to the following five SIS goals (FDOT, 2008):

1. *Safety and Security*: A safer and more secure transportation system for residents, businesses and visitors
2. *System Preservation*: Effective preservation and management of Florida's transportation facilities and services
3. *Mobility*: Increased mobility for people and for freight and efficient operations of Florida's transportation system
4. *Economic Competitiveness*: Enhanced economic competitiveness and economic diversification
5. *Quality of Life*: Enriched quality of life and responsible environmental stewardship

Table 3-1 lists the 24 measures along with their maximum scores. As aforementioned, FDOT District One adopted seven out of these 24 SIT measures for implementation in the CMP. These seven measures are (FDOT, 2008):

1. Crash ratio
2. Fatal crash
3. v/c ratio
4. AADT per lane
5. Truck volume per lane
6. Truck percent
7. Delay

Table 3-2 presents the CMP quantitative performance measures, their corresponding SIS goals and weights (i.e., CMP maximum score) for prioritizing low-cost near-term highway improvements on Florida's SIS network. These measures are described in further detail below (FDOT, 2008).

Table 3-1: SIT Highway and Connector Measures (Source: FDOT, 2008)

Goal	Measure	Maximum Score
Safety and Security	Crash Ratio*	10
	Fatal Crash*	4
	Bridge Appraisal Rating	3
	Link to Military Base	3
	Possible Subtotal	***20 points***
System Preservation	Volume/Capacity Ratio*	10
	Truck Volume (AADTT)*	6
	Vehicular Volume (AADT)*	2
	Bridge Condition Rating	2
	Possible Subtotal	***20 points***
Mobility	Connector Location	1
	Volume/Capacity Ratio*	4
	Truck Volume (% Trucks)*	2
	Vehicular Volume (AADT)*	2
	System Gap	2
	Change in v/c – Level of Service (for Mainline segments only) Interchange Operations (for Interchanges only)	3
	Bottleneck/Grade Separation	2
	Delay*	4
	Possible Subtotal	***20 points***
Economics	Demographic Preparedness	5
	Private Sector Robustness	5
	Tourism Intensity	5
	Supporting Facilities	5
	Possible Subtotal	***20 points***
Quality of Life	Land and Social Criteria	4
	Geology Criteria	4
	Habitat Criteria	4
	Water Criteria	8
	Possible Subtotal	***20 points***
	Total Maximum Score	***100 points***

* Performance measures currently included in the CMP.

Table 3-2: Quantitative Performance Measures, Goals, and Weights of CMP (FDOT, 2008)

Quantitative Measure	SIS Goal(s) Addressed	Weight (i.e., CMP Maximum Score)
Crash Ratio	Safety and Security	22.00
Fatal Crash	Safety and Security	9.00
Volume-to-capacity (v/c) Ratio	System Preservation and Mobility	31.00
Vehicular Volume per Lane (AADT/lane)[1]	System Preservation and Mobility	10.00
Truck Volume per Lane (AADTT/lane)[2]	System Preservation	13.00
Truck Volume (% Trucks)	Mobility	6.00
Delay	Mobility	9.00
	Total	**100.00**

[1] average annual daily traffic per lane; [2] average annual daily truck traffic per lane.

Crash Ratio

Crash ratios are used to indicate roadways where the actual crash rate is higher than the average crash rate. A higher than average crash rate at a location is a prime indicator of a safety problem at that location. Crash ratio is calculated as the ratio of the annual crash rate for each roadway segment to the corresponding year's District One average system-wide crash rate for that type of roadway segment (see Equation 3-1). Equation 3-2 gives the formula to calculate crash rate in crashes per million vehicle miles (MVM). The crash ratio of a particular segment is calculated by averaging the crash ratios of the segment over the past three years (FDOT, 2008).

$$Crash\ Ratio = \frac{Actual\ Crash\ rate}{Average\ Crash\ Rate} \tag{3-1}$$

$$Crash\ Rate\ (in\ crashes\ per\ MVM) = \frac{\#\ of\ Crashes}{Segment\ Length \times AADT \times 365/1{,}000{,}000} \tag{3-2}$$

Fatal Crash

This measure indicates the average number of fatal crashes per mile for a roadway segment over the past three years. It is used in conjunction with crash ratio to identify locations with potentially serious safety problems. Fatal crashes are calculated by dividing the average number of fatal crashes per year over the past three years by the length of the roadway segment, as shown in Equation 3-3 (FDOT, 2008).

$$Fatal\ Crash = \frac{Average\ Annual\ Fatal\ Crashes\ Over\ Past\ 3\ Years}{Segment\ Length} \tag{3-3}$$

Volume-to-capacity (v/c) Ratio

The volume-to-capacity (v/c) ratio indicates the amount of traffic versus the carrying capacity of a roadway. Higher v/c ratios indicate roadways approaching or exceeding capacity. A larger volume of vehicles on a roadway increases the amount of wear and tear on the roadway surface and decreases the service life of the pavement. The v/c ratio is calculated for each roadway by dividing the peak hour two-way traffic volume by the capacity of each roadway, as shown in Equation 3-4. Peak hour two-way traffic volumes are calculated by multiplying the AADT volume by the standard K factor for each roadway segment. As defined in the FDOT Quality/LOS Handbook, the capacity of a roadway is defined as the service volume at LOS E (FDOT, 2008).

$$v/c = \frac{Peak\ Hour\ Two\ way\ Volume}{Roadway\ Capacity} \tag{3-4}$$

Vehicular Volume per Lane (AADT/lane)

The SIT score for vehicle volume is based solely on AADT. In the CMP, the AADT is normalized by the number of travel lanes, i.e., AADT per lane. Roadways with high volumes of vehicle traffic tend to degrade faster and require more maintenance than similar roadways with less vehicle traffic. Also, high traffic volumes increase vehicular density, raising the possibility of conflicts as well as the need for drivers to adjust their driving according to drivers adjacent to them. Further, on high volume roadways, adjustments such as braking, swerving, etc. can effectively send shockwaves through surrounding vehicles decreasing roadway mobility (FDOT, 2008).

Truck Volume per Lane (AADTT/lane)

The SIT score for truck volume is based solely on the average annual daily truck traffic (AADTT). Similar to the AADT per lane measure, this truck volume measure in the CMP is normalized by the number of travel lanes, i.e., AADTT per lane. A high AADTT/lane value indicates a roadway with large volumes of truck traffic which has the potential to affect system integrity (FDOT, 2008).

Truck Volume (% Trucks)

Percent trucks indicate the portion of total traffic on a roadway that is comprised of trucks. Trucks often require longer distances to accelerate, decelerate, and pass other vehicles. Trucks also require slower speeds to negotiate roadways, especially where turns are required. Thus, a high truck percentage indicates a roadway with a large portion of truck traffic with respect to total traffic, which has the potential to affect system mobility (FDOT, 2008).

Delay

As delay increases, the LOS provided by a roadway decreases, thereby causing a direct decrease in roadway mobility. Delay as defined in the CMP application is based on the LOS of a roadway segment, and whether a roadway exceeds the established LOS standards, i.e., LOS D for roadways in urbanized areas and LOS C for roadways outside urbanized areas. Three general levels of the delay condition are defined in the CMP application (FDOT, 2008):

1. "Fails" if the existing LOS is F,
2. "Exceeds Standard" if the existing LOS exceeds its corresponding LOS standard, and
3. "At or Below Standard" if the existing LOS is at or below its corresponding LOS standard.

The LOS calculation and the LOS standards for District One are maintained in the District One LOS Workbook.

3.2 Update to the Existing Performance Measures

As discussed in the previous section, the existing CMP system uses the following seven quantitative performance measures to screen highway improvement locations: crash rate, fatal crash, AADT per lane, v/c ratio, delay, truck percent, and truck volume per lane. Of these seven measures, AADT per lane, v/c ratio, and delay are retained as they are common measures of mobility and level of service. Although these measures are related, they serve to capture highway locations of different conditions. For example, a location with a low AADT may have a high v/c if it has a low capacity. As in the case of the existing CMP method to prioritize highway improvement locations, these measures can be aggregated to serve as inputs to several policy-related and traffic-related analyses such as identification of congested corridors, screening of critical locations meriting improvements using state-of-the-art methods, etc. Further, truck volume per lane and truck percent are also retained in the revised list as they provide key measures of freight transportation, which is an emphasis area in the 2060 Florida Transportation Plan, Florida Freight Mobility and Trade Plan, as well as the Florida's SIS Strategic Plan.

In the strategic area of safety and security, the two existing safety performance measures, crash ratio and fatal crash, are proposed to be replaced with "number of excess fatalities" and "number of excess injuries". One main issue with the two existing safety performance measures is that they do not account for the regression-to-the-mean (RTM) effect. This bias may cause locations with high crashes that were due merely to random fluctuations in crash numbers to be erroneously selected for safety improvements, thus, reducing the cost-effectiveness of safety programs. In other words, when locations are identified for safety improvements based on high crash frequencies and crash rates, they will often experience fewer crashes after the safety improvement even if the improvement is not effective. Therefore, because of the RTM bias, safety countermeasures often appear to be more effective than they really are. This effect is explained further with a hypothetical example below.

Figure 3-1 provides the line graph of crash frequencies at a signalized intersection during the years 1997-2010. During the three-year period from 2005-2007, this location experienced an average of 5 crashes per year, and as a result, in 2007, this location was chosen for safety improvements. During the three years after the safety improvements (i.e., from 2008-2010), the location experienced 2.67 crashes per year. In this scenario, when a mere three-year before and after period is considered, the observed safety benefit of the safety improvement is 2.33 crashes per year (calculated as 5.00 - 2.67). However, the long-term average crash frequency at this location (i.e., from 1997-2007) is 3.45 crashes per year. Therefore, the true safety benefit of the improvement at this location is 0.78 crashes per year (calculated as 3.45 - 2.67), which is much lower than the observed safety benefit of 2.33 crashes per year.

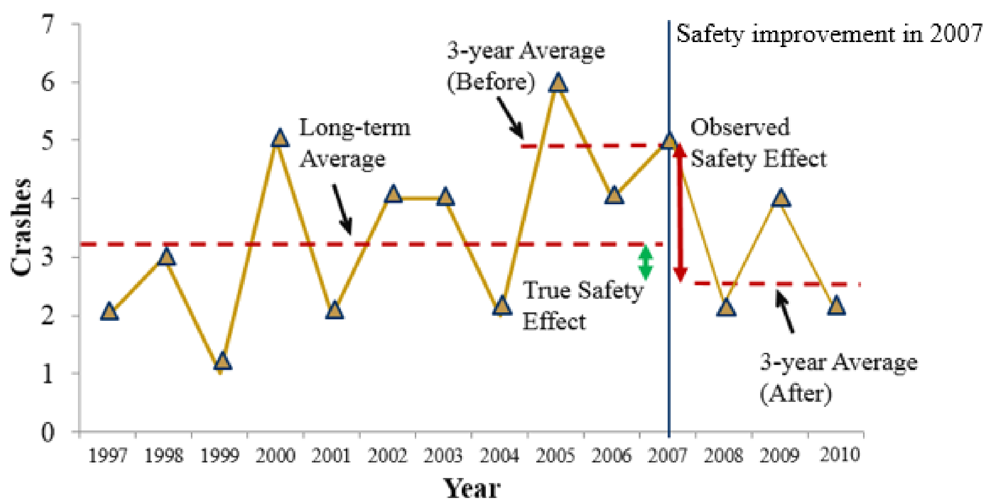

Figure 3-1: An Illustration of RTM Effect (Herbel, *et al.*, 2010)

This issue can be addressed through statistically advanced methods such as the EB method. The EB method is superior to crash rates and frequencies for several reasons, including:

- it addresses the RTM effect,
- it produces more stable and precise estimates of safety, and
- it estimates expected crashes over time.

The EB approach to safety analysis combines the observed crash frequency with the predicted crash frequency to calculate the expected crash frequency at a study location. The predicted crash frequency is calculated using a safety performance function (SPF), which describes the relationship between the mean crash frequency and the exposure. The expected crash frequency is the crash frequency expected at a study location estimated based on its crash experience (i.e., observed frequency) and the performance of similar locations (i.e., predicted frequency). Accordingly, the expected frequency is the weighted average of the observed and predicted crash frequencies, as follows:

$$\textit{Expected Crashes} = \textit{Weight} \times \textit{Predicted Crashes} + (1\text{-}\textit{Weight}) \times \textit{Observed Crashes} \qquad (3\text{-}5)$$

This weight depends on the reliability of the SPF.

Figure 3-2 illustrates the different crash frequencies associated with the EB approach. It can be observed from the figure that the expected crash frequency lies between the observed frequency and the predicted frequency. The difference between the expected crashes (obtained from the EB method) and the predicted crashes (obtained from SPFs) is the expected excess frequency, also known as the potential for safety improvement (PSI). It is defined as "the expected number of crashes above and beyond that which would be considered normal for the site, given its current site characteristics and traffic volume" (Harwood *et al*., 2010). As the name implies, when PSI is greater than zero, it indicates that the location has a potential for safety improvement.

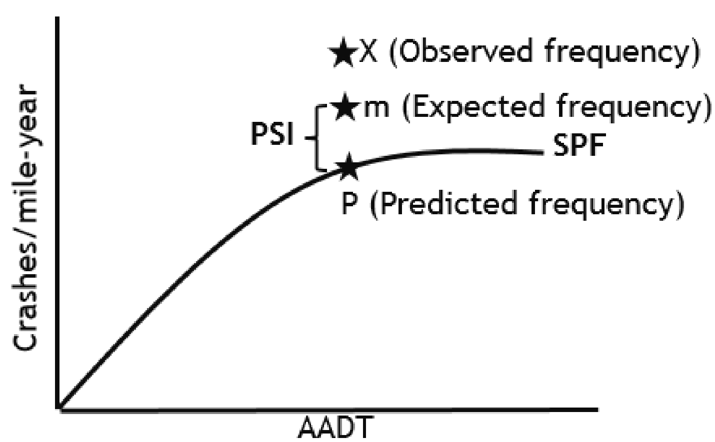

Figure 3-2: Empirical Bayes Method (Herbel, *et al.*, 2010)

For the above reasons and as part of the revision to the existing performance measures, it is recommended the two existing safety-related performance measures, i.e., fatal crash and crash ratio, be replaced with "number of excess fatalities" and "number of excess injuries". The "number of excess fatalities" is the expected number of excess fatalities for the final year of the analysis period for the location. Similarly, the "number of excess injuries" is the expected number of excess injuries for the final year of the analysis period for the location. These two measures give the prediction of the number of excess fatalities and injuries at the person level given the location's existing traffic volume and roadway geometric characteristics. Any location with excess fatalities (or injuries) greater than zero would be experiencing more fatalities (or injuries) than expected, and larger values of excess fatalities (or injuries) indicate greater potential for safety improvement. On the other hand, negative excess number of fatalities (or injuries) suggests that the location experiences fewer fatalities (or injuries) than expected.

For example, if the number of excess fatalities and excess injuries on a 2.2-mile section is 1.77 and 17.05, respectively, it implies that in the final analysis year, this location is expected to experience 1.77 more fatalities per mile and 17.05 more injuries per mile than what is considered normal for the location, given its current traffic volume and site characteristics. Similarly, if the number of excess fatalities is -0.9 fatalities per mile, it implies that this location is expected to experience 0.9 fewer fatalities per mile than what is considered normal for the location, given its current AADT and site characteristics. The following subsections documents the procedure for developing these two performance measures.

3.2.1 Development of Safety Performance Functions (SPFs)

The two new safety-related performance measures are calculated based on the EB approach recommended in the HSM. A major effort in implementing the EB procedure lies in the development of SPFs. The SPF is a statistical model that establishes a relationship between crash frequency and the contributing factors. The SPFs are generated using the procedure similar to the one used to develop the *SafetyAnalyst* default SPFs, which consider AADT as the only significant variable in predicting crash frequency. Three years of crash and traffic data were used to develop the SPFs. Although more years of data might possibly improve the model, longer analysis periods such as five years are avoided as they are more likely to be affected by changes in roadway conditions and travel patterns.

The process to develop SPFs involves the following four steps, which are described below:

1. Determine site subtype of the given segments
2. Extract AADT data and make necessary adjustments
3. Extract crash data and assign crashes to the given segments
4. Estimate SPF model coefficients

As the SPFs only need to be developed once for the District One data, they were developed outside of the CMP system, and the model coefficients (listed in Table 3-5) are entered into the updated CMP system. Note that the time period for which the SPFs were developed is different from the time period to which these SPFs are applied. Hence, these SPFs need to be adjusted using calibration factors to account for the potential changes in crash experience over time. The annual calibration factors are automatically generated in the CMP system, and are included in the EB analysis. More details about the calibration factors are provided in Section 3.2.2.

Step 1: Determine Site Subtype

The objective of this step is to divide the road network into different subtypes such that the segments within each subtype have similar roadway characteristics. To the extent possible, the following default *SafetyAnalyst* site subtypes were adopted (Harwood *et al.* 2010):

- Rural two-lane highway segments
- Rural multilane undivided highway segments
- Rural multilane divided highway segments
- Rural freeway segments – 4 lanes
- Rural freeway segments – 6+ lanes
- Rural freeway segments within an interchange area – 4 lanes
- Rural freeway segments within an interchange area – 6+ lanes
- Rural direct and semidirect connection ramps
- Urban two-lane arterial segments
- Urban multilane undivided arterial segments
- Urban multilane divided arterial segments
- Urban one-way arterial segments
- Urban freeway segments – 4 lanes
- Urban freeway segments – 6 lanes
- Urban freeway segments – 8+ lanes
- Urban freeway segments within an interchange area – 4 lanes
- Urban freeway segments within an interchange area – 6 lanes
- Urban freeway segments within an interchange area – 8+ lanes

Segments were categorized based on the following variables:

- area type (e.g., rural, urban),
- functional class (e.g., freeway, arterial),
- roadway type (e.g., undivided, divided, one-way), and
- number of lanes in both directions.

Table 3-3 lists the names and the levels of the variables in the Roadway Characteristics Inventory (RCI) (FDOT, 2014) database that were used to determine the segment site subtype. Note that the number of lanes for divided roads is reported by each direction in the RCI. In the case of divided roads, the variable ROADSIDE indicates the side of the roadway (i.e., left or right). The data for each of these variables were extracted for 2014, the most recent year for which the data are available at the time of analysis.

The extracted data were first used to generate homogeneous segments, where none of the variables of interest (i.e., area type, functional class, roadway type, number of lanes, and roadway side) vary within each segment. The site subtype for each segment was then determined. Table 3-4 gives the descriptive statistics of the site subtypes for the SIS network in District One. Unlike the *SafetyAnalyst*-default categories, urban freeway segments with 8+ lanes were not considered separately due to insufficient sample size. Also, presence of interchange influence area was not considered while segmenting freeways due to data unavailability.

Table 3-3: RCI Variables for Determining Site Subtype

RCI Variable	Description	Levels
FUNCLASS	Functional class by area type	01 – Rural principal arterial - interstate 02 – Rural principal arterial - freeways and expressways 04 – Rural principal arterial - other 06 – Rural minor arterial 07 – Rural major collector 08 – Rural minor collector 09 – Rural local 11 – Urban principal arterial - interstate 12 – Urban principal arterial - freeways and expressways 14 – Urban principal arterial - other 16 – Urban minor arterial 17 – Urban major collector 18 – Urban minor collector 19 – Urban local
TYPEROAD	Roadway type	0 – Undivided 2 – Divided 4 – One-way
NOLANES	Number of lanes	Discrete number (e.g., 1, 2, 3, 4, …)
RDWYSIDE	Roadway side	C – Center L – Left R – Right

Table 3-4: Summary of Segments by Site Subtype

Site Subtype	Designation	Total Miles	Number of Segments	Average Length (mi)
Rural two-lane highway segments	R2L	655.13	438	1.50
Rural multilane undivided highway segments	RUML	0.03	1	0.03
Rural multilane divided highway segments	RDML	138.39	56	2.47
Rural freeway segments – 4 lanes	RF4L	83.90	19	4.42
Rural freeway segments – 6+ lanes	RF6L	30.22	11	2.75
Rural direct and semidirect connection ramps	RSDR	1.55	4	0.39
Urban two-lane arterial segments	U2L	226.96	575	0.39
Urban multilane undivided arterial segments	UUML	8.33	28	0.30
Urban multilane divided arterial segments	UDML	567.28	572	0.99
Urban one-way arterial segments	UOW	41.64	83	0.50
Urban freeway segments – 4 lanes	UF4L	24.36	16	1.52
Urban freeway segments – 6+ lanes	UF6L	83.15	51	1.63

Step 2: Extract AADT Data

The AADT data for three years from 2011 through 2013 were extracted from the corresponding year's RCI database. The SECTADT variable in the RCI corresponds to AADT data. After extraction, the AADT data for each year were merged with the generated site subtype data. To include as many segments as possible in the analysis, the following assumptions were made regarding AADT data:

- If AADT data were available for only one year, that same value was assumed to apply to all the analysis years.
- If two years of AADT data were available, the AADT for the missing year was computed by either interpolation or extrapolation.
- If AADT data for a location was not available for all the three years, then the location was not included in the analysis.
- Locations with extremely high or low AADT values were considered as outliers, and were excluded from the analysis.

