GREEN GENERATES GREEN

Final Report

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Abstract: This project reflects a collaboration between Tennessee Department of Transportation (TDOT) and project team members from the University of Tennessee aiming to understand and improve Tennessee's transportation system sustainability and design a plan of action. The project team members started by using results from text analytics to determine sustainability actions discussed in the literature and taken by other state departments of transportation. The result was a series of well-defined performance measures developed by team members. The performance measures highlight the ease with which TDOT personnel can transfer cost-effective green practices from other places to their divisions. Furthermore, in line with the "green generated green" concept, cost-benefit and cost-effectiveness analysis are used to provide examples of sustainable strategies and their impacts in terms of performance measures. A TDOT Division Directors' survey provides a baseline of sustainability practices, and indicated a willingness to embrace sustainability concepts. Using this information, the report provides concrete action items for next steps that TDOT can take to implement specific sustainability strategies. Finally, potential funding sources for recommended sustainable projects provide methods for implementation.

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Short Summary

Sustainable transportation involves providing accessibility and mobility in the most efficient and safe manner while being a good steward of public funds and environmental resources. More broadly, sustainability is defined in ecology as the "capacity to endure" over a long time. This project was a collaboration between the Tennessee Department of Transportation and the project team from the University of Tennessee that designed a plan of action for improving the sustainability of Tennessee's transportation system. Project members used results from text analytics to determine sustainability actions taken by other state departments of transportation. A series of well-defined performance measures is listed. The performance measures highlight the ease with which TDOT personnel can transfer cost-effective green practices from other places to their divisions. Furthermore, in line with the "green generated green" concept, cost-benefit and cost-effectiveness analysis are used to provide examples of sustainable strategies and their impacts in terms of performance measures. A TDOT Division Directors' survey provides a baseline of sustainability practices, and indicated a willingness to embrace sustainability concepts. Using this information, the report provides concrete action items for next steps that TDOT can take to implement specific sustainability strategies. Finally, potential funding sources for recommended sustainable projects provide methods for implementation.

Executive Summary

Sustainable transportation involves providing accessibility and mobility in the most efficient and safe manner while being a good steward of public funds and environmental resources. More broadly, sustainability is defined in ecology as the "capacity to endure" over a long-time horizon. The Tennessee Department of Transportation (TDOT) can integrate sustainability practices, protocols, procedures and policies in its planning and day-to-day operations in order to improve the performance of the Tennessee's transportation system. This report provides a framework that is based on defining sustainability as the capacity to endure and for sustainable strategies to be cost-effective, in line with the concept of "green generates green."

In July and August 2017, project team members at the University of Tennessee's Center for Transportation Research conducted a survey of fifteen TDOT Division Directors as part of the "Green Generates Green" project. TDOT division participants included Aeronautics, Central Services, Construction, Environmental, Freight Logistics, Long-range Planning, Maintenance, Materials and Testing, Multimodal, Roadway Design, Right-of-way, Strategic Planning, Strategic Transportation Investments, Structures and Traffic Operations.

The 22-question survey included five sections: Division Background Data, Policy Information, Cost-Benefit Information, Barriers to Sustainability and Sustainability Practices of Other Departments of Transportation (DOT). The survey provided a summary of current and desired sustainability actions planned by TDOT personnel.

As a continuation of the survey, Division Directors met in March 2018 in order to provide input on the next steps for TDOT should take to integrate sustainability policies, protocols and procedures into TDOT operations. Researchers from the Lipscomb University Institute for Sustainable Practice used a weighted metric so that directors could identify a priority list of actions. This list provides a series of guidelines for TDOT personnel.

Additionally, using data (text) mining techniques, the team for this "Green Generates Green" project performed analysis on other transportation agencies' best sustainability strategies and programs. The goal was to mine for data and find specific examples of sustainability initiatives currently practiced by other DOTs that are applicable to TDOT divisions. The resultant data set includes approximately 40 reports pertaining to sustainability, and more than 50 specific examples of sustainability initiatives used by other DOTs.

Finally, based on the text mining results, the project team used an ease-of-transferability framework to identify specific actions the fifteen divisions surveyed could implement. This framework defined specific sustainability examples that would be easy or moderately easy to implement into each TDOT Division. Additionally, we identified and included high impact strategies for Tennessee and potential funding sources.