Step 3: Extract Crash Data and Assign Crashes to Segments

The 2011-2013 crash data were extracted from the Unified Basemap Repository (UBR) system. Note that only fatal and injury (FI) crashes are required to calculate the two new safety performance measures, number of excess fatalities and number of excess injuries. The following variables were retrieved from the crash database:

- KEYFIELD1
- CALYEAR
- ROADWAYID
- LOCMILEPT
- HIGHESTINJ
- CNTOFFATL
- CNTOFINJ

KEYFIELD1 is a unique identifier of crash occurrence. This variable was used to remove any duplicate entry of crash records during data processing. CALYEAR indicates the year the crashes occurred. This variable was used to record crashes by year. The variables ROADWAYID and LOCMILEPT, indicating segment ID and milepost of the crash location, respectively, were used to assign crashes to the segments. The crashes that occurred on the point between two continuous segments were consistently assigned to the first segment. HIGHESTINJ represents crash injury severity with the following codes: "2" for possible injury, "3" for non-incapacitating injury, "4" for incapacitating injury, and "5" for fatality. The variables CNTOFFATL and CNTOFINJ give the number of fatalities and the number of injuries in a crash, respectively. These two variables were used to estimate the number of excess fatalities and the number of excess injuries in *Step 8* in Section 3.2.2.

Step 4: Estimate SPF Model Coefficients

Crashes are random and non-negative events and crash frequency data are usually highly dispersed (i.e., the variance exceeds the mean). Negative binomial (NB) distribution is typically used (Abdel-Aty and Radwan, 2000; Hadi *et al*., 1995; Hauer *et al*., 2004; Sawalha and Sayed, 2001; Shankar *et al*., 1995; Tegge *et al*., 2010) to account for overdispersion in non-negative crash data. The NB model is a member of the generalized linear models family, where a nonlinear link function (e.g., logarithm) is used to establish the relationship between predictor variables and the response variable (McCullagh and Nelder, 1989).

SPFs were developed to model crash frequency as a function of traffic volume (i.e., AADT) using the NB distribution for the site subtypes listed in Table 3-4. The *glm.nb* function of the MASS package of the statistical software R (R Core Team, 2014) was used to estimate the NB regression coefficients and the overdispersion parameter. The following items were specified in the model function:

- Dependent Variable: number of FI crashes in 3 years.
- Independent Variable: natural logarithm of the sum of AADT for three years, i.e., *ln*(AADT).
- Link Function: logarithmic.
- Offset Term: natural logarithm of the product of segment length and number of years of data used (i.e., 3 years), to obtain crash frequency by number of crashes per mile per year.

Table 3-5 provides the SPF regression coefficients, α and β, and the overdispersion parameter κ.

Table 3-5: SPF Model Coefficients

Site Subtype	Designation	α	β	κ
Rural two-lane highway segments	R2L	-7.631	0.764	0.719
Rural multilane undivided highway segments	RUML[1]	-4.200	0.500	0.530
Rural multilane divided highway segments	RDML	-7.189	0.730	0.495
Rural freeway segments – 4 lanes	RF4L[2]	-10.492	0.955	0.166
Rural freeway segments – 6+ lanes	RF6L[2]	-1.657	0.243	0.046
Rural direct or semidirect connection ramp	RSDR	-4.220	0.550	1.390
Urban two-lane arterial segments	U2L	-9.644	1.053	1.124
Urban multilane undivided arterial segments	UUML[2]	-16.758	1.749	0.204
Urban multilane divided arterial segments	UDML	-11.291	1.203	0.743
Urban one-way arterial segments	UOW	-3.690	0.506	0.843
Urban freeway segments – 4 lanes	UF4L[2]	-13.340	1.236	0.273
Urban freeway segments – 6+ lanes	UF6L	-10.873	1.00	0.065

[1] Because of limited observations, the SPF model coefficients were not estimated and the *SafetyAnalyst* default model coefficients are used.

[2] SPFs were developed using relatively smaller sample sizes.

3.2.2 The Empirical Bayes Calculation Procedure

The steps to compute the number of excess fatalities and the number of excess injuries using the EB procedure are detailed below (Harwood *et al.*, 2010). Note that crash frequency in these steps, if not otherwise stated, refers to FI crashes.

Step 1: Calculate the predicted average crash frequency for each year of the study period using the appropriate SPF model coefficients. The general form of the SPF is given below:

$$N_{spf,i,y} = \exp\left[\alpha + \beta \times ln\left(AADT_{i,y}\right)\right] \quad (3\text{-}6)$$

where,

$N_{spf,i,y}$ = predicted average crash frequency for segment *i* in year *y*,
$AADT_{i,y}$ = average annual daily traffic (AADT) for segment *i* in year *y*, and
α, β = SPF model coefficients.

Note that because the SPFs are developed using base years of crash data; a multiplicative factor, commonly known as the calibration factor (CF), is usually applied to the SPF to account for the effect of potential changes in crash experience over time. The calibration factor for a particular site subtype is defined as the ratio of the total number of crashes occurred on the segments under a particular site subtype to the total number of predicted crashes calculated using the SPFs for the segments of that site subtype (Harwood *et al*., 2010). The calibration factor is calculated using the following equation:

$$CF_{x,y} = \frac{\sum_i \left(\frac{N_{o,i,y}}{SL_i}\right)}{\sum_i N_{spf,i,y}}, \qquad i \in x \quad (3\text{-}7)$$

where,

$CF_{x,y}$ = calibration factor for site subtype *x* in year *y*,
$N_{o,i,y}$ = observed average crash frequency for segment *i* in year *y*,
SL_i = length of segment *i*, and
$N_{spf,i,y}$ = predicted average crash frequency for segment *i* in year *y*.

Step 2: For each site subtype, calculate the calibrated predicted average crash frequency for each year of the study period by multiplying the predicted average crash frequency with the corresponding calibration factor, as follows:

$$N'_{spf,i,y} = CF_{x,y} \times N_{spf,i,y} \quad (3\text{-}8)$$

where,

$N'_{spf,i,y}$ = calibrated predicted average crash frequency for segment *i* in year *y*, and
$CF_{x,y}$ = calibration factor for site subtype *x* in year *y*, and
$N_{spf,i,y}$ = predicted average crash frequency for segment *i* in year.

Step 3: Using the calibrated predicted average crash frequency estimated in *Step 2*, calculate the yearly correction factor for each year of the study period. The yearly correction factor is defined as a ratio of the calibrated predicted crash frequency for each year of the study period to the calibrated predicted crash frequency during the first year, as follows:

$$C_{i,y} = \frac{N'_{spf,i,y}}{N'_{spf,i,y_1}} \tag{3-9}$$

where,

$C_{i,y}$ = correction factor for segment *i* in year *y*,

$N'_{spf,i,y}$ = calibrated predicted average crash frequency for segment *i* in year *y*, and

N'_{spf,i,y_1} = calibrated predicted average crash frequency for segment *i* during year y_1 (i.e., the first year).

<u>Step 4</u>: Using the calibrated predicted average crash frequency and the overdispersion parameter *k*, calculate the weight as follows:

$$w_i = \frac{1}{1 + \kappa \times \sum_{y=y_1}^{y_n} N'_{spf,i,y} \times SL_i} \tag{3-10}$$

where,

w_i = weighted adjustment for segment *i*,

κ = overdispersion parameter,

SL_i = length of segment *i*, and

$N'_{spf,i,y}$ = calibrated predicted average crash frequency for segment *i* in year *y*.

<u>Step 5</u>: Calculate the EB-adjusted expected crash frequency for the first year of the study period, as follows:

$$N_{e,i,y_1} = w_i \times N'_{spf,i,y_1} + \frac{(1 - w_i)}{SL_i} \times \frac{\sum_{y=y_1}^{y_n} N_{o,i,y}}{\sum_{y=y_1}^{y_n} C_{i,y}} \tag{3-11}$$

where,

N_{e,i,y_1} = expected average crash frequency for segment *i* during year y_1 (i.e., the first year),

N_{spf,i,y_1} = calibrated predicted average crash frequency for segment *i* during year y_1 (i.e., the first year),

$N_{o,i,y}$ = observed average crash frequency for segment *i* in year *y*,

w_i = weighted adjustment for segment *i*,

SL_i = length of segment *i*, and

$C_{i,y}$ = correction factor for segment *i* in year *y*.

<u>Step 6</u>: Calculate the EB-adjusted expected crash frequency for the last year of the study period, as follows:

$$N_{e,i,y_n} = N_{e,i,y_1} \times C_{i,y_n} \tag{3-12}$$

where,

N_{e,i,y_n} = expected average crash frequency for segment *i* during year y_n (i.e., the last year),

N_{e,i,y_1} = expected average crash frequency for segment i during year y_1 (i.e., the first year), and

C_{i,y_n} = correction factor for segment i during year y_n (i.e., the last year).

Step 7: Calculate the excess crash frequency as follows:

$$Excess_{i,y_n} = N_{e,i,y_n} - N'_{spf,i,y_n} \tag{3-13}$$

where,

N_{e,i,y_n} = expected average crash frequency (per mile per year) for segment i during year y_n (i.e., the last year), and

N'_{spf,i,y_n} = calibrated predicted average crash frequency (per mile per year) for segment i during year y_n (i.e., the last year).

Step 8: Calculate the number of excess fatalities (per mile per year) by multiplying the excess crash frequency by the fatal crash rate, which is the ratio of the number of fatalities over all the segments of a specific site subtype to the number of FI crashes occurred on that site subtype, as follows:

$$Number\ of\ Excess\ Fatalities = Excess_{i,y_n} \times \left(\frac{\sum_i Number\ of\ fatalities\ in\ site\ i}{\sum_i Number\ of\ FI\ crashes\ in\ site\ i}\right)_{i \epsilon x} \tag{3-14}$$

where x indicates the site subtype. The number of excess injuries (per mile per year) is similarly calculated as follows:

$$Number\ of\ Excess\ Injuries = Excess_{i,y_n} \times \left(\frac{\sum_i Number\ of injuries\ in\ site\ i}{\sum_i Number\ of\ FI\ crashes\ in\ site\ i}\right)_{i \epsilon x} \tag{3-15}$$

Step 9: Since the performance measures calculated in Step 7 are for homogeneous segments which are shorter than the standard segments in the District One segment file, the final step is to determine the number of excess fatalities and number of excess injuries for the standard CMP segments. The final measures are calculated by adding the values of the individual shorter segments that make up the longer standard segments in the District One segment file.

3.2.3 Automation in CMP

The SPF model coefficients from Table 3-5 are used to calculate the number of excess fatalities and number of excess injuries based on the steps presented in Section 3.2.2. These steps are automated within the CMP system, and are repeated annually when new data becomes available. The annual data updates will require the following data uploads for the new analysis year: new raw crash data extracted from UBR, AADT data, RCI data in the original format, and the District One Segment file including the non-safety measures, the state road layer containing the standard segments (in the Keyhole Markup Language (KML) format).

3.3 Summary

The existing CMP system prioritizes highway project locations based on the following measures: crash ratio, fatal crash, v/c ratio, AADT per lane, truck volume per lane, truck percent, and delay. Of these seven measures, the following five are retained: v/c ratio, AADT per lane, truck volume per lane, truck percent, and delay. The existing two safety-related performance measures, fatal crash and crash ratio, are replaced with "number of excess fatalities" and "number of excess injuries". The final seven performance measures being considered in prioritizing highway improvement locations are:

1. Number of excess fatalities
2. Number of excess injuries
3. v/c ratio
4. AADT per lane
5. Truck volume per lane
6. Truck percent
7. Delay

The two new safety performance measures are calculated using the EB procedure discussed in Section 3.2.2. These calculations are automated within the updated CMP system.

CHAPTER 4
PRIORITIZATION METHOD

Prioritizing highway improvement locations is a process through which the most desirable highway locations are ranked and selected from a number of competitive locations based on specific criteria. This chapter describes a new prioritization method adopted for implementation in the updated CMP system.

4.1 Selection of Prioritization Method

The state-of-the-practice review in Chapter 2 indicates that transportation agencies have been prioritizing highway locations using simple scoring method which assigns fixed weights for the performance measures. This approach requires that each performance measure be assigned a weight, which can be difficult to do especially in the presence of several criteria that could also be overlapping, i.e., the measures are correlated.

In decision making involving multiple criteria, the Analytic Hierarchy Process (AHP) has been widely used for its ability to solve multi-criteria decision problems by comparing pairs of criteria (alternatives) instead of all criteria (alternatives) at once. Developed by Professor Thomas L. Saaty in 1980, the method stresses the importance of the intuitive judgments of a decision maker as well as the consistency of the comparison of criteria (alternatives) in the decision-making process (Saaty, 1980).

In applying the AHP method, a set of evaluation criteria and a set of alternatives are considered at first. A weight is then generated for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. The higher the weight, the more important the corresponding criterion is. For each criterion, AHP assigns a score to each alternative according to the decision maker's pairwise comparisons of the alternatives based on that criterion. The higher the score, the better the performance of the alternative is with respect to the considered criterion. Finally, AHP combines the criteria weights and the alternatives' scores to determine a global score for each alternative, and a consequent ranking. The global score for a given alternative is a weighted sum of the scores obtained with respect to all the criteria (Saaty, 1980).

While the AHP method has been widely used in multi-criteria decision making, the fact that the method requires a decision problem be structured hierarchically makes it unable to consider the impacts of interdependencies that exist among the selection criteria on the selection outcomes. Of the performance measures being considered by Florida District One, it is clear that v/c and AADT are interdependent, so are truck volume and truck percentage. Further, delay and v/c (thus AADT) are also interdependent as delay is a function of v/c. It can thus be concluded that most if not all the performance measures are interdependent to an extent and would benefit from a method that can take account of the impacts of such interdependencies. This led to the consideration of the Analytic Network Process (ANP), which is a generalized methodology of AHP. Unlike AHP, ANP does not only have the capability of breaking down a decision problem into a logical order, but it can also account for the interdependencies among the criteria.

Figure 4-1 compares the hierarchical structure of AHP and the network structure of ANP in their decision-making process. As shown, the AHP structure analyzes any decision problem in a hierarchical order, i.e., the decision process follows a top-down approach from goal to criteria, and then from criteria to alternatives; however, the interaction among elements of each cluster (i.e., goal, criteria, or alternatives) or between clusters of a decision process cannot be addressed in this hierarchical structure. On the other hand, the ANP structure breaks down a decision problem into logical order and considers possible interactions among different elements of a cluster and between clusters.

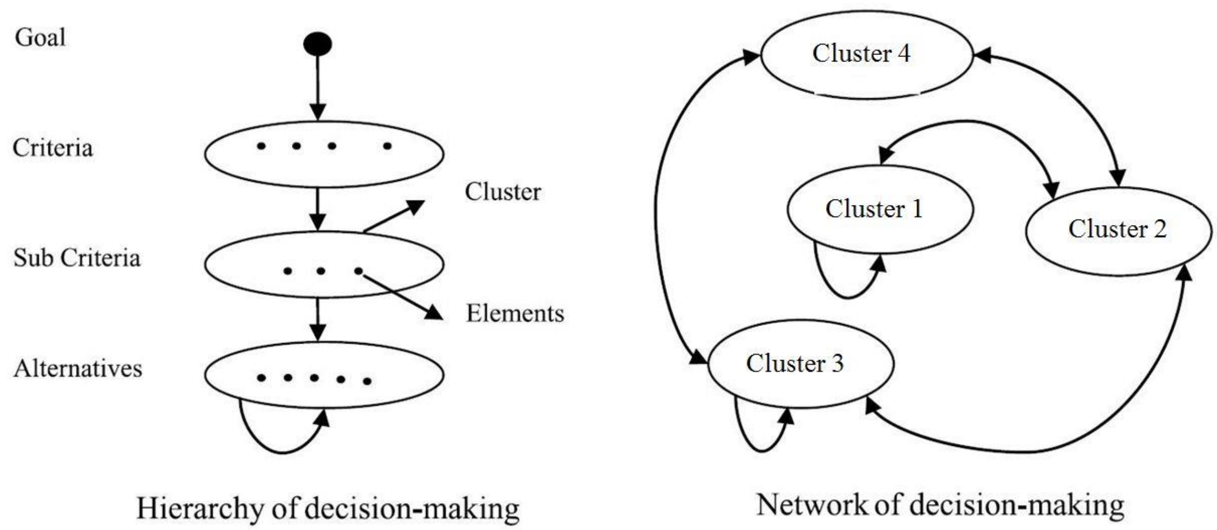

Figure 4-1: Hierarchical vs. Network Decision-Making Structures
(Source: Sadeghi *et al.*, 2012)

The ANP method is described further in the following subsections using an example. The context of this hypothetical example is as follows: A total of five highway improvement locations, SR-1, SR-2, SR-3, SR-4, and SR-5, are to be prioritized based on three performance measures: (a) AADT, (b) v/c ratio, and (c) Environmental Impact (EI), which is a qualitative measure on a scale of 1 (best) to 20 (worst). Table 4-1 provides the values of these performance measures for the five highway locations.

Table 4-1: Performance Measures for SR-1, SR-2, SR-3, SR-4, and SR-5

Highway	AADT (veh/day)	v/c	Environmental Impact (EI)
SR-1	10,000	0.6	10
SR-2	2,000	0.3	2
SR-3	14,000	0.9	14
SR-4	18,000	0.6	10
SR-5	10,000	0.9	18

Figure 4-2 illustrates the hierarchical structure of this example. As can be observed from the figure, Level 0 is the analysis goal, i.e., to prioritize the five locations. Level 1 is the multi-criteria that consist of the three performance measures, AADT, v/c, and EI. Finally, Level 2 consists of the alternative choices, i.e., the five locations. The lines between the three levels indicate the relationship between goal, performance measures, and the alternatives (i.e., highway locations). The following sections elaborate the computational steps of the ANP, which include (Chung, 2005; and Yüksel and Dağdeviren, 2007):

- Model construction and problem structuring;
- Pairwise comparison matrices and priority vectors;
- Supermatrix, weighted supermatrix, and limit matrix formations; and
- Ranking of alternatives.

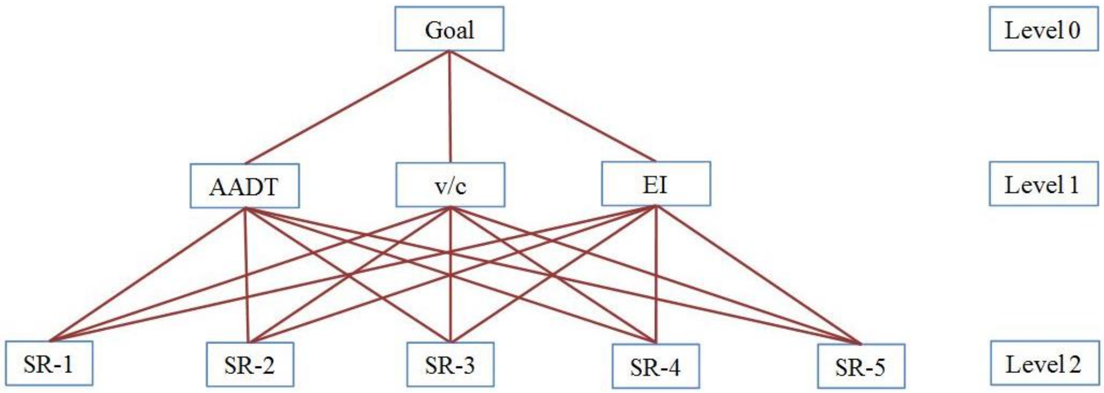

Figure 4-2: Hierarchical Structure of Highway Improvement Location Selection

4.2 ANP Model Construction and Problem Structuring

The first step in the ANP is to disintegrate the problem into a rational system similar to a network. As can be observed from Figure 4-2, the problem can be disintegrated into three levels (similar to hierarchical structure): goal to rank the alternatives, performance measures to achieve the goal, and alternatives (i.e., the highway locations that need to be prioritized). The performance measures AADT, v/c, and EI are interdependent. The ANP addresses this interdependency by including an inner dependence loop in the network structure. Figure 4-3 illustrates the potential network structure for this example.

In this figure, each arrow and loop has specific impacts on the interrelation of different levels, and on the next steps. W_{21} represents the impact of goal on each of the criterion and W_{32} represents the impact of criteria on each of the alternatives. The interdependency within the criteria is represented by W_{22} in the network structure. The direction of arrows is dependent on the rationale of this problem structure. For the stated problem, the goal of prioritizing highway locations can be achieved through the criteria, i.e., the criteria are impacting the goal; and these criteria determine the ranking of the alternatives. On the other hand, the criteria can be interdependent in nature. All these facts lead to the network structure illustrated in Figure 4-3. This structure forms the basis of the next steps, i.e., supermatrix, pairwise comparison matrices, and priority vectors, required for the analysis. A supermatrix is a comparatively large square matrix where the cluster priority vectors are entered in appropriate columns to obtain global priorities with interdependent influence (Yüksel and Dağdeviren, 2007). Table 4-2 presents the general supermatrix framework for this example.

Each of the elements in the matrix represents a submatrix which is discussed in the next step. Zero (0) elements correspond to those elements which do not have any influence. Since each alternative depends only on itself, identity matrix (I) submatrix is used in the supermatrix framework in row: Alternatives and column: Alternatives.