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1.0 INTRODUCTION

Sustainable transportation implies providing accessibility and mobility in the most efficient and safe manner while being a good steward of public funds and environmental resources. More broadly, sustainability has also been defined in ecology as the "capacity to endure" over a long time. Approaches to improving the sustainability of a transportation system typically considers a wide range of issues that affect, or are affected by, the system. A sustainability framework is needed that encourages sustainable actions that are cost-effective, i.e., green practices that generate a good return on investment.

Various practices can contribute to sustainable transportation. For example, sustainable options include using recycled materials in construction projects, retrofitting fleets to reduce vehicle emissions, or investing in multimodal infrastructure to provide more transportation options to the public. Due to financial feasibility concerns, it is important to make informed decisions based on sustainable strategies that offer the most benefits. Therefore, we must determine what sustainable practices are feasible and, given a set of options, which ones are cost-effective. In this report, the project team presents an approach that is ideally suited for exploring sustainable practices and assessing their long-term value and success in Tennessee.

Decisions that improve transportation systems are affected by the distribution of costs and benefits that various stakeholders accrue. Economic analysis of sustainable transportation investment decisions examines how to make the best use of constrained resources over time. It can help define issues and assess benefits and costs that achieve sustainability goals. When evaluating projects for inclusion in plans and programs, transportation agencies are increasingly considering the return-on-investment (ROI). However, some of the benefits of sustainability projects are not traditionally included in benefit-cost analysis.

This project deals with developing a methodology that quantifies the key economic, social, and environmental benefits to evaluate return-on-investment of sustainable transportation projects. We use a benefit-cost analysis (BCA) to measure the return-on-investment for available feasible options. The method developed in this research will better reflect the benefit of sustainable strategies and help TDOT make informed decisions about sustainable options.

The objective of this project is to establish a conceptual framework that measures return-on-investment for potential strategies and programs for sustainable transportation. The project team developed performance measures that assess the return-on-investment for sustainable transportation strategies and programs that includes traditional transportation metrics, but also incorporate unique economic development opportunities from sustainable projects.

To this end, the Tennessee Department of Transportation and the project team from the University of Tennessee collaborated to understand and potentially improve Tennessee's

transportation system sustainability and design a plan of action. The project team members started by using results from text analytics to determine sustainability actions discussed in the literature and taken by other state departments of transportation. The result was a series of well-defined performance measures developed by team members. The performance measures highlight the ease with which TDOT personnel can transfer cost-effective green practices from other places to their own division. Furthermore, cost-benefit and cost-effectiveness analysis are used to provide examples of sustainable strategies and their impacts in terms of performance measures. A TDOT Division Directors' survey identified a current baseline of sustainability practices, as well as a willingness to embrace sustainability concepts. Using this information, the report provides concrete action items for next steps that TDOT Division Directors can take to implement specific sustainability strategies. Finally, potential funding sources for recommended sustainable projects provide methods for implementation.

2.0 REVIEW OF SUSTAINABLE PRACTICES

In this chapter, we identify and discuss sustainable practices across the United States. To achieve this goal, the project team performed text mining techniques to extract vital information from retrieved data from state Departments of Transportation (DOT).

Text Analytics, also known as text mining, is the process of examining large collections of written documents in order to generate new information and to transform the seemingly unstructured text into structured knowledge for use in further analysis. Text mining identifies facts, relationships and assertions that would otherwise remain buried in the mass of textual big data. These facts are extracted and turned into structured data for analysis, visualization, integration with structured data in databases or warehouses, and further refinement using machine learning (ML) systems.

Figure 1 summarizes the stages of text mining. The first stage is identifying relevant documents by conducting online searches through state DOT websites. Section 2.1 discusses the specifics of this stage. The second step is transforming the document text into a machine-readable format by performing text pre-processing. The document is further refined by removing unwanted words such as stop words (i.e. common words like “and”, “at”, “This”, “The”, etc.), and unnecessary or unwanted information such as lists of content, figures, and tables. Other removal techniques include stemming words, which is the process of reducing the inflected words to their base form (e.g., “save”, “saves”, “saving” reduced to the stem “sav”), and lemmatization, which is the process of grouping different forms of the same word (e.g. “stop” is the lemma for “stopped”, “stopping”, “stops”). Stage three, known as the derived dataset, extracts crucial information after conducting the textual analysis on the data. Finally, the analyzed information is mined to synthesize the information into knowledge.