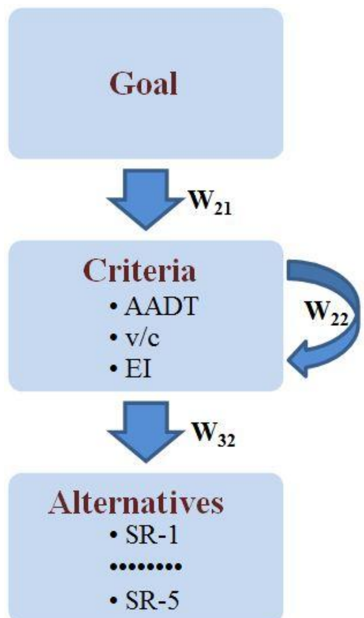

Figure 4-3: ANP Network Model Structures

Table 4-2: General Supermatrix Framework

	Goal	Criteria	Alternatives
Goal	0	0	0
Criteria	W_{21}	W_{22}	0
Alternatives	0	W_{32}	I

4.3 Pairwise Comparison Matrices and Priority Vectors

The second step of the ANP requires pairwise comparisons of the elements at the cluster and sub-cluster levels. The number of pairwise comparison matrices and priority vectors depends on the supermatrix framework. More specifically, if the supermatrix framework is expanded according to the stated problem, then the expanded matrix identifies the required pairwise comparison matrices and priority vectors. For example, the matrix in Table 4-3 can be attained if the supermatrix framework developed in the previous step is expanded. Note that the groups of each pairwise comparison matrices and priority vectors are color coded.

A total of four comparison matrices and their corresponding priority vectors (represented by W_{21} and W_{32} submatrices) are cluster-level priorities. The ANP method also requires comparison matrices for criteria (AADT, v/c, and EI) versus criteria with respect to each of them (W_{22}

submatrices). The computational steps are discussed in the following sub-sections: (a) pairwise comparison, (b) comparison matrix, (c) priority vector, and (d) consistency ratio.

Table 4-3: Expanded Supermatrix Framework

		Goal	Criteria			Alternatives				
			AADT	v/c	EI	SR-1	SR-2	SR-3	SR-4	SR-5
Goal		0	0	0	0	0	0	0	0	0
Criteria	AADT	W_{21}	W_{22}	W_{22}	W_{22}	0	0	0	0	0
	v/c	W_{21}	W_{22}	W_{22}	W_{22}	0	0	0	0	0
	EI	W_{21}	W_{22}	W_{22}	W_{22}	0	0	0	0	0
Alternatives	SR-1	0	W_{32}	W_{32}	W_{32}	1	0	0	0	0
	SR-2	0	W_{32}	W_{32}	W_{32}	0	1	0	0	0
	SR-3	0	W_{32}	W_{32}	W_{32}	0	0	1	0	0
	SR-4	0	W_{32}	W_{32}	W_{32}	0	0	0	1	0
	SR-5	0	W_{32}	W_{32}	W_{32}	0	0	0	0	1

4.3.1 Pairwise Comparison

Level 1 parameters of Figure 4-2 (i.e., the performance measures) are used in this section to explain the pairwise comparison concept. This comparison sets the preference of the three measures on a pre-defined relative scale of 1-9. It then compares how much preference one measure gets over the other. For instance, if AADT is preferred 3 times over v/c, AADT is preferred 5 times over EI, and v/c is preferred 3 times over EI, then the preferences may be selected as highlighted in Figure 4-4. The even values (i.e., 2, 4, 6, and 8) can also be used as intermediate values in selecting the preference.

The number of pairwise comparisons is a function of the number of performance measures (n) to be compared, and can be calculated using the following formula:

$$\textit{Number of pairwise comparisons} = \frac{n\,(n-1)}{2} \tag{4-1}$$

Since three performance measures are considered in this example, three pairwise comparisons are made. An additional step is required when the five locations need to be pairwise compared with respect to each of the performance measures (i.e., the pairwise comparison of Level 2 parameters). For instance, v/c is assumed as 0.6 for SR-1; 0.3 for SR-2; 0.9 for SR-3; 0.6 for SR-4; and 0.9 for SR-5. The lowest value of v/c is 0.3; and the highest value is 0.9. Therefore, if the highest value is compared to the lowest value as 0.9/0.3 = 3, then the quantitative scale ranges from 1 to 3 for lower to higher value comparisons. This 1 to 3 range does not match with the pre-defined 1 to 9 platform; therefore, a conversion is required. The conversion translates the scale of 1-3 to 1-9 equidistantly. Note that this conversion provides the same platform for both quantitative and qualitative measures.

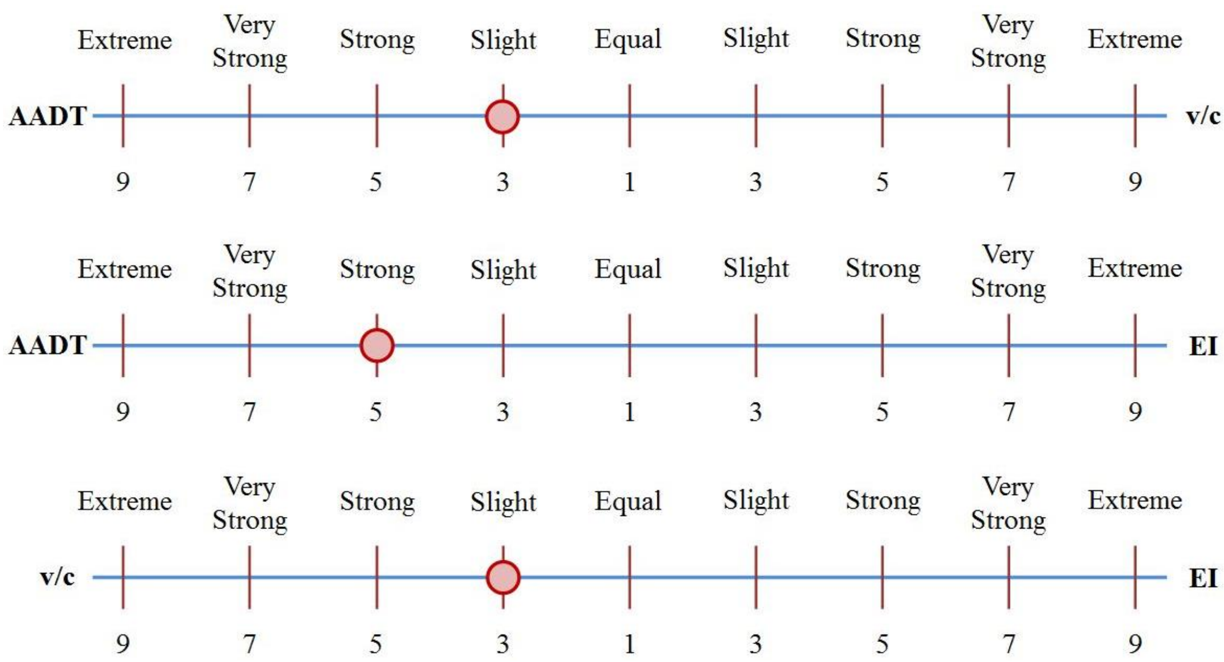

Figure 4-4: Pairwise Comparison of AADT, v/c, and EI

4.3.2 Comparison Matrix

Once the pairwise comparisons are made, the next step is to convert these pairwise comparisons into quantitative judgments and create a comparison matrix. Level 1 corresponds to one 3×3 comparison matrix for the pairwise comparison between three performance measures with respect to the goal. Similarly, since the five locations are connected to each of the three performance measures, three 5×5 comparison matrices are created to evaluate the five locations. For instance, the following comparison matrix M is created from Figure 4-4 considering AADT is preferred 3 times over v/c, AADT 5 times over EI, and v/c 3 times over EI. In this matrix, the diagonal elements are always 1, and the upper triangular matrix is first filled per the following guidelines: the actual value is used if the judgment value in the pairwise comparison is on the left side of 1, and the reciprocal value is used if the judgment value in the pairwise comparison is on the right side of 1. Next, the reciprocal values of the upper triangular matrix are used directly to fill the lower triangular matrix.

$$\mathbf{M} = \begin{array}{c} \\ \textbf{AADT} \\ \textbf{v/c} \\ \textbf{EI} \end{array} \begin{array}{c} \begin{array}{ccc} \textbf{AADT} & \textbf{v/c} & \textbf{EI} \end{array} \\ \begin{bmatrix} 1 & 3 & 5 \\ \frac{1}{3} & 1 & 3 \\ \frac{1}{5} & \frac{1}{3} & 1 \end{bmatrix} \end{array}$$

The same procedure leads to three matrices from the pairwise comparison of five locations with respect to each of the performance measures and three matrices from the pairwise comparisons of criteria (AADT, v/c, and EI) with respect to each of them.

4.3.3 Priority Vector

Priority vector is the normalized Eigen vector of the comparison matrix. An approximate method to estimate the Eigen vector and Eigen value of the comparison matrix is used in this project (Chung et al., 2005). The following priority vector (***w***) for the Level 1 parameters is calculated from matrix M:

$$\mathbf{w} = \begin{bmatrix} 0.6333 \\ 0.2605 \\ 0.1062 \end{bmatrix}$$

Since the matrix is normalized, the sum of all elements in the priority vector is 1. This vector shows the relative weights of the three performance measures that are compared. The Principal Eigen value (λ_{max}) is required to perform consistency checks discussed in the next step. This value is obtained from the summation of products between each element of priority vector and the sum of columns of the matrix formed from the pairwise comparison.

$$\lambda_{max} = \frac{23}{15}(0.6333) + \frac{13}{3}(0.2605) + 9(0.1062) = 3.0557$$

Statistical software applications can be used to calculate the Eigen values and Eigen vectors. For example, the comparison matrix is imported into R software (R Core Team, 2014) to determine whether or not the Eigen value and Eigen vectors approximated using the above discussed method are similar to the actual Eigen value and Eigen vectors computed using R. The largest Eigen value (or Principal Eigen value), i.e., $\lambda^*_{max} = 3.0385$ is obtained, and is very close to the approximated value of 3.0557 (approximately 0.57% error). Thus, the approximation is acceptable. The same procedure is repeated for all the remaining matrices. Tables 4-4 and 4-5 present the priority vectors of the five highway locations and the performance measures at sub-cluster level with respect to the three performance measures, respectively.

4.3.4 Consistency Ratio

This step checks the consistency of subjective judgments. For instance, if A is preferred to B, in logical statement, it can be written as A > B. Next, if C if preferred to A, it implies C > A. Since A > B and C > A, logically, the preference between B and C is C > B. This logic of preference is called transitive property. If the last comparison is found transitive, then the judgments are consistent; otherwise inconsistent.

Professor Saaty (1987) proved that for any consistent reciprocal matrix, the largest Eigen value is equal to the number of performance measures, i.e., $\boldsymbol{\lambda}_{max} = n$. He also provided a measure called consistency index (CI) as deviation or degree of consistency calculated using the following formula:

$$\textit{Consistency Index, CI} = \frac{\lambda_{max} - n}{n - 1} \qquad (4\text{-}2)$$

Table 4-4: Priority Vectors of the Five Locations with Respect to AADT, v/c, and EI

Location	SR-1	SR-2	SR-3	SR-4	SR-5	Priority Vector
AADT						
SR-1	1	5	1	1/2	1	**19.44%**
SR-2	1/5	1	1/7	1/9	1/5	**3.68%**
SR-3	1	7	1	1	1	**24.13%**
SR-4	2	9	1	1	2	**33.31%**
SR-5	1	5	1	1/2	1	**19.44%**
Sum	5.20	27.00	4.14	3.11	5.20	**100.00%**
v/c						
SR-1	1	5	1/3	1	1/3	**13.13%**
SR-2	1/5	1	1/9	1/5	1/9	**3.27%**
SR-3	3	9	1	3	1	**35.24%**
SR-4	1	5	1/3	1	1/3	**13.13%**
SR-5	3	9	1	3	1	**35.24%**
Sum	8.20	29.00	2.77	8.20	2.77	**100.00%**
EI						
SR-1	1	5	1	1/2	1	**19.44%**
SR-2	1/5	1	1/7	1/9	1/5	**3.68%**
SR-3	1	7	1	1	1	**24.13%**
SR-4	1	5	1	1/2	1	**19.44%**
SR-5	2	9	1	1	2	**33.31%**
Sum	5.20	27.00	4.14	3.11	5.20	**100.00%**

Table 4-5: Priority Vectors at Sub-cluster Level with Respect to AADT, v/c, and EI

AADT	v/c	EI	Priority Vector
v/c[a]	1	3	75.00%
EI[a]	1/3	1	25.00%
Sum	1.33	4.00	100.00%
v/c	**AADT**	**EI**	**Priority Vector**
AADT[b]	1	5	83.33%
EI[b]	1/5	1	16.67%
Sum	1.20	6.00	100.00%
EI	**AADT**	**v/c**	**Priority Vector**
AADT[c]	1	3	75.00%
v/c[c]	1/3	1	25.00%
Sum	1.33	4.00	100.00%

[a] Priority vectors with respect to AADT; [b] priority vectors with respect to v/c; [c] priority vectors with respect to EI.

Thus, for the example, the largest Eigen value is found as $\boldsymbol{\lambda}_{max}$ = 3.0557, and the number of performance measures (or matrix order) is 3, i.e., n = 3; therefore, the consistency index (CI) is 0.0278. The next step is to compare the calculated consistency index with Random Consistency Index (RI). Professor Saaty generated matrices using scale 1/9, 1/8, 1/7,…, 1,…, 7, 8, 9 (similar to the idea of Bootstrap) and calculated the standard RIs for comparison. The average RIs estimated for n = 1 to n = 10 are: 0, 0, 0.58, 0.9, 1.12, 1.24, 1.32, 1.41, 1.45, and 1.49 (Saaty, 1987). The comparison is termed as consistency ratio (CR), and is calculated as:

$$\text{Consistency Ratio, } CR = \frac{CI}{RI} \tag{4-3}$$

If CR is ≤ 10%, then the inconsistency in judgment is within acceptable range, i.e., the judgment is consistent; otherwise, a revision on the subjective judgment is required. For the previous example, CI is 0.0278 and RI for n = 3 is 0.58. So, the consistency ratio is 4.8% < 10%. Therefore, the judgment is consistent. The same procedure is repeated for the other three Level 2 matrices, and were found to be consistent.

The matrix ***M*** with AADT, v/c, and EI in the cluster level priorities was found to be consistent in judgment. As the same preferences are used in the sub-cluster levels, the consistency check becomes redundant for this sub-cluster level. Therefore, consistency check with each of the two performance measures is not performed. In general, quantitative data is fundamentally more consistent, and has lower probability of inconsistency. Note that this measure is more important while dealing with subjective data that are more prone to inconsistencies.

4.4 Supermatrix, Weighted Supermatrix, and Limit Matrix

Supermatrix is used to calculate the final rankings of the alternatives. Table 4-6 provides the unweighted supermatrix which includes the priority vectors in their corresponding sub-matrices within the supermatrix.

Table 4-6: Unweighted Supermatrix

		Goal	Criteria			Alternatives				
			AADT	**v/c**	**EI**	**SR-1**	**SR-2**	**SR-3**	**SR-4**	**SR-5**
Goal		0	0	0	0	0	0	0	0	0
Criteria	**AADT**	0.6333[a]	0[b]	0.8333[b]	0.7500[b]	0	0	0	0	0
	v/c	0.2605[a]	0.7500[b]	0[b]	0.2500[b]	0	0	0	0	0
	EI	0.1062[a]	0.2500[b]	0.1667[b]	0[b]	0	0	0	0	0
Alternatives	**SR-1**	0	0.1944[c]	0.1313[c]	0.1944[c]	1	0	0	0	0
	SR-2	0	0.0368[c]	0.0327[c]	0.0368[c]	0	1	0	0	0
	SR-3	0	0.2413[c]	0.3524[c]	0.2413[c]	0	0	1	0	0
	SR-4	0	0.3331[c]	0.1313[c]	0.1944[c]	0	0	0	1	0
	SR-5	0	0.1944[c]	0.3524[c]	0.3331[c]	0	0	0	0	1

[a] Vectors obtained from matrix ***w***; [b] vectors obtained from Table 4-5; [c] vectors obtained from Table 4-4.

The ANP's principle is to derive the limit priorities of influence from the supermatrix. To obtain such priorities, the supermatrix needs to be transformed to a matrix each of whose column sums to unity, known as column stochasticity (Saaty and Vargas, 2006). The resulting stochastic matrix is known as weighted supermatrix. The rationale behind this transformation is to convert the elements' local cluster priorities to global priorities. The same principle is applied for the example. The columns of the supermatrix are normalized to unity to keep the procedure simple and to obtain the weighted supermatrix. Table 4-7 provides the weighted supermatrix for the example.

Table 4-7: Weighted Supermatrix

		Goal	Criteria			Alternatives				
			AADT	v/c	EI	SR-1	SR-2	SR-3	SR-4	SR-5
Goal		0	0	0	0	0	0	0	0	0
Criteria	AADT	0.6333	0	0.4166	0.3750	0	0	0	0	0
	v/c	0.2605	0.3750	0	0.1250	0	0	0	0	0
	EI	0.1062	0.1250	0.0833	0	0	0	0	0	0
Alternatives	SR-1	0	0.0972	0.0656	0.0972	1	0	0	0	0
	SR-2	0	0.0184	0.0163	0.0184	0	1	0	0	0
	SR-3	0	0.1207	0.1762	0.1207	0	0	1	0	0
	SR-4	0	0.1666	0.0656	0.0972	0	0	0	1	0
	SR-5	0	0.0972	0.1762	0.1666	0	0	0	0	1

Note: The column sums may not add up to one due to rounding error.

The limit supermatrix is obtained by raising the weighted supermatrix to exponential powers 2*k*+1, where *k* is an arbitrary number. It provides the long-term relative influences of the elements on each other through convergence on the importance weights. In this example, the weighted supermatrix is raised to power 16 to obtain the convergence of the alternatives' priorities up to four decimal places. The limit matrix, as shown in Table 4-8, was found to converge when raised to the power 16. The matrix can be raised to higher powers to achieve convergence up to more than four decimal places.

Table 4-8: Limit Matrix

		Goal	Criteria			Alternatives				
			AADT	v/c	EI	SR-1	SR-2	SR-3	SR-4	SR-5
Goal		0	0	0	0	0	0	0	0	0
Criteria	AADT	0	0	0	0	0	0	0	0	0
	v/c	0	0	0	0	0	0	0	0	0
	EI	0	0	0	0	0	0	0	0	0
Alternatives	SR-1	0.1728	0.1783	0.1552	0.1835	1	0	0	0	0
	SR-2	0.0354	0.0357	0.0342	0.0361	0	1	0	0	0
	SR-3	0.2792	0.2696	0.3102	0.2606	0	0	1	0	0
	SR-4	0.2441	0.2677	0.1956	0.2220	0	0	0	1	0
	SR-5	0.2685	0.2487	0.3046	0.2979	0	0	0	0	1

4.5 Ranking of Alternatives

The final priorities of all elements can be obtained by normalizing each cluster of the limit matrix. This step is required only when the alternatives' priorities do not add up to one. Table 4-9 provides the ranking of alternatives for the example. As can be observed from the table, SR-3 gets the highest priority among the five alternatives, and SR-2 gets the lowest priority.

Table 4-9: ANP Ranking of the Five Alternatives

Alternative	Alternatives' Priorities in Limit Matrix under Goal (Prior to Normalization)	Alternatives' Priorities after Normalization	Priorities in Percentage	Final Rank
SR-1	0.1728	0.1728	17.28%	**4**
SR-2	0.0354	0.0354	3.54%	**5**
SR-3	0.2792	0.2792	27.92%	**1**
SR-4	0.2441	0.2441	24.41%	**3**
SR-5	0.2685	0.2685	26.85%	**2**
Sum	1.0000	1.0000	100.00%	**--**

Note: If alternatives' priorities prior to normalization do not add up to one, the priorities need to be normalized.

4.6 Summary and Conclusions

The ANP approach is a state-of-the-art multi-criteria decision-making algorithm that has not yet been applied by transportation agencies to prioritize highway improvement locations. The ANP method has several advantages over the traditional simple ranking method, including:

- ANP does not give undue weight to a specific performance measure,
- ANP accounts for the interdependence of the performance measures for prioritizing highway locations,
- ANP facilitates pairwise comparison of the projects with respect to each of the performance measures, and
- ANP takes into consideration any subjective judgment required for decision making.

The ANP is therefore considered to be a more reliable approach to prioritize highway improvement locations, and is automated within the Web-based CMP system updated as part of this project.

CHAPTER 5
CMP SYSTEM

This chapter focuses on the data preparation and processing efforts undertaken while implementing the ANP method within an updated Web-based CMP system. The chapter also includes a brief discussion of the updated CMP system.

5.1 ANP Implementation

This section focuses on the ANP implementation steps and assumptions within the updated CMP system. More specifically, the performance measures' computations, the approach used to convert the values of the performance measures into the pre-defined 1-9 scale, the logic used to automatically perform pairwise comparisons of the segments, and the approach used to determine the final scaled scores of the highway locations are discussed.

5.1.1 Performance Measure Computations

As identified in Chapter 3, the following seven performance measures are used to prioritize highway project locations:

1. Number of excess fatalities
2. Number of excess injuries
3. v/c ratio
4. AADT per lane
5. Truck volume per lane
6. Truck percent
7. Delay

The data variables used to compute the above-listed performance measures are derived from the District One segment data file and the crash data file. For each of the 747 roadway segments in the District One SIS network, the District One segment data file includes the following relevant variables:

- Volume
- Capacity
- Truck percent
- v/c ratio
- LOS
- Posted speed
- Number of lanes

The crash data file includes information on several roadway geometry-related, crash-related, and occupant-related variables; crash location and crash severity are the only two crash-related variables that are required for calculating the safety-related performance measures.

Of the seven performance measures, the v/c ratio and truck percent are directly obtained from the District One segment data file. AADT per lane value is calculated by dividing the traffic volume by number of lanes. Truck volume per lane is calculated by multiplying the AADT per lane value with the corresponding truck percent. Delay is interpreted from the LOS. The safety-related performance measures, number of excess fatalities and injuries on each segment, are calculated using the EB approach discussed in Section 3.2.2. Note that the segments are first divided into facility types based on number of lanes, presence or absence of medians, and area type, and the corresponding SPFs are used to estimate the number of excess fatalities and injuries.

5.1.2 Data Normalization

As discussed in Section 4.3.1, for each of the seven performance measures, one of the initial steps of the ANP method is to conduct pairwise comparisons of all the 747 alternatives (i.e., roadway segments). Since the roadway geometric characteristics of the segments (e.g., number of lanes, area type, presence of median, etc.) vary considerably, the performance measures (e.g., AADT/lane, v/c ratio, etc.) are not directly comparable. Besides, outliers present another potential issue. For example, if there are 100 rural two-lane segments, and if a couple of segments have unrealistically high AADT values (i.e., outliers), the pairwise comparisons, when generated automatically, will be biased toward these segments.

To address these two issues, the segments are first divided into facility types, and the values of the performance measures of all the segments within each facility type are converted into the pre-defined 1-9 scale based on percentiles. When there are more than 9 segments in a facility type, the values from the 1st to the 11th percentile are given a value of 1, the values from the 12th to the 22nd percentile are given a value of 2, etc. When there are 5-9 segments in a facility type, the values are converted into the 1, 3, 5, 7, 9 scale based on percentiles. When there are fewer than five segments, all the segments are assigned a value of 5.

5.1.3 Pairwise Comparisons of Segments

The number of pairwise comparisons is a function of the number of performance measures (or alternatives) (n) to be compared, and can be calculated using the following formula:

$$\textit{Number of pairwise comparisons} = \frac{n\,(n\text{-}1)}{2} \tag{5-1}$$

For each of the seven performance measures, the 747 segments (i.e., alternatives) will result in 278,631 pairwise comparisons. Since it is impossible to manually compare these many alternatives, an automated procedure was developed to generate the final pairwise comparisons. This automated procedure is possible only because all the performance measures are quantitative.

For each performance measure, the segments (i.e., the alternatives) are compared by calculating the ratio of the two alternatives. For example, if the normalized value of v/c is 3 for segment A and 6 for segment B, the pairwise comparison of segments A and B is given a value of 3/6. Similarly, if the normalized value of truck percent is 8 for segment C and 1 for segment D, the pairwise comparison of segments C and D is given a value of 8/1.

5.1.4 Pairwise Comparisons of Performance Measures

The seven performance measures will result in 21 pairwise comparisons, which can be performed within the CMP system. In this application, the default values are set to 1, implying that all the seven performance measures are equally important. As discussed in Section 4.3.4, consistency check is automatically performed using the consistency index calculated based on the pairwise comparisons of the seven performance measures. Note that the consistency ratio of less than 10% is required for the pairwise comparisons to be consistent.

5.1.5 Final Scaled Scores

The final output of the ANP process gives the priorities of the alternatives (i.e., segments). These priorities add up to 1.00. Since a total of 747 segments are to be prioritized, the priorities are multiplied by 10,000 to obtain scaled scores that are easier for comparison.

5.2 Application of the Updated CMP System

The CMP is a Web-based tool designed for use by FDOT District One to prioritize state road segments and develop a prioritized list of congestion and safety related projects for funding consideration. The updated CMP system provides the following key functions:

- Upload various traffic-related data and crash records.
- Calculate performance measures from uploaded data.
- Determine the importance of each performance measure based on pairwise comparisons.
- Prioritize roadway segments by applying the ANP method with multiple performance measures.
- Create thematic maps of performance measures and other input variables on Google Maps.
- Evaluate potential projects and record project information.
- Manage user accounts and assign account privileges.

As mentioned earlier, the system considers the following seven performance measures in prioritizing roadway segments:

1. Number of excess fatalities (per mile per year)
2. Number of excess injuries (per mile per year)
3. AADT per lane
4. Truck volume per lane
5. Truck percent
6. v/c ratio
7. Delay

The first two measures address the roadway safety needs while the remaining five measures address the roadway capacity needs, with a separate emphasis on the level of freight trucks on the roadways.

5.2.1 Data Preparation

The first step in prioritizing locations is to upload all the required input data into the CMP system. The CMP system requires the following three input files to be uploaded for each analysis year:

- Crash database
- RCI database
- District One segment file

Crash Data

The FDOT Unified Basemap Repository (UBR) provides shapefiles for plotted crash points for long-form-reported crashes for Florida, separated into crash, vehicle, and occupant files. Note that all the crashes are separated into on-system and off-system, depending on crash location. As the name implies, crashes that occurred on on-system roads are included in the on-system crashes shapefile, and those that occurred on off-system roads are included in the off-system crashes shapefile. Detailed descriptions of the fields included in the shapefiles are available on the FDOT UBR website.

The CMP system requires crash-level attribute data to be imported in .dbf format. It is recommended to just import the District One on-system crash data. The following crash data variables are used in the analysis (the name in the parentheses gives the description of the variable):

- CALYEAR (year)
- CRASHNUM (crash number)
- ROADWAYID (roadway ID where the crash had occurred)
- LOCMILEPT (milepost where the crash had occurred)
- HIGHESTINJ (highest injury severity that has occurred because of the crash)

RCI Data

The original standard RCI Access database including only the data for District One is required to be imported into the CMP system. The system exports the following data variables from the RCI database (the name in the parentheses gives the description of the variable):

- FUNCLASS (functional classification)
- SECTADT (traffic volume)
- NOLANES (number of lanes)
- TYPEROAD (type of road)

District One Segment File

Table 5-1 provides the data dictionary of the District One segment file to be imported in .kml format. This segment file includes a total of 747 segments, totaling 1,856.21 miles.

Table 5-1: District One Segment File Data Dictionary

Data Variable	Description	Data Type
RID	Roadway ID	Text (8 digits, 2 digits for county, 3 digits for section, and 3 digits for subsection)
FMP	From Milepost	Float
FrmLimit	From Roadway Name	Text
TMP	To Milepost	Float
ToLimit	To Roadway Name	Text
Local_Name	Local Name	Text
State_Road	State Road Number	Text
Truck_Percent	Percent of Trucks	Float (decimal)
VC	V/C Ratio	Float
Volume	Traffic Volume	Long Integer
Capacity	Capacity	Long Integer
LOS	Level of Service	Text
NoLanes	Number of Lanes	Integer
FIHS	Indicates Segment on FIHS Network	Text
SIS	Indicates Segment on SIS Network	Text

The data preparation process in CMP includes the following two major steps:

1. *Upload Data*: This step allows the user to upload the following input data files into the system database: crash data from UBR, RCI data, and the District One segment file.

2. *Calculate Measures*: This step allows the user to calculate the performance measure data for use in project prioritization. Specifically, the calculations performed in this step include:

   - Calculating the truck volume from truck percent.
   - Standardizing the volume data (i.e., vehicular volume and truck volume) from the total volume for all lanes to volume per lane.
   - Calculating the excess injuries and excess fatalities based on the EB method discussed in Section 3.2.2.
   - Calculating the v/c ratios based on the District One LOS Workbook and the standard K factor.
   - Determining the delay condition based on existing LOS with respect to the design LOS.

5.2.2 Project Analysis

After the performance measure data are successfully calculated, they are ready to be applied to prioritize and analyze projects. The project analysis process in the updated CMP includes three steps: Build Scenarios, Prioritize Projects, and Manage Selected Projects.

Build Scenarios step allows an authorized user to build scenarios that weigh the importance of different performance measures. *Prioritize Projects* step allows an authorized user to calculate scores using the ANP method together with a weight scenario built in the previous step. The scores are then used to gauge a roadway segment's overall need for improvements. A list of roadway segments is then selected for further consideration for potential funding. Finally, *Manage Selected Projects* step allows an authorized user to further analyze the roadway segments selected in the previous step to further shortlist the selections, document the selection decisions, and populate additional information for the final selections including, specific proposed improvements, the estimated project costs, etc.

5.2.3 Updated CMP System

The following paragraphs provide a brief overview of the steps to be followed within the CMP system to prioritize and manage project locations. Appendix A provides the User's Guide for the system.

As mentioned earlier, the CMP uses the ANP method to prioritize highway locations based on seven performance measures. Determining the relative importance of each performance measure is an integral part of the prioritization method implemented within the CMP system. It is achieved via pairwise comparisons which aim to compare the relative importance of two performance measures at a time. This approach theorizes that an analyst can better assess the relative importance of a set of performance measures when given only two measures to compare at a time, than when given all measures at once.

One result from the pairwise comparisons is that the user selections are not likely to be completely logical. For example, if the user indicates that Measure A is more important than Measure B, and Measure B is more important than Measure C, the selections would be inconsistent if the user also indicates that Measure C is more important than Measure A, which is not logical. However, such conflicts will arise naturally, especially when several performance measures are involved. The questions are how to quickly gauge the level of consistency and at what level of inconsistency is considered acceptable.

To help the user gauge the degree of consistency in a set of pairwise comparisons made, CMP calculates a so-called consistency ratio as a quick measure of the level of consistency. A 0% consistency ratio indicates that the pairwise comparisons are perfectly consistent. The literature suggests that a consistency ratio of below 10% can be considered to be acceptable. Otherwise, the pairwise comparisons should be revised to improve their consistency. Section 4.3.4 discusses this in more detail.

When the consistency ratio is calculated, the system also calculates the relative weight for each performance measure based on the result from the pairwise comparisons. These relative weights, which sum up to 100%, are available for use in the second step of the project analysis process to prioritize project locations. Once the scenario is built and the relative weights of the performance measures are calculated, the system can prioritize the roadway segments. The final prioritized list of locations is then generated, which can be exported into Excel. This list is now available for further analysis, which primarily focuses on managing projects.

CHAPTER 6
SUMMARY AND CONCLUSIONS

The Florida Department of Transportation (FDOT) District One developed the Congestion Management Process (CMP) to prioritize low-cost, near-term highway improvements on its Strategic Intermodal System (SIS). The CMP is designed to screen and prioritize all project locations system-wide and is able to automatically generate a ranked list of project locations. The existing system screens locations based on the following seven performance measures, with their maximum scores in percentage given in parentheses:

1. Crash ratio (22%)
2. Fatal crash (9%)
3. Volume-to-capacity ratio (31%)
4. Average annual daily traffic (AADT) per lane (10%)
5. Truck volume per lane (13%)
6. Truck percent (6%)
7. Delay (9%)

Since the development of the CMP in 2009, a number of new developments have taken place, including, but not limited to, the development of the 2060 Florida Transportation Plan (FTP), the publication of the Highway Safety Manual (HSM), and a new emphasis on freight transportation for economic development. At the same time, more advanced methods for identifying improvement sites and ranking projects have become available. For example, the HSM includes more advanced methods that could be adopted in the CMP to better screen and prioritize highway locations for safety improvements. As such, there is a need to update the existing performance measures and the ranking method to better reflect the current conditions and align more consistently with the Department's current strategic goals.

Accordingly, the objectives of this project are to research and update:

1. the existing performance measures to better reflect the current conditions and strategic goals of the Department;
2. the current ranking methodology, including the weighting strategy and the method of prioritization; and
3. the CMP system to incorporate the updated project prioritization process and include visualization and mapping capabilities in the system.

As the first step toward achieving the aforementioned objectives, the existing FDOT policy goals and objectives including the Florida's SIS Strategic Plan, the 2060 Florida Transportation Plan, and the Florida Freight Mobility and Trade Plan are reviewed. Additionally, the project prioritization practices (i.e., prioritization methods and performance measures) currently being adopted by the state DOTs, MPOs, and other local transportation agencies are reviewed and documented. This task provided some insight on the advanced prioritization methods that could be adopted to prioritize project locations. Besides, the review helped identify the quantitative performance measures that align with the goals listed in the 2060 Florida Transportation Plan, and which could potentially be included in the updated CMP system.

6.1 Performance Measures

Of the existing seven measures, AADT, v/c ratio, and delay are retained as they are common measures of mobility and level of service. Although these measures are related, they serve to capture highway locations of different conditions. Truck volume and truck percent are also retained in the revised list as they provide key measures of freight transportation, an emphasis area in the 2060 Florida Transportation Plan, Florida Freight Mobility and Trade Plan, as well as the Florida's SIS Strategic Plan. In the strategic area of safety and security, the two existing safety performance measures, crash ratio and fatal crash, are replaced with "number of excess fatalities" and "number of excess injuries," which are calculated using the EB approach. The final updated list of performance measures includes:

1. Number of excess fatalities (per mile per year)
2. Number of excess injuries (per mile per year)
3. Volume-to-capacity ratio
4. Average annual daily traffic (AADT) per lane
5. Truck volume per lane
6. Truck percent
7. Delay

6.2 Prioritization Method

The existing prioritization method consists of the application of quantitative criteria followed by qualitative questionnaire. Each of the seven quantitative performance measures is assigned a maximum score. The actual score of each measure is then determined based on site-specific characteristics. Finally, for each project location, scores from the seven measures are summed up to obtain the overall score which is then used in project prioritization. Top-ranked project locations are scrutinized through the qualitative criteria to determine the final location list for funding.

This simple scoring method which assigns fixed weight for each of the performance measures does not account for correlation between performance measures. Of the performance measures being considered by Florida District One, it is quite clear that v/c and AADT are interdependent, so are truck volume and truck percentage. Further, delay and v/c (thus AADT) are also interdependent as delay is a function of v/c. Similarly, the SPFs are a function of AADT and, thus, has a direct impact on the excess crash frequency. It can thus be concluded that all the performance measures are essentially interdependent and would benefit from a method that can take account of the impacts of such interdependencies. The Analytic Network Process (ANP), an advanced multi-criteria decision-making technique, accounts for these interdependencies. The ANP breaks down a decision problem into logical order and addresses the interaction among the criteria, the alternatives, and the overall goal. It reduces the risk of undue weight of any one criterion on decision making, and can effectively consider subjective judgments in a systematic way. For these reasons, the ANP approach was implemented within the updated CMP system.

6.3 Updated CMP System

The updated CMP provides the following key functions:

- Upload various traffic-related data and crash records.
- Calculate performance measures from uploaded data.
- Determine the importance of each performance measure based on pairwise comparisons.
- Prioritize roadway segments by applying the ANP method with multiple performance measures.
- Create thematic maps of performance measures and other input variables on Google Maps.
- Evaluate potential projects and record project information.
- Manage user accounts and assign account privileges.

A detailed user's manual of the system was prepared and included in Appendix A.

The system requires crash and roadway segment data for each analysis year. The crash data consist of crash records for the District in a standard format used by FDOT's Unified Basemap Repository (UBR). The segment data include the standard Roadway Characteristics Inventory (RCI) file for four variables needed in the calculation of safety-related performance measures, and a Keyhole Markup Language (KML) file that is converted from the shapefiles prepared by District One Consultants annually. The KML file contains data for capacity, vehicular volume, truck percent, level of service (LOS), and number of lanes. These data files are used to calculate the seven performance measures.

After the performance measure data are successfully calculated, the next step is to apply the ANP method. The relative importance of each performance measure is determined via pairwise comparisons of the performance measures. The final scores of each roadway segment are next calculated using the ANP method. The scores are then used to gauge a roadway segment's overall need for improvements. A list of roadway segments is then selected for further consideration for potential funding. Finally, the selected roadway segments are further analyzed to identify and "short-list" projects to be reviewed in detail regarding operational analysis, specific improvements, cost estimates, potential funding opportunities, etc.

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APPENDIX A:

CMP USER'S GUIDE

Congestion Management Process (CMP)

User's Guide

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1. INTRODUCTION

This guide is intended for users of automated Congestion Management Process (CMP), a web-based tool designed for use by the District to prioritize state road segments and develop a prioritized list of congestion and safety related projects for funding consideration. The development of this tool builds on the work by PBS&J which developed the initial version of CMP. This guide provides detailed instructions on how to use the various components of the system. It assumes that the user is familiar with the general operation of a web browser.

1.1. Key CMP Functions

CMP provides the following key functions:

- ✓ Upload various traffic-related data and crash records.
- ✓ Calculate performance measures from uploaded data.
- ✓ Determine the importance of each performance measure based on pairwise comparisons.
- ✓ Prioritize roadway segments by applying the Analytical Network Process (ANP) method with multiple performance measures.
- ✓ Create thematic maps of performance measures and other input variables on Google Maps for data visualization.
- ✓ Evaluate potential projects and record project level information.
- ✓ Manage user accounts and assign account privileges.

The system is designed for desktop environment including Tablet PCs, and is compatible with all commonly used browsers including Internet Explorer, Chrome, Firefox, and Safari. The system is accessible to, but not optimized for, mobile devices such as smart phones.

1.2. Performance Measures

In prioritizing roadway segments, the system considers the following seven performance measures:

1. Excess Fatalities (per mile per year)
2. Excess Injuries (per mile per year)
3. Average Annual Daily Traffic (AADT) (per lane)
4. Truck Volume (per lane)
5. Truck Percent
6. Volume-to-Capacity Ratio
7. Delay

The first two measures address the roadway safety needs while the remaining five measures address the roadway capacity needs, with a separate emphasis on the proportion of freight trucks on the roadways.

1.3. User Types

CMP supports the following four user types:

- *User*: This user type can view projects and project information sheets, and print or export information.
- *Project Manager*: This user type can upload and process data, view projects, export project list, build scenarios, apply prioritization method, make project selections, enter project information for selected projects, and generate project information sheets.
- *Decision Maker*: This user type can make final decision on project selections, in addition to all that can be done by a Project Manager.
- *Administrator*: This user type can manage user accounts and scenarios, in addition to all that can be done by a Decision Maker.

2. GETTING STARTED

To access the CMP system, the user first opens a web browser and navigates to the application. The browser will open the main CMP screen shown in Figure 1. The screen includes a login panel for which the user will need to have a valid user account to enter the system. The main screen also includes a brief introduction to the system, plus a Google Maps application that displays the map area covered by District One.

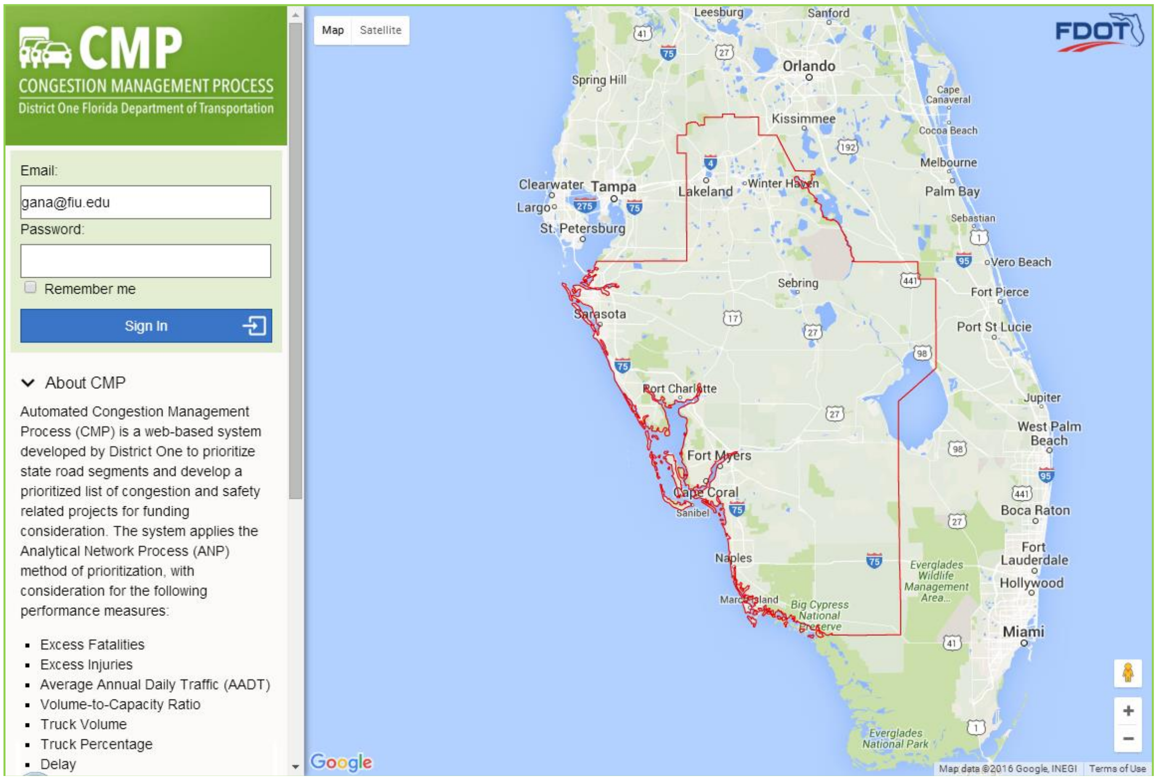

Figure 1: CMP Main Screen Before Login

After logging into the system, the user will be presented with a new left panel shown in Figure 2. The new panel includes a dropdown list for the user to select an analysis year, plus a list of menu items to provide access to various CMP functions. Access to some of the menu items, including Steps 2 and 3 under the **Analysis** menu, will require that the user first selects an analysis year. An analysis year corresponds to the year of data for which an analysis session is to be based on.