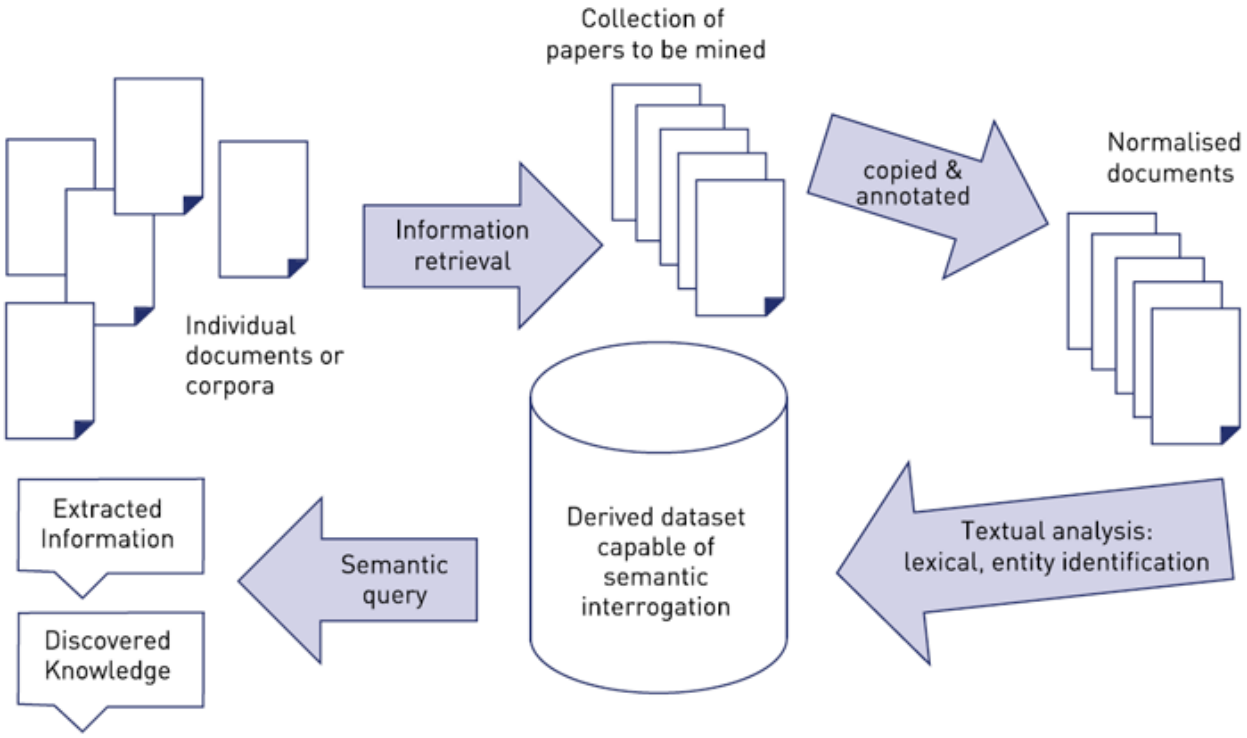

Figure 1: Stages in the Text Mining Process

2.1 Identifying Relevant Documents

A review of sustainable practices across the United States includes a survey of current sustainable practices of the Tennessee Department of Transportation (TDOT), a review of other transportation agencies, the development of measures on return-on-investment, a recommendation of best practices in sustainability and, finally, an assessment of their transferability or implementation feasibility in Tennessee. To obtain a sense of sustainable transportation practices across the United States, the project team began by searching through state DOT websites to locate plans or documents related to sustainable transportation activities. Based on this search, the project team was able to identify 196 documents pertaining to sustainability practices in some way. This includes documentation that may not have addressed sustainability in a direct way, but as a periphery to the main topic. Figure 2 shows the distribution of sustainability-related documentation across the United States. The green states indicate DOTs with materials directly relating to sustainable transportation, while yellow states indicate DOTs with partial or indirect materials relating to sustainable transportation. Some states, shown in white, may have sustainable documentation, but that documentation could not be retrieved.