Similarly, visualization of data on the Google Maps application also requires that an analysis year be selected first. The operations of the Google Maps application are detailed in Section 5 of this guide.

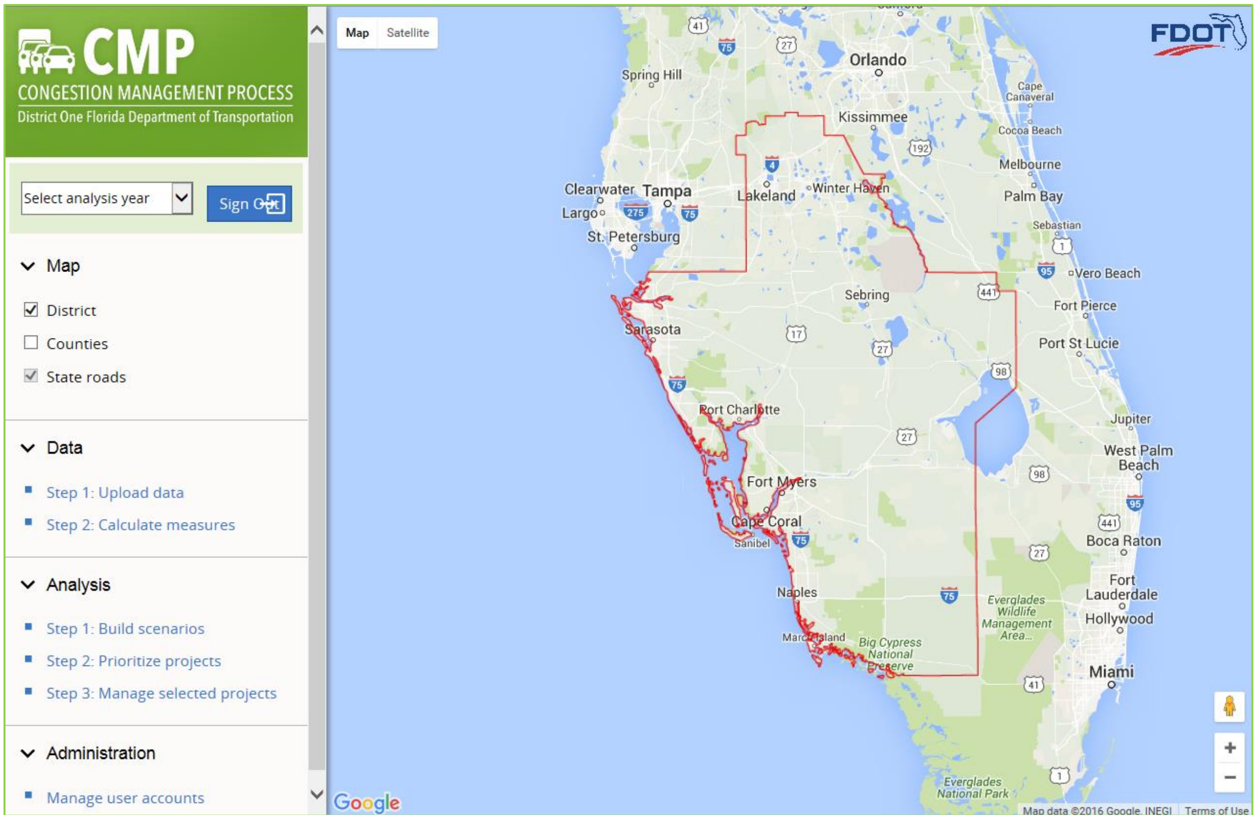

Figure 2: CMP Main Screen After Login

3. DATA PREPARATION

The first step in applying CMP is to upload all required input data into the system. CMP provides tools for authorized user to upload and process the required data. An authorized user is one with a user account of at least the Project Manager user type (refer to Subsection 1.3 for more details on user types). The data preparation process in CMP includes the following two major steps:

1. Upload data: This step allows the user to upload the input data into the system database.

2. Calculate Measures: This step allows the user to calculate the performance measure data for use in project prioritization.

These steps are further detailed below.

3.1. Step 1: Uploading Data

The input data for CMP include all those that are needed to derive the seven performance measures used in project prioritization, in addition to the state roads geographic network covered by the District. The data are divided into three data files for crashes, segments, and RCI variables, and are uploaded for each analysis year when their respective data become available.

The crash data consist of crash records in a standard format used by FDOT's Unified Basemap Repository (UBR) and can be downloaded from the UBR website when a new year of crash data become available.[1] It is noted that the original data file from the UBR website contains crash records for the entire state. The file should be filtered to exclude crashes outside the District before being uploaded to the system.

The segment data are uploaded as a KML file that is converted from a shapefile prepared annually by District One consultants. The file contains data for capacity, vehicular volume, truck percent, level of service, and number of lanes for each segment.

The RCI data are uploaded in the standard RCI Access database format. They include data for four specific variables that are needed in the calculation of safety-related performance measures, i.e., FUNCLASS for functional classification, SECTADT for section average daily traffic, NOLANES for number of lanes, and TYPEROAD for type of road. Note that unlike the number of lanes in the KML file, which is the number of lanes that best represents that of an analysis segment in the KML file, the number of lanes in the RCI file represents the actual number of lanes of each RCI segment.

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[1] FDOT Unified Basemap Repository, https://www3.dot.state.fl.us/unifiedbasemaprepository/.

To upload a data file in CMP, the user follows the steps below:

1. Click the **Upload data** menu item to open the window shown in Figure 3.
2. Select the year of the data to be uploaded.
3. Select a data category, which could be "Standard D1 segment data file (.kml)" for all segment data, "Standard crash data file (.csv)" for crash data for D1, or "Standard RCI data file (.csv or .txt)" for roadway inventory data for D1.
4. Click the **Browse** button to locate the data file in a local folder.
5. Click the **Upload** button to start uploading the file.
6. Repeat Steps 3-5 for the second data file of the year (if available).

The file upload history, including the data year, the data category, the file name, the upload date, and the user who uploaded the file, will be listed in a table below the **Upload** button.

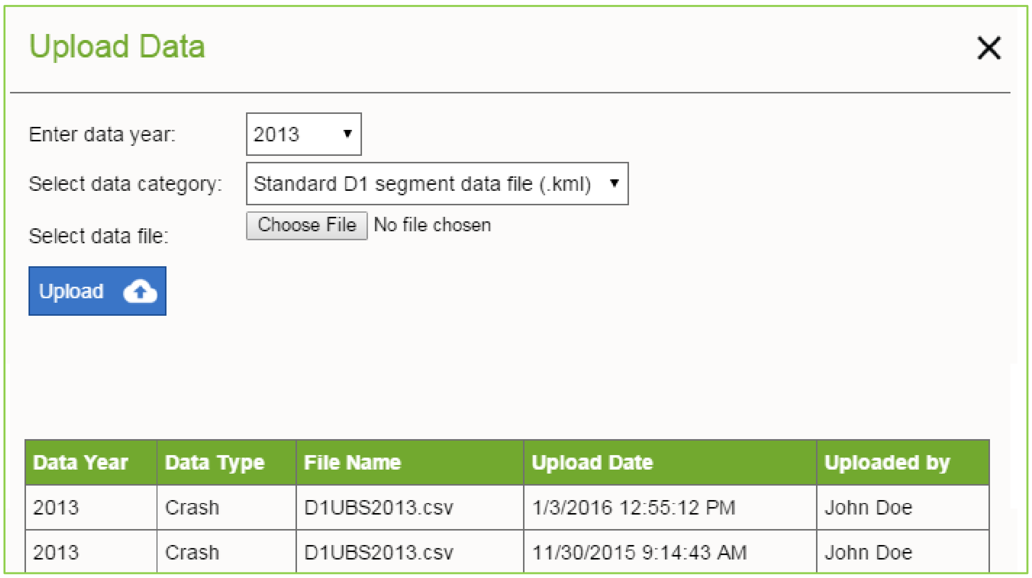


Figure 3: Window for Uploading Data

3.2. Step 2: Calculating Measures

After all the required data files are successfully uploaded, they can be used in this step to calculate the performance measure data used in the project prioritization process. Specifically, the calculations performed in this step include:

- Calculating the truck volume from truck percent.
- Standardizing the volume data (i.e., vehicular volume and truck volume) from the total volume for all lanes to volume per lane.
- Calculating the excess injuries and excess fatalities based on the *SafetyAnalyst* method.
- Calculating the volume-to-capacity ratios based on the D1 LOS Workbook and the standard K factor.

- Determining the delay condition based on existing level of service (LOS) with respect to the design LOS.

To access the function, click the **Calculate measures** menu item to open the window shown in Figure 4. The window includes a table that lists the data uploaded for each data year. The list is sorted from the newest to the oldest year. Only one data set can exist in the system for each year. However, data can be uploaded multiple times to update existing data in the system.

When all the required data sets including those for crashes, segments, and RCI variables for a specific data year are shown to have been successfully uploaded, as indicated by the "Ready" status indicator (otherwise, the status will indicate "Missing"), the **Calculate** link will appear, allowing the user to click it to start calculating the performance measure data. After the calculation is completed, the table will list the date and time the calculation was made, in addition to the name of the user who ran the calculation, and the status of the calculation. The calculated measure data will also be available for export to Excel by clicking the **Export** link on the second action column.

In the case when the performance measure data have been calculated based on previously uploaded data files, the **Calculate** link will be replaced with **Re-calculate** to signal the existence of performance measure data in the system for the same year. Thus, the recalculation, if performed, will replace the existing data.

Calculate Measures ✕

Action	Action	Data Year	Segment Data	Crash Data	RCI Data	Calculation Date	User	Result
		2015	Missing	Missing	Ready	4/1/2016 4:07:40 PM	John Doe	N/A
Re-calculate	Export	2014	Ready	Ready	Ready	4/28/2016 3:06:09 PM	Kaiyu Liu	Successful
Re-calculate	Export	2013	Ready	Ready	Ready	4/18/2016 6:07:50 PM	Kaiyu Liu	Successful

Figure 4: Window for Calculating Measures

4. PROJECT ANALYSIS

After the performance measure data are successfully calculated, they are ready to be applied by authorized users to prioritize and analyze projects. A user authorized to perform project analysis in CMP must be at least of the Project Manager user type (refer to Subsection 1.3 for more details on user types).

The project analysis process in CMP includes the following three steps:

1. Build Scenarios: This step allows an authorized user to build scenarios that weigh the importance of different performance measures.

2. Prioritize Projects: This step allows an authorized user to calculate scores using the ANP method together with a weight scenario built in the previous step. The scores are then used to gauge a roadway segment's overall need for improvements. A list of roadway segments is then selected for further consideration for potential funding.

3. Manage Selected Projects: This step allows an authorized user to further analyze the roadway segments selected in the previous step to further shortlist the selections, document the selection decisions, and populate additional information for the final selected projects including specific proposed improvements, the estimated project costs, etc.

These steps are further detailed below.

4.1. Step 1: Building Scenarios

Determining the relative importance of each performance measure is an integral part of the prioritization method implemented in CMP. It is achieved via pairwise comparisons which aim to compare the relative importance of two performance measures at a time. This approach theorizes that an analyst can better assess the relative importance of a set of performance measures when given only two measures to compare at a time, than when given all measures at once. The system includes the following seven measures:

1. *Excess Fatalities*: It gives the prediction of the number of excess fatalities at the person level given the location's existing traffic volume and roadway geometric characteristics. Any location with the number of excess fatalities greater than zero would be experiencing more fatalities than expected, and a negative excess number of fatalities suggests that the location would be experiencing fewer fatalities than expected.

2. Excess Injuries: Similar to excess fatalities, this measure gives the prediction of the number of excess injuries at the person level given the location's existing traffic volume and roadway geometric characteristics. Any location with excess injuries greater than zero would be experiencing more injuries than expected. On the other

hand, a negative excess number of injuries indicates that the location would be experiencing fewer injuries than expected.

3. *Volume-to-capacity (v/c) Ratio:* The v/c ratio indicates the amount of traffic versus the carrying capacity of a roadway. High v/c ratios indicate roadways approaching or exceeding capacity. The ratio is calculated for each roadway by dividing the peak hour two-way traffic volume by the capacity of each roadway. The peak hour two-way traffic volume for a roadway segment is calculated by multiplying the AADT volume of the segment by the standard K factor. The capacity of a roadway is defined as the service volume at LOS E based on the FDOT Quality/LOS Handbook.

4. *Vehicular Volume per Lane (AADT/lane):* This measure is simply the average annual daily traffic (AADT) divided by the number of travel lanes. Roadways with high volumes of vehicle traffic tend to degrade faster and require more maintenance than similar roadways with less vehicle traffic. Also, high traffic volumes increase vehicular density, raising the possibility of conflicts as well as the need for drivers to adjust their driving according to drivers adjacent to them.

5. *Truck Volume per Lane (AADTT/lane):* This measure is based solely on the average annual daily truck traffic (AADTT). Similar to the AADT per lane measure, this truck volume measure in the CMP is normalized by the number of travel lanes to get per-lane AADTT. A high AADTT/lane value indicates large volumes of truck traffic on the roadway which has the potential to affect the system integrity.

6. *Truck Volume (% Trucks):* Percent trucks indicate the portion of total traffic on a roadway that is comprised of trucks. Trucks often require longer distances to accelerate, decelerate, and pass other vehicles. Trucks also require slower speeds to negotiate roadways, especially where turns are required. Thus, a high truck percentage indicates a roadway with a large portion of truck traffic with respect to total traffic, which has the potential to affect system mobility.

7. *Delay:* As delay increases, the LOS provided by a roadway decreases, thereby causing a direct decrease in roadway mobility. Delay as defined for this CMP application is based on the LOS of a roadway segment, and whether a roadway exceeds the established LOS standards, i.e., LOS C for rural roadways and LOS D for urban roadways. Three general levels of the delay condition are defined in the CMP application:

   a) "Fails" if the existing LOS is F,
   b) "Exceeds Standard" if the existing LOS exceeds its corresponding LOS standard, and
   c) "At or Below Standard" if the existing LOS is at or below its corresponding LOS standard.

To start building scenarios based on pairwise comparisons of these performance measures, the user clicks the **Step 1: Build scenario** menu item to open the window shown in Figure 5. For a new scenario, the system starts by assuming that all performance measures are equally important. The user can then go through each pair of measures to assess and indicate their relative importance. This is done by marking on the scale between each pair of measure. For example, if the user feels very strongly that Excess Fatalities is more important than Delay, he/she would mark the radio button highlighted in a red box in Figure 5.

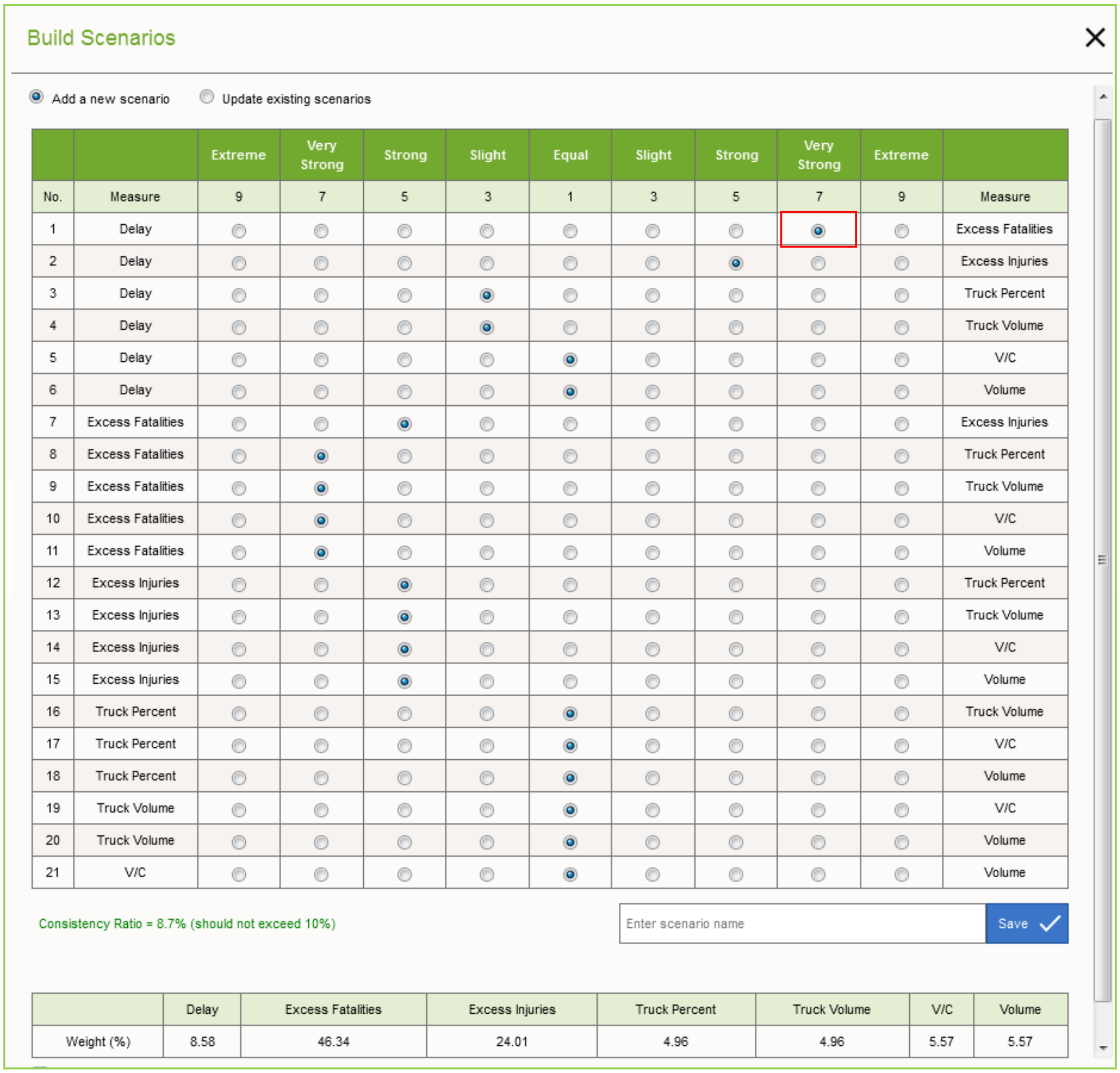


Figure 5: Window for Performing Pairwise Comparisons and Building Weight Scenarios

One result from the pairwise comparisons is that the user selections are not likely to be completely logical. For example, if the user indicates that Measure A is more important than Measure B, and Measure B is more important than Measure C, the selections would be inconsistent if the user also indicates that Measure C is more important than Measure A, which is not logical. However, such conflicts are difficult to avoid completely, especially when many performance measures are involved. The questions are how to gauge the level of consistency and at what level of inconsistency is considered acceptable.

To help the user gauge the degree of consistency in a set of pairwise comparisons made, CMP calculates a so-called consistency ratio as a quick measure of the level of consistency. The consistency ratio, expressed in percent, is calculated and displayed with the each use selection of the preference level. A 0% consistency ratio indicates that the pairwise comparisons are perfectly consistent. The literature suggests that a consistency ratio of below 10% can be considered to be acceptable. Otherwise, the pairwise comparisons shoud be revised to improve their consistency.

When the consistency ratio is calculated, the system also calculates the relative weight for each performance measure based on the result from the pairwise comparisons. The relative weights, which sum up to 100%, are shown at the bottom of the window. These weights can be saved as a scenario and are available for use in the second step of the project analysis process to prioritize the projects.

To save the results of pairwise comparisons including the relative weights as a scenario, the user first enters a scenario name in the textbox provided and then click **Save**. The user may update any saved scenarios by selecting the **Update Existing Scenarios** option on top of the window. The user can then select a saved scenario on the dropdown list to retrieve the scenario for editing.

4.2. Step 2: Prioritizing Projects

After a weight scenario is built and saved, it can be applied in this step of the project analysis process to prioritize the roadway segments, also referred herein as the projects. To access this step the user must have first selected an analysis year from the **Select analysis year** dropdown list. The user can then click the **Step 2: Prioritize projects** menu item to open the window shown in Figure 6. In this window, the user can perform the following tasks:

- Select a saved scenario from the **Select Scenario** dropdown list. The **Calculate Scores** button will be activated, as shown in Figure 6. If the scores have been calculated previously, this will also display the segment table complete with the calculated scores. In addition, the **Export to Excel** button will also be activated, allowing the table to be downloaded to an Excel file on the local drive. Only project records that are on display will be included in the downloaded file.

- If the scores have not been calculated, click the **Calculate Scores** button to start calculating the score for each roadway segment. The calculation will take several minutes to complete. When completed, the window will display a table complete with the calculated scores, the project location information, and the performance measures for each roadway segment (see Figure 7).

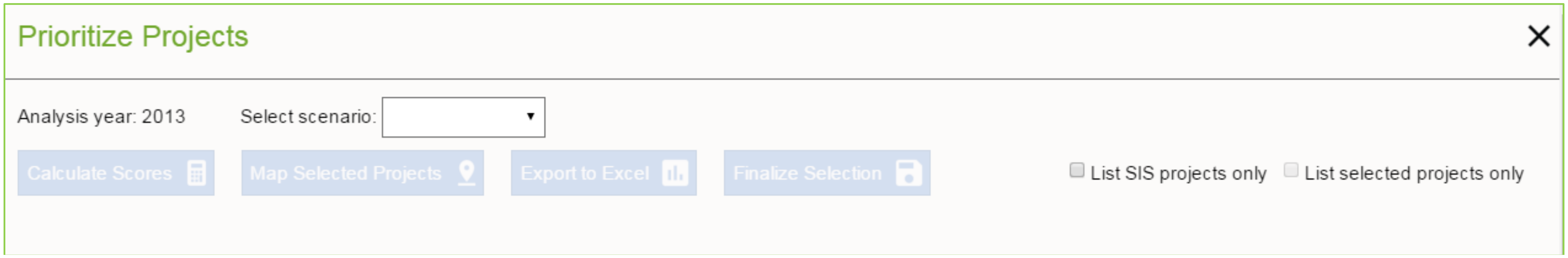
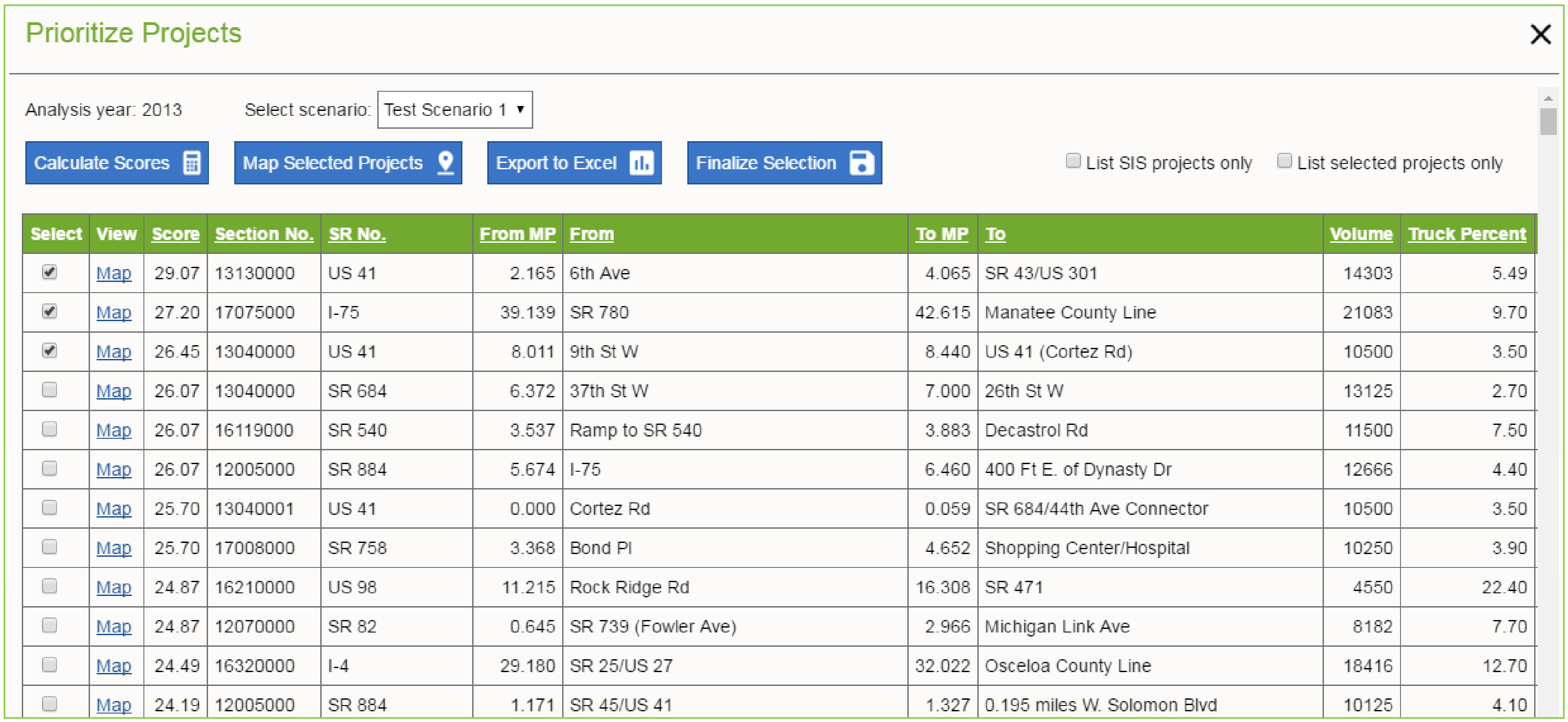


Figure 6: Project Prioritization Window Before Score Calculation



Select	View	Score	Section No.	SR No.	From MP	From	To MP	To	Volume	Truck Percent
☑	Map	29.07	13130000	US 41	2.165	6th Ave	4.065	SR 43/US 301	14303	5.49
☑	Map	27.20	17075000	I-75	39.139	SR 780	42.615	Manatee County Line	21083	9.70
☑	Map	26.45	13040000	US 41	8.011	9th St W	8.440	US 41 (Cortez Rd)	10500	3.50
☐	Map	26.07	13040000	SR 684	6.372	37th St W	7.000	26th St W	13125	2.70
☐	Map	26.07	16119000	SR 540	3.537	Ramp to SR 540	3.883	Decastrol Rd	11500	7.50
☐	Map	26.07	12005000	SR 884	5.674	I-75	6.460	400 Ft E. of Dynasty Dr	12666	4.40
☐	Map	25.70	13040001	US 41	0.000	Cortez Rd	0.059	SR 684/44th Ave Connector	10500	3.50
☐	Map	25.70	17008000	SR 758	3.368	Bond Pl	4.652	Shopping Center/Hospital	10250	3.90
☐	Map	24.87	16210000	US 98	11.215	Rock Ridge Rd	16.308	SR 471	4550	22.40
☐	Map	24.87	12070000	SR 82	0.645	SR 739 (Fowler Ave)	2.966	Michigan Link Ave	8182	7.70
☐	Map	24.49	16320000	I-4	29.180	SR 25/US 27	32.022	Osceloa County Line	18416	12.70
☐	Map	24.19	12005000	SR 884	1.171	SR 45/US 41	1.327	0.195 miles W. Solomon Blvd	10125	4.10

Figure 7: Project Prioritization Window After Score Calculation

- Click any of the variables on the table header to sort the table in ascending or descending order. By default, the table is sorted from the highest to the lowest calculated scores.

- Select a project record by clicking the check box in front of it. As soon as a project record is selected, both the **Map Selected Projects** and **Finalize Selection** buttons will be activated.

- Click the **Map Selected Projects** button to display all selected roadway segments on Google Maps on a pop-up window. Figure 8 shows an example.

- Click the **Finalize Selection** button to finalize the selected project records, making them available for further analysis in the third and final step of the project analysis process.

- Click the **List selected projects only** check box above the table to list only the selected project records. Uncheck the check box to list all (i.e., selected and unselected) project records.

- Click the **List SIS project only** check box to list project records that are part of the Strategic Intermodal System only. Uncheck the check box to list all (i.e., SIS and non-SIS) project records.

- Click the **Export to Excel** button to download all project records that are currently on display, depending on which of the **List selected projects only** and **List SIS project only** check boxes are checked.

- Click a **Map** link on the **View** column to display a specific roadway segment on Google Maps on a pop-up window. Figure 9 shows an example. Multiple such windows may be open concurrently.

- Click a selected roadway segment on Google Maps to open an Infobox that lists the roadway information.

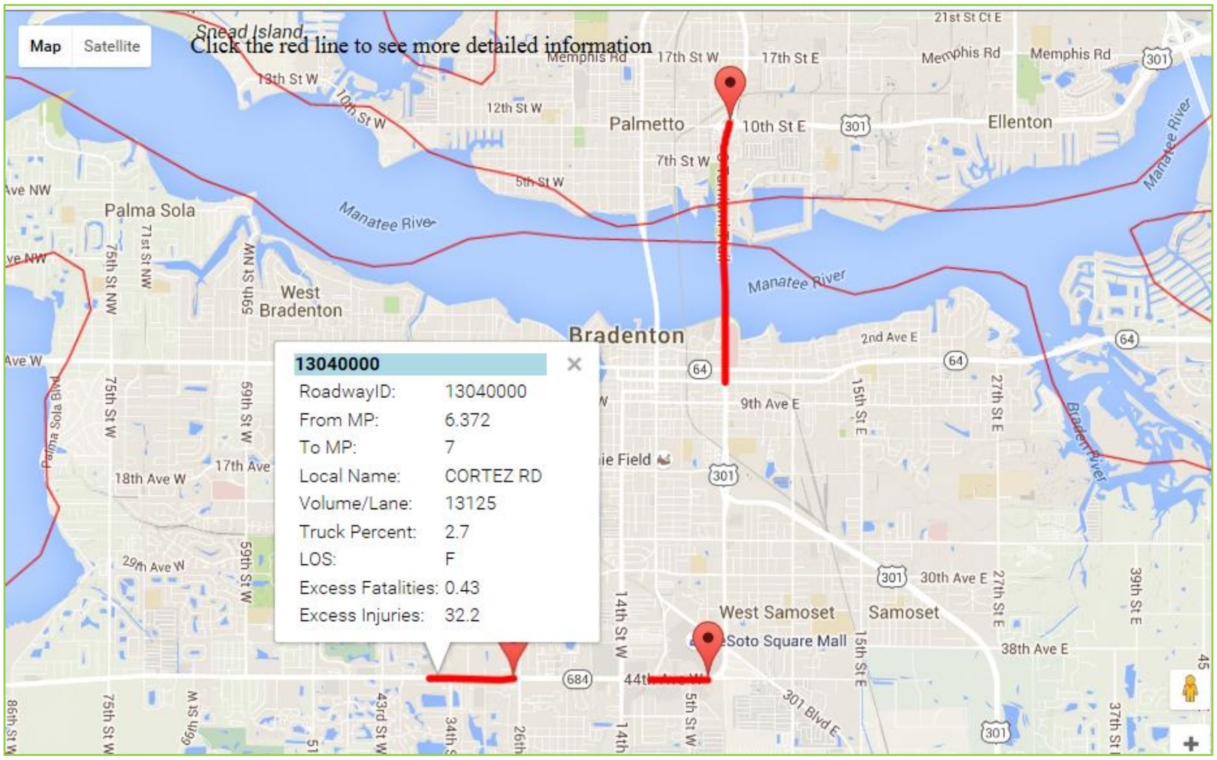


Figure 8: Map Display When Multiple Roadway Segments are Selected

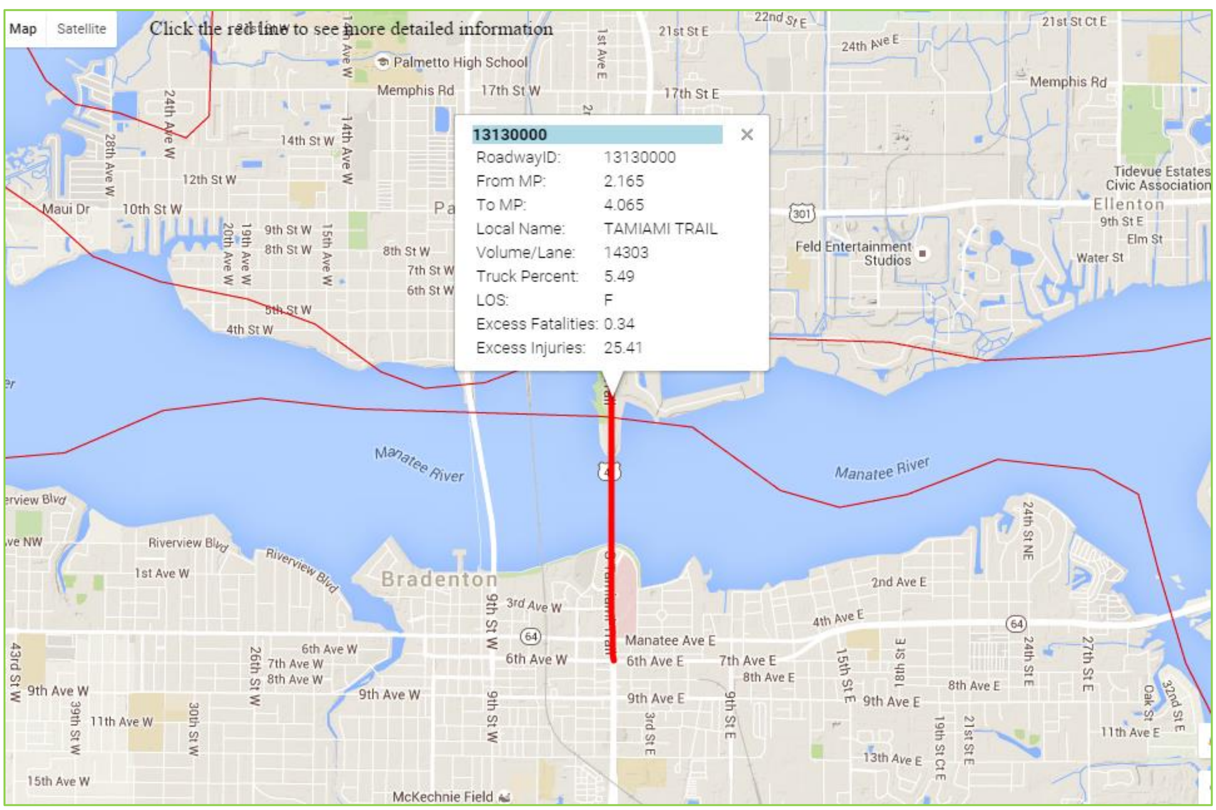


Figure 9: Map Display When Single Roadway Segment is Selected

4.3. Step 3: Managing Selected Projects

The final step in the project analysis process is to further analyze the roadway segments selected in the previous step to further shortlist the project selections, document the selection decisions, and populate the selected project (i.e., the "Go" projects) with detailed project-level information. Similar to the previous steps, the user must have selected an analysis year from the **Select analysis year** dropdown list. The user can then click the **Step 3: Manage Selected Projects** menu item to open the window shown in Figure 10. The window displays a list of the projects selected in the previous step. The user may click the **Export to Excel** button to download the table into an Excel file. The downloaded file will include all records on display.

All projects will initially display "None" under the Decision dropdown list, pending the review and decision by a decision maker. Once the project has been reviewed it must be assigned a decision status of "Go" or "No Go". To select the status, simply click the dropdown arrow in the **Decision Status** column. The project will have a status of Reviewed and the "Go" or "No Go" data will become available, as show in the figure. The status can be changed without a loss of data. A "Go" decision that is changed to a "No Go" decision will still have the "Go" information saved and kept.

Section No.	SR. No.	From	To	Review Status	Decision Status	Action
01040101	US 17	SR 35/US 17	US 41 (Cross St)	Reviewed	Go	View
12000569	ALICO RD	I-75	Benhill/Griffin Pkwy	Reviewed	No Go	View

Figure 10: Manage Selected Projects Window

To view the "Go" or "No Go" data, click the **View** action link. This will open the **Project Completion Status** window shown in Figure 11 for a "Go" project. On this window the user can see the status of available data, which includes those for the following sections: general project information, CMP documents, intersection characteristics, and location images. If data have been entered for a section, it will show the ✓ status button; otherwise, the ✗ status button is shown. On this window the user can click:

- the **Justify** button to open the **Go Project Information** window,
- the **Report** button to view all of the data entered on a report, or
- the **Back** button to return to the project listing window.

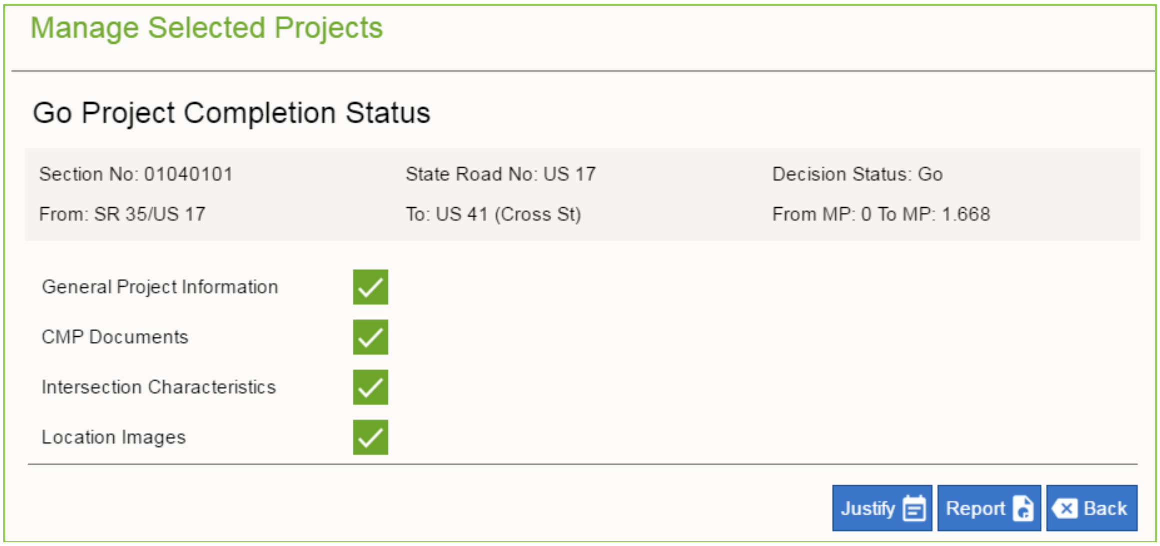


Figure 11: "Go" Project Completion Status Window

There are four contiguous sections to complete on **Go Project Information** window: General Project Information, CMP Documents, Intersection Characteristics, and the Image Upload. The data entry items are shown in Figures 12(a) to 12(d), respectively.

Figure 12(a) shows the first section of the **Go Project Information** window that allows the user specify the general project information, including the Project Name, Section No. Header, Milepost Header, and County fields, which are automatically filled in. Except for County, the other three fields may be edited if needed. In addition, the section also allows the user to enter information on the proposed improvement, the project, and other additional comments.

Figure 12(b) shows the second section of the **Go Project Information** window that allows the user to upload any CMP related documents. These documents are provided to the Department Management to assist in their decision making on the proposed improvements. After a document file is uploaded, the user can click **View** to open and view the uploaded file or click **Delete** to remove the file.

Figure 12(c) shows the third section of the **Go Project Information** window that allows the user to enter detailed intersection information, including those for major intersection characteristics and different project costs.

Figure 12(d) shows the fourth section of the **Go Project Information** window that allows the user to upload the image files for the intersection, including a general map to show the location of the intersection and an image file for each of the standard four intersection legs. Note that uploaded images must be either GIF or JPG files only. To upload an image file, click the **Choose File** button to navigate to the folder where the file is located. After a file is selected and uploaded, the corresponding **View** link will be activated, allowing the user to click to open and view the uploaded image.

Once the data for a section is entered, the user can click the **Save** button (see Figure 12(d)) to save the data. Clicking the adjacent **Back** button will return to the **Go Project Completion Status** window shown in Figure 11, where the user can see an ✓ icon next to the section, indicating that data have been entered for the section.

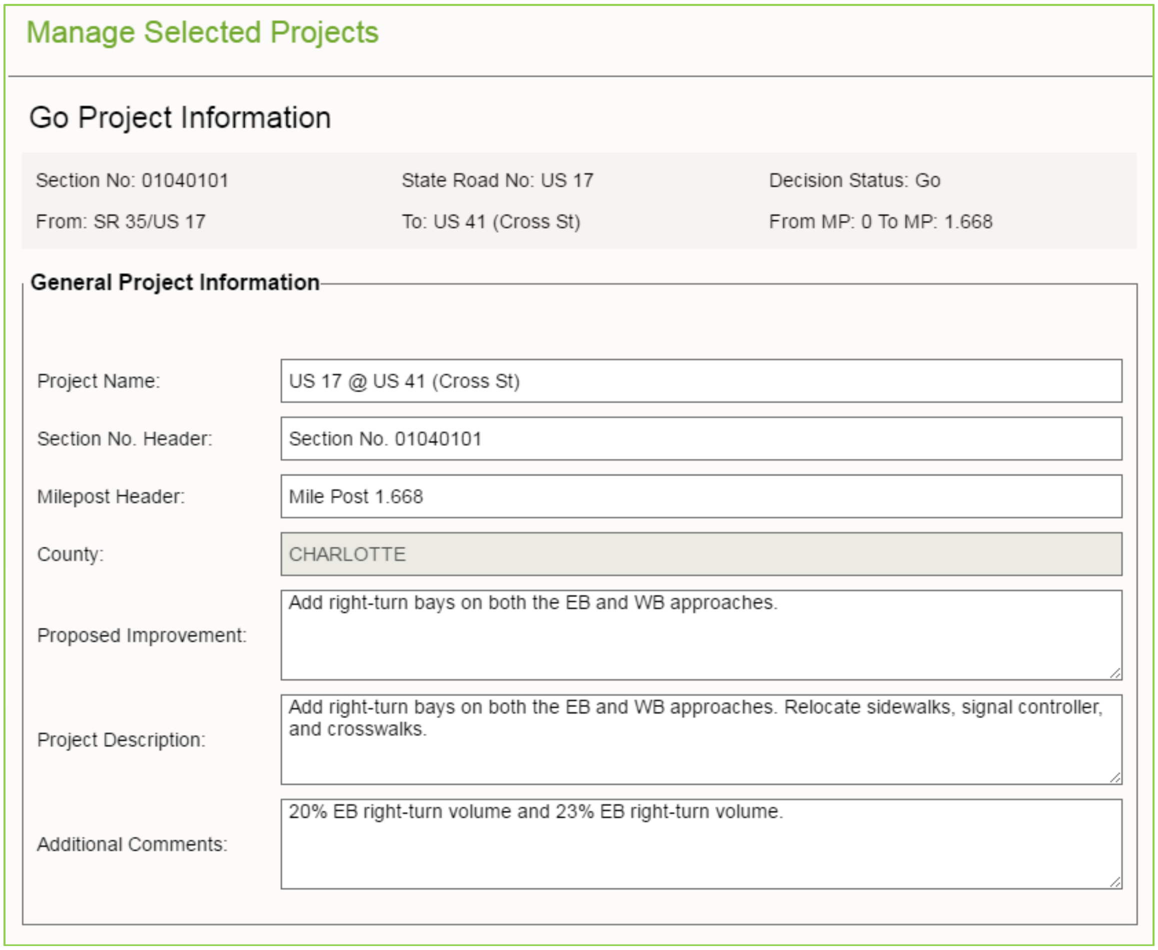


Figure 12(a): "Go" General Project Information Data Entry Section

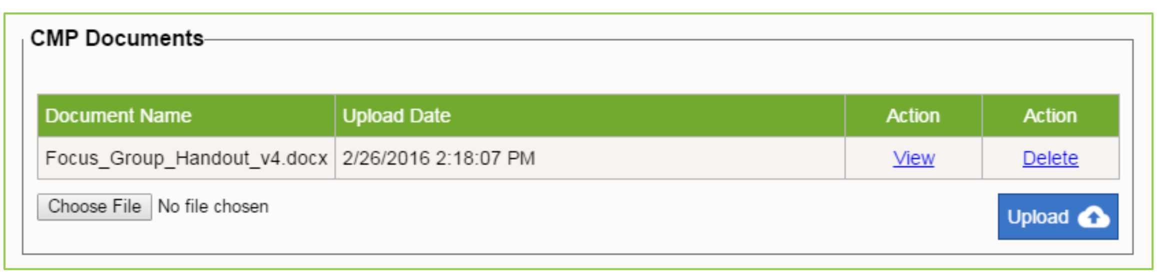


Figure 12(b): "Go" CMP Document File Upload Section

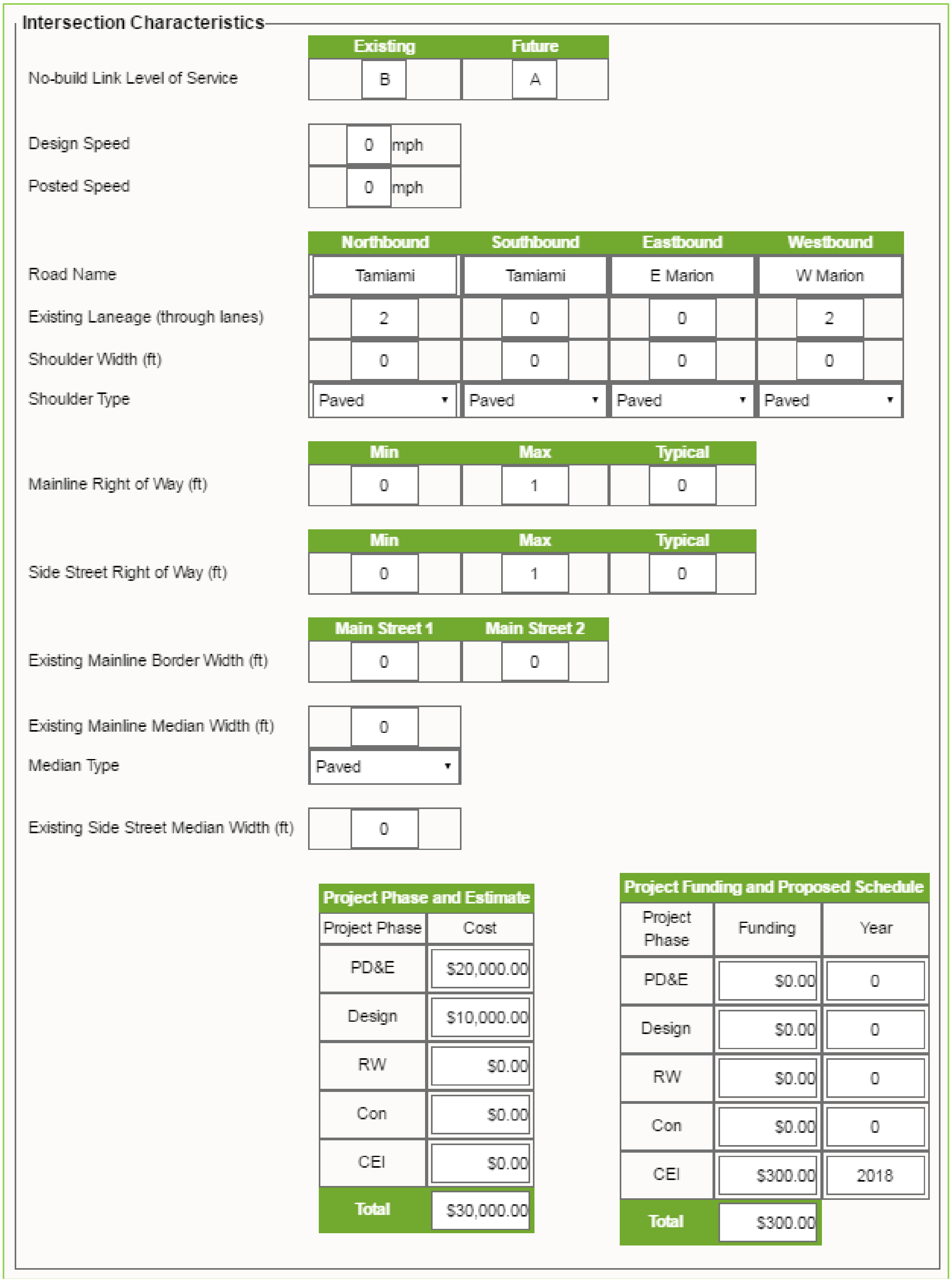


Figure 12(c): "Go" Intersection Characteristics Data Entry Section

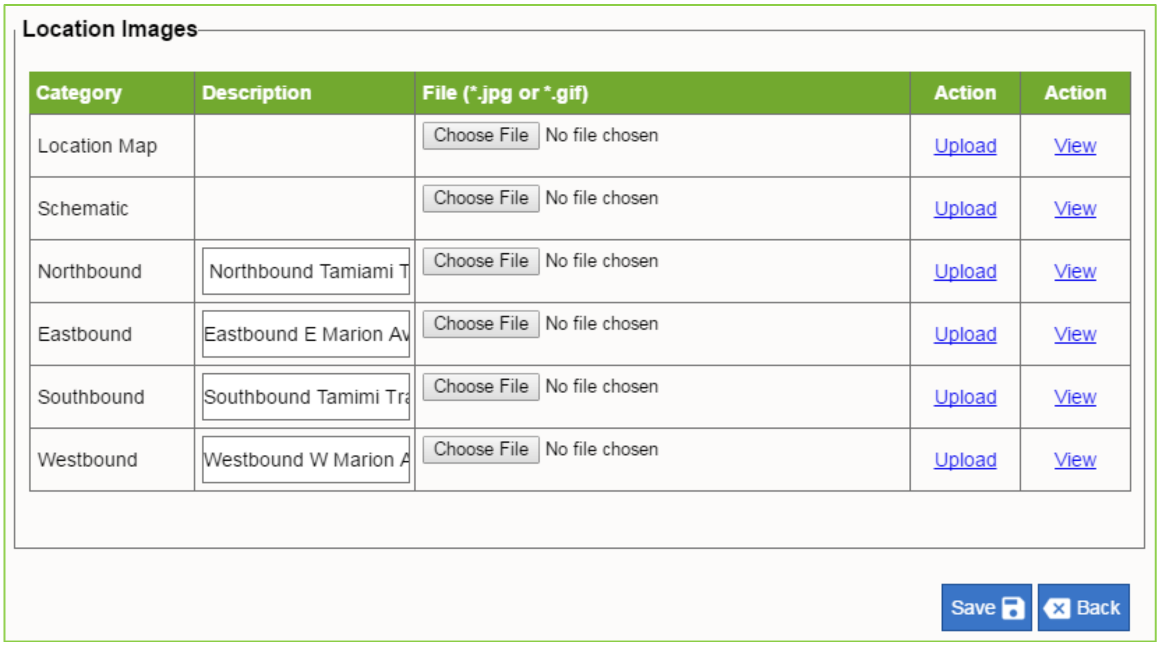


Figure 12(d): "Go" Location Images Data Entry Section

After project data are entered, the user may click on the **Report** button on the **Go Project Completion Status** window (see Figure 11) to generate a one-page pre-formatted report. Figure 13 shows an example. As shown in the example, the report includes all the project information and the uploaded location images. The user may then click the  export button to select one of the available file formats (Excel, PDF, or Word). As soon as a file format is selected, the report will open on a file of the selected file format (depending on browser type and/or browser settings, additional actions may be needed by the user to open the file). Figure 14 shows an example PDF report.

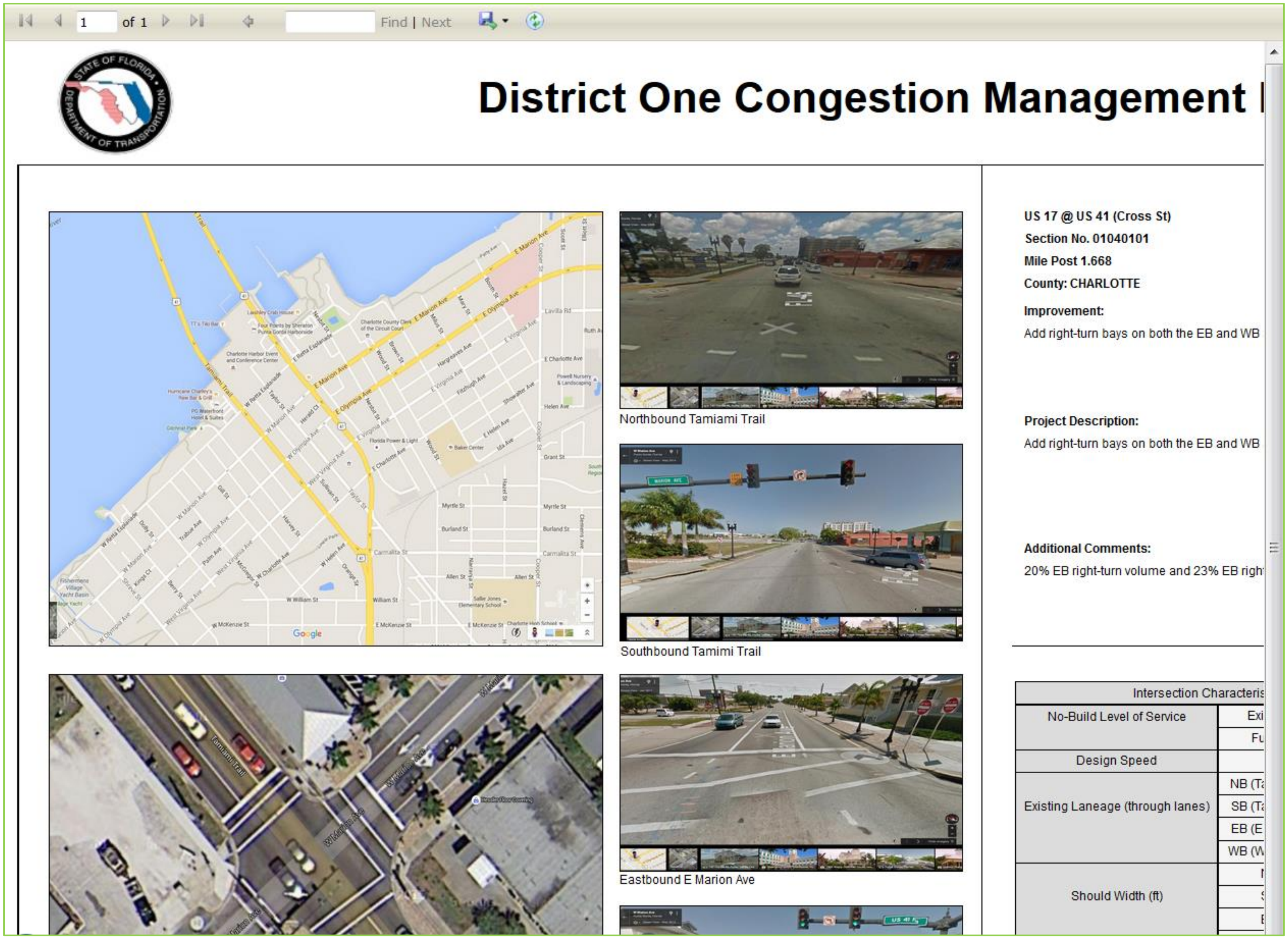
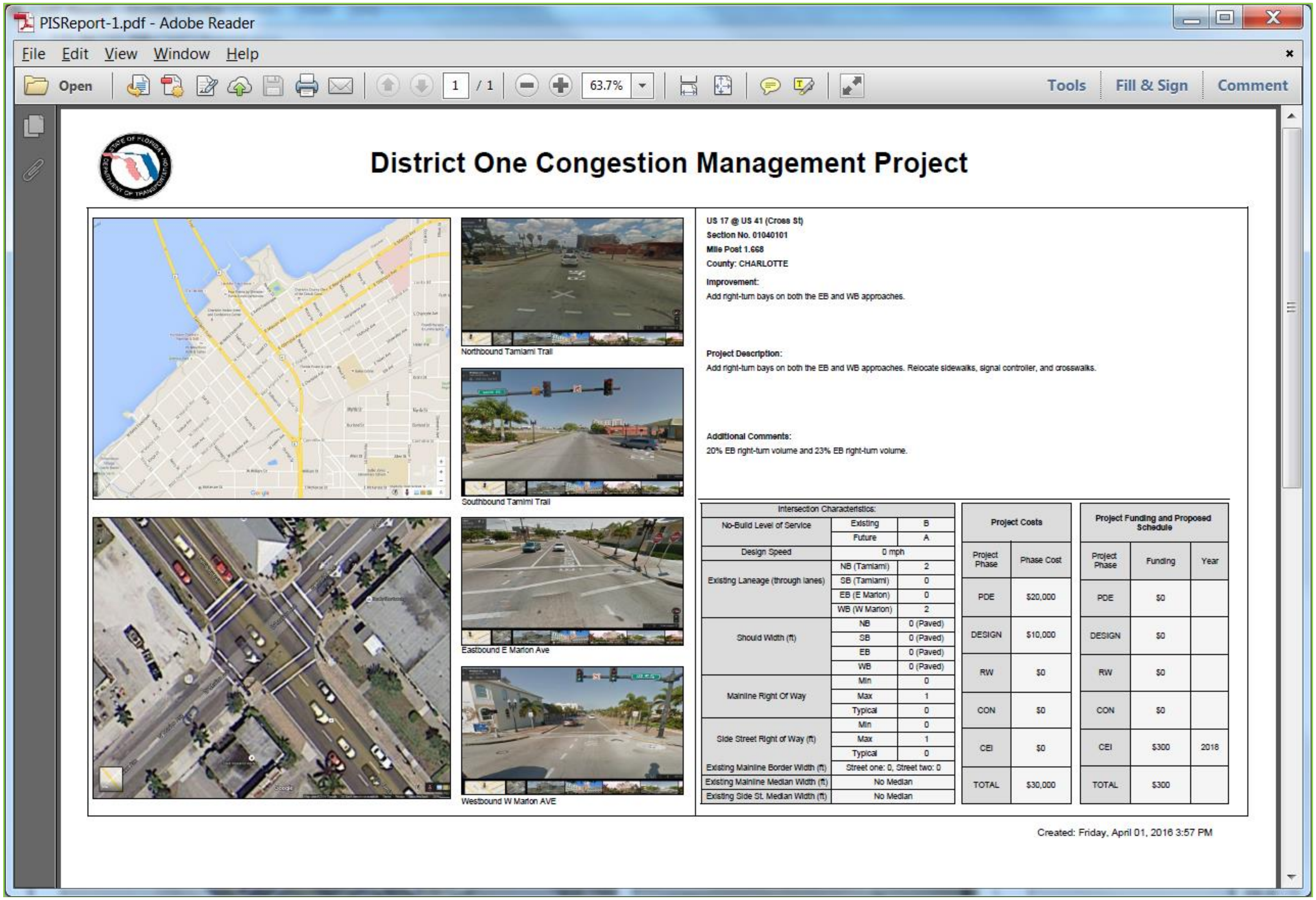


Figure 13: Project Information Report



District One Congestion Management Project

US 17 @ US 41 (Cross St)
Section No. 01040101
Mile Post 1.668
County: CHARLOTTE

Improvement:
Add right-turn bays on both the EB and WB approaches.

Project Description:
Add right-turn bays on both the EB and WB approaches. Relocate sidewalks, signal controller, and crosswalks.

Additional Comments:
20% EB right-turn volume and 23% EB right-turn volume.

Intersection Characteristics:		
No-Build Level of Service	Existing	B
	Future	A
Design Speed	0 mph	
Existing Laneage (through lanes)	NB (Tamiami)	2
	SB (Tamiami)	0
	EB (E Marion)	0
	WB (W Marion)	2
Should Width (ft)	NB	0 (Paved)
	SB	0 (Paved)
	EB	0 (Paved)
	WB	0 (Paved)
Mainline Right Of Way	Min	0
	Max	1
	Typical	0
Side Street Right of Way (ft)	Min	0
	Max	1
	Typical	0
Existing Mainline Border Width (ft)	Street one: 0, Street two: 0	
Existing Mainline Median Width (ft)	No Median	
Existing Side St. Median Width (ft)	No Median	

Project Costs	
Project Phase	Phase Cost
PDE	$20,000
DESIGN	$10,000
RW	$0
CON	$0
CEI	$0
TOTAL	$30,000

Project Funding and Proposed Schedule		
Project Phase	Funding	Year
PDE	$0	
DESIGN	$0	
RW	$0	
CON	$0	
CEI	$300	2016
TOTAL	$300	

Created: Friday, April 01, 2016 3:57 PM

Figure 14: Project Information Report in PDF File Format

In the case that a "No Go" decision is selected for a project location, clicking the **View** action link (see Figure 10) will open the window shown in Figure 15. On this window, the user can click the **Justify** button to open the window shown in Figure 16, which allows the user to enter the reasons for not selecting the project. The same window also allows the user to upload documents in support of the decision.

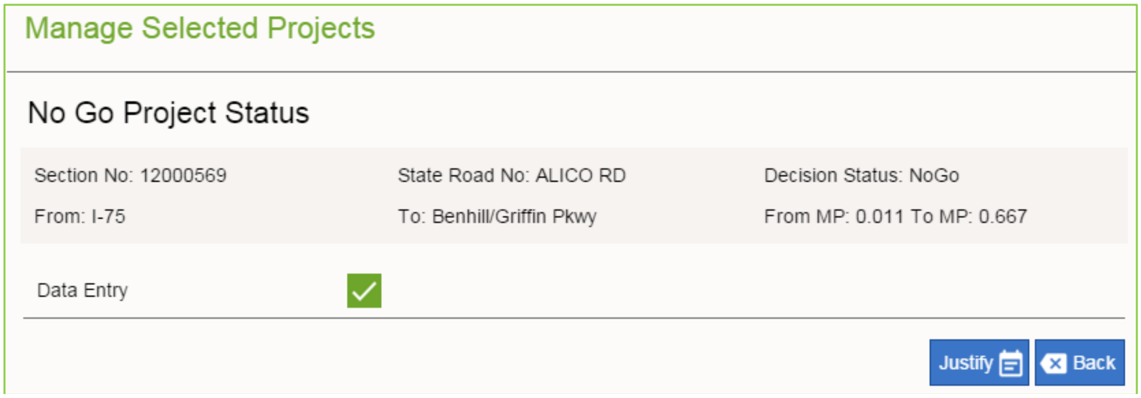


Figure 15: "No Go" Project Status Window

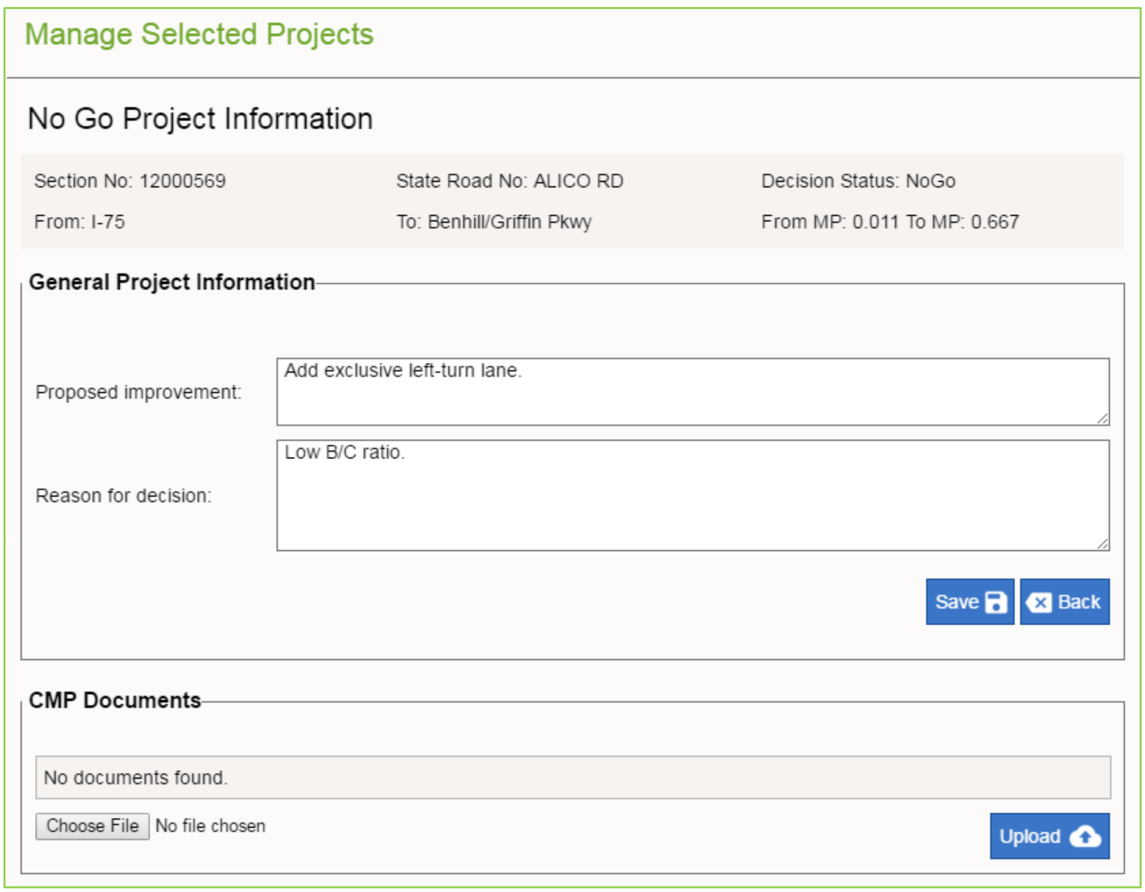


Figure 16: "No Go" Project Information Window

5. DATA VISUALIZATION

CMP includes a Google Maps application that allows the user to plot thematic maps of both the input variables and the performance measures. To access the application, the user must first select an available analysis year. As soon as an analysis year is selected, the map view will display the state roads layer for the selected analysis year, along with a search box and four dropdown lists. As shown in Figure 17, the search box allows the user to enter a standard 8-digit roadway ID to find a specific roadway segment. The four dropdown lists combine to provide the user the ability to create different thematic maps.

To create a thematic map, the user must first select a variable to plot from the first dropdown list. The remaining three dropdown lists provides the following plotting options:

- Number of intervals: select from a range of 2 to 10 intervals. The default is 6 intervals.
- Line width: select from a range of level 1 to level 9. The default is level 5.
- Line color: select either fixed colors or one of four color ramps.

Figure 18 shows a thematic map of the Level of Service (LOS) with fixed colors and Figure 19 shows another thematic map of Excess Injuries based on a green color ramp. As can be seen in both figures, the legend for the thematic map is displayed in the **Map** menu area, where the user can also check or uncheck to add or remove the map layers for the district, counties, and state roads form the map display.

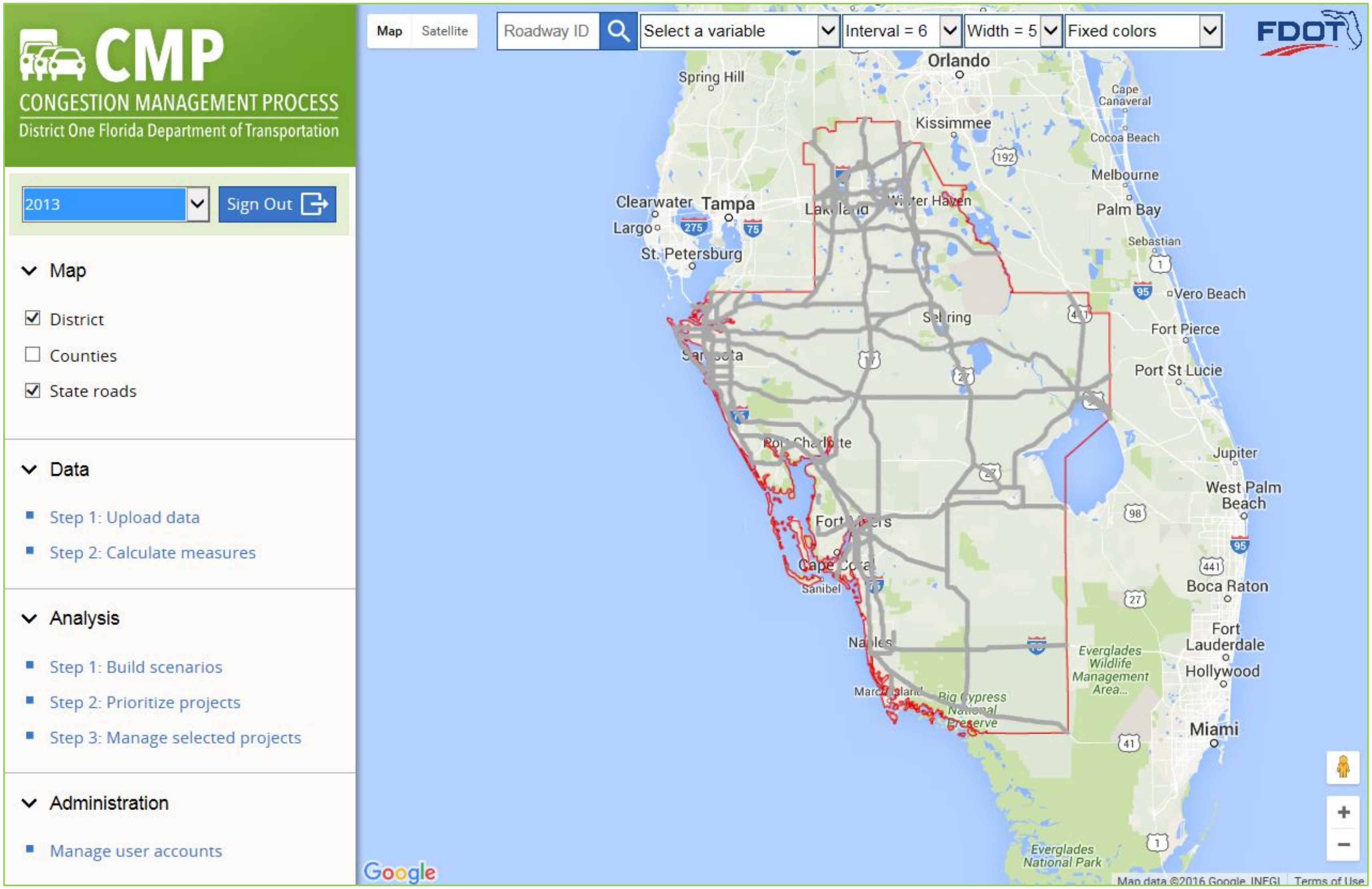


Figure 17: Google Maps Display After an Analysis Year is Selected

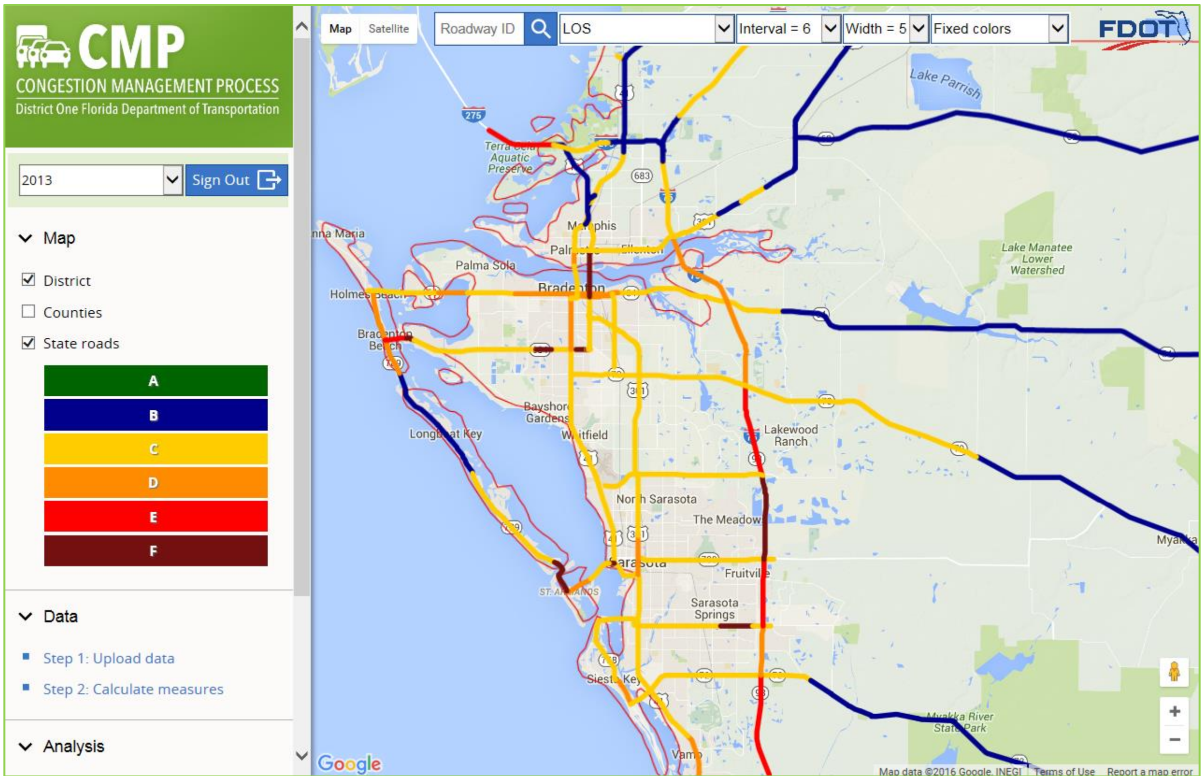


Figure 18: Thematic Map of Level of Service with Fixed Colors

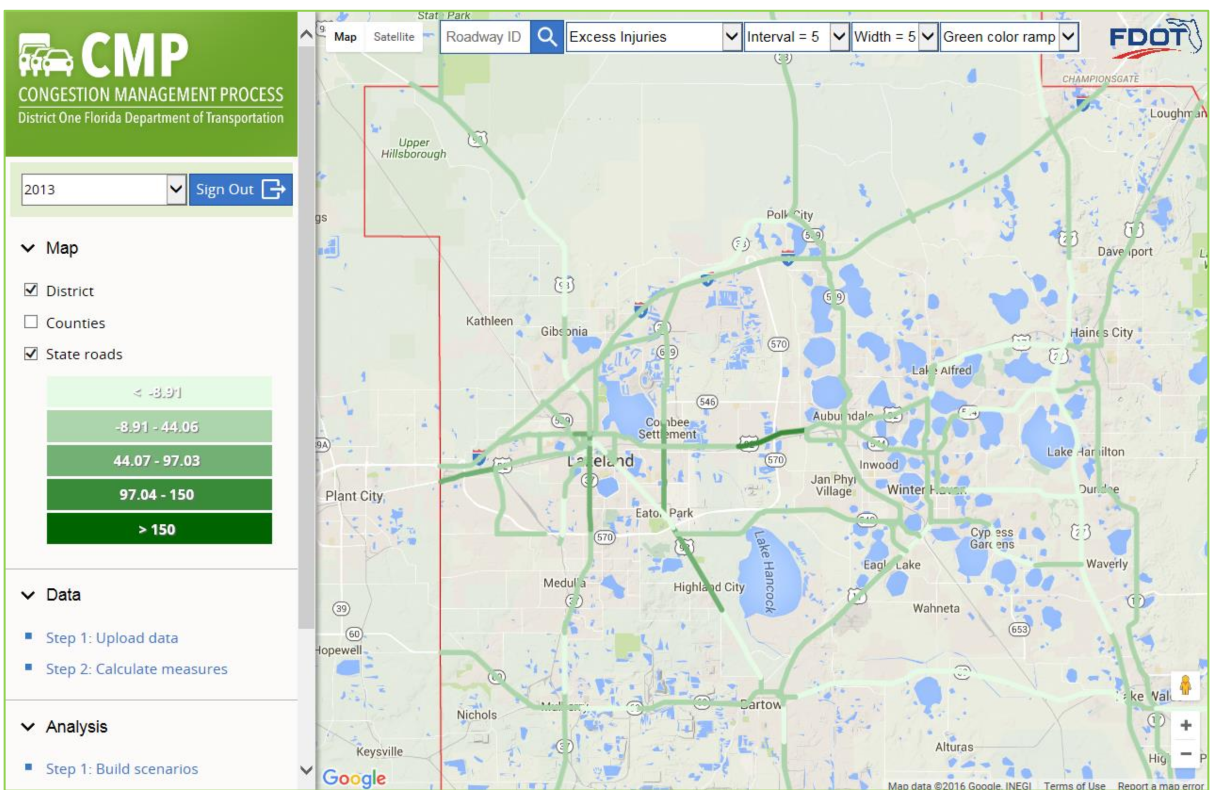


Figure 19: Thematic Map of Excess Injuries Based on a Green Color Ramp

6. ADMINISTRATION

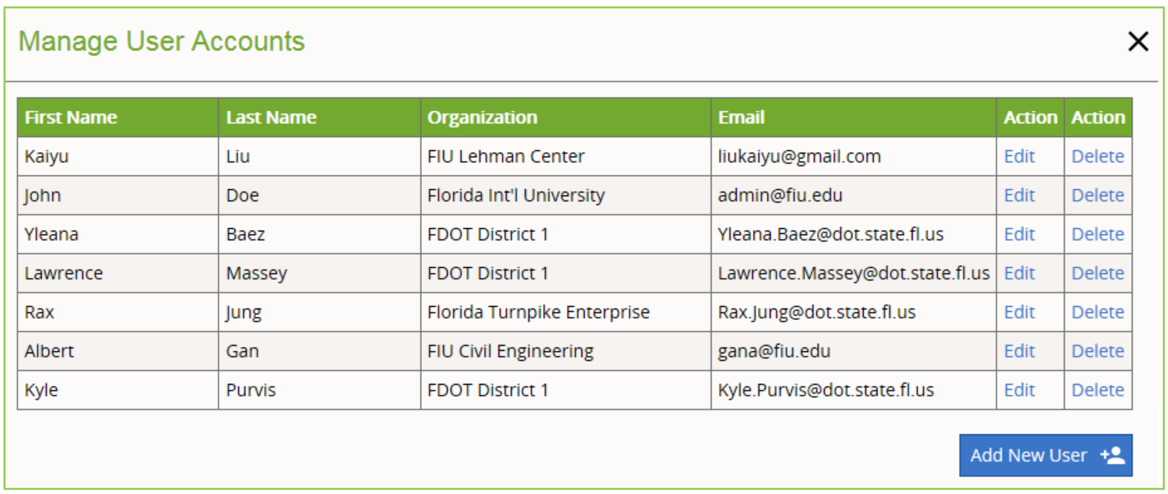
The **Administration** section of the CMP menu currently provides only one major function which is to manage the CMP user accounts. As indicated in Subsection 1.3 of this guide, CMP includes four user account types, i.e., user, project manager, decision maker, and administrator. Only user accounts assigned with the **Administrator** user type has access to this function.

To access this function, the user simply clicks the **Manage User Accounts** menu item to open the window shown in Figure 20. The window lists all existing user accounts identified by their first name, last name, organization, and email. On this window, the user can perform the following tasks:

- Create a new user account by first clicking the **Add New User** button to open a form shown in Figure 21, and then fill out the user account information, including the general user information, the assigned password, and the account user type.

- Update an existing user account by clicking the **Edit** action link.

- Delete an existing user account by clicking the **Delete** action link.


Manage User Accounts

First Name	Last Name	Organization	Email	Action	Action
Kaiyu	Liu	FIU Lehman Center	liukaiyu@gmail.com	Edit	Delete
John	Doe	Florida Int'l University	admin@fiu.edu	Edit	Delete
Yleana	Baez	FDOT District 1	Yleana.Baez@dot.state.fl.us	Edit	Delete
Lawrence	Massey	FDOT District 1	Lawrence.Massey@dot.state.fl.us	Edit	Delete
Rax	Jung	Florida Turnpike Enterprise	Rax.Jung@dot.state.fl.us	Edit	Delete
Albert	Gan	FIU Civil Engineering	gana@fiu.edu	Edit	Delete
Kyle	Purvis	FDOT District 1	Kyle.Purvis@dot.state.fl.us	Edit	Delete

Add New User

Figure 20: Window for Managing User Accounts

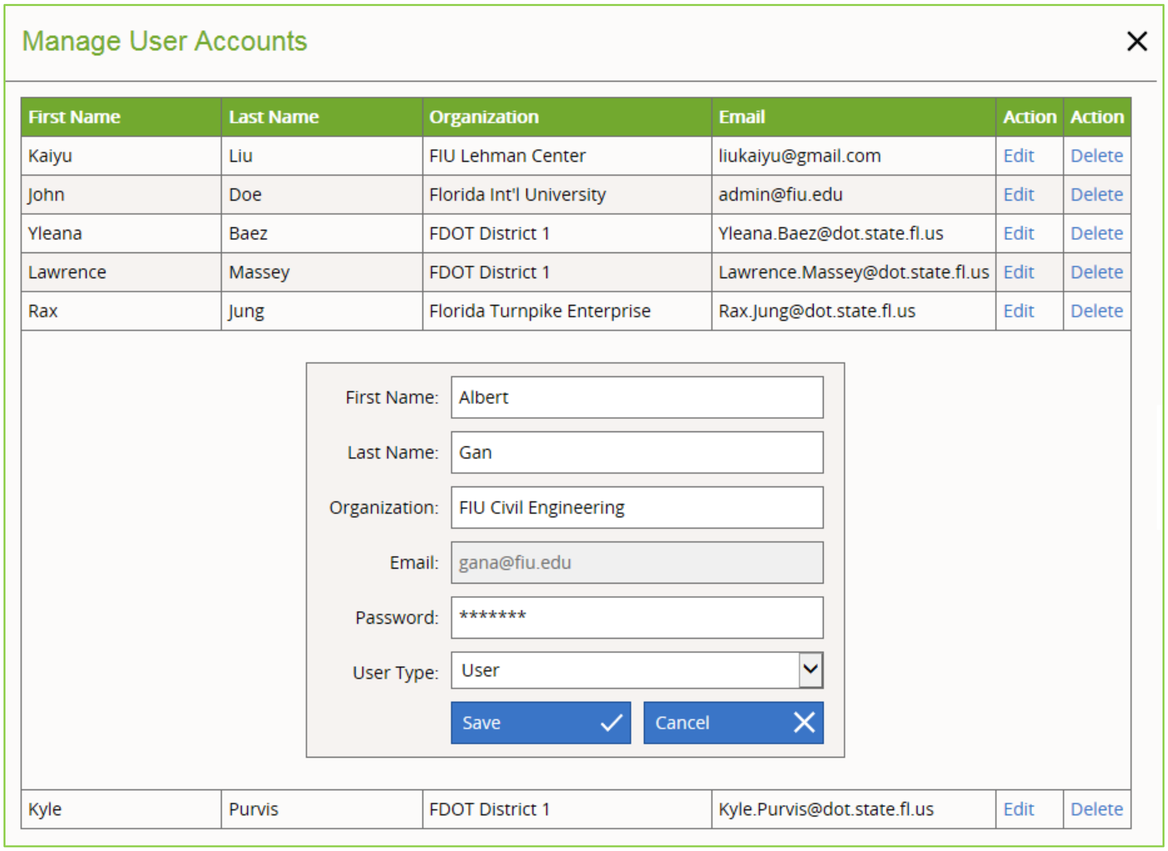


Figure 21: Data Entry Form for Creating a New User Account