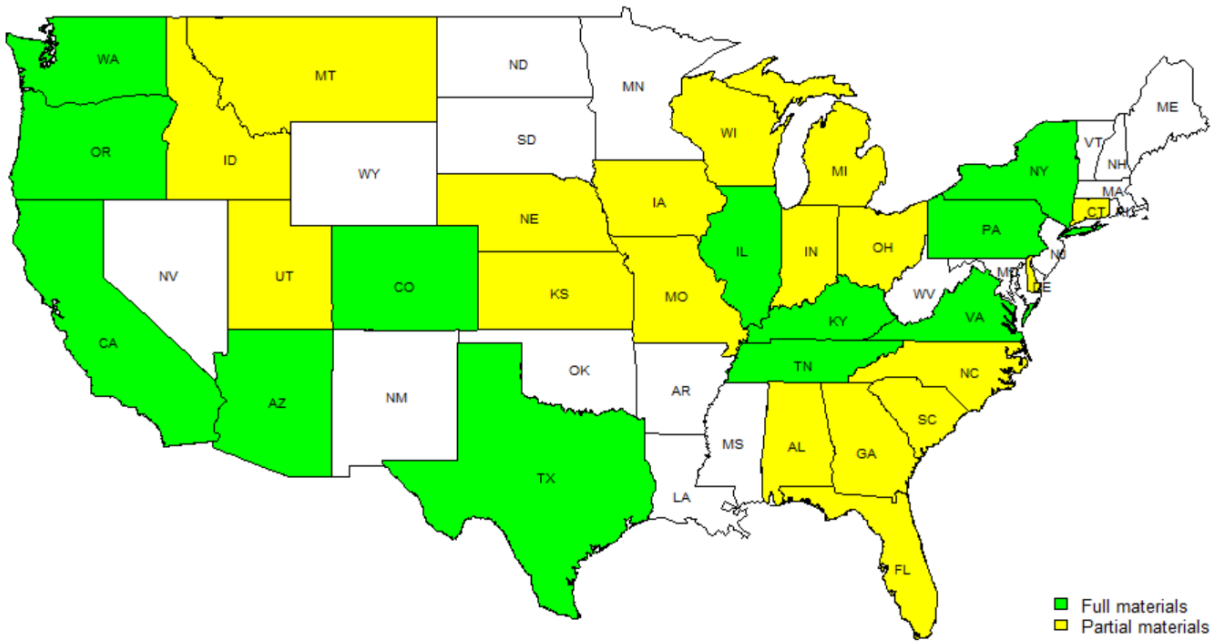

Figure 2: Distribution of Sustainability Materials Across the United States

Table 1 lists the number of reports or documents found relating in any way to the field of sustainable transportation. These reports are categorized as high (***), moderate (**) and low (-) in their relevance to sustainability. This study reviews and applies text mining technique on reports generated by state DOTs that are considered highly related to sustainable transportation. Finally, this project selects seven reports from Tennessee's DOT, four reports from surrounding DOTs, and eight other DOT reports.

2.2 Comparison of Sustainable Practices in Different DOTs Using Text Mining

In this section, we performed rigorous text mining analysis to study the sustainable practices in Tennessee and compare the results with the ones from surrounding and other DOTs. Word clouds are used to identify the most prevalent topics/words contained in sustainability-related documents. Based on the most prevalent words, we can use topic modeling technique to identify thematic concepts or emerging topics buried in textual big data. As a result, concise meaningful insights can be obtained regarding sustainable transportation practices in a particular domain, which otherwise would be very difficult to obtain if not impossible. Finally, TDOT sustainability practices are compared with strategies suggested by the participants of the Smart City Challenge.

Table 1. Relevance of Documents to Sustainability

State DOT	Reports	Relevance to sustainability	State DOT	Reports	Relevance to sustainability
Alabama DOT	4	**	Minnesota DOT	4	-
Alaska DOT	1	-	Missouri DOT	2	**
Arizona DOT	6	***	Montana DOT	3	**
Arkansas DOT	2	-	Nebraska DOT	8	**
California DOT	6	***	Nevada DOT	1	-
Colorado DOT	7	***	New Jersey DOT	3	-
Connecticut DOT	2	**	New York DOT	11	***
Delaware DOT	2	-	North Carolina DOT	9	**
District of Columbia DOT	4	-	North Dakota DOT	1	-
Florida DOT	13	**	Ohio DOT	1	**
Georgia DOT	9	**	Oregon DOT	1	***
Illinois DOT	5	***	Pennsylvania DOT	5	***
Indiana DOT	3	**	South Carolina DOT	4	**
Iowa DOT	5	**	South Dakota DOT	1	-
Kansas DOT	2	**	Tennessee DOT	19	***
Kentucky DOT	4	***	Texas DOT	3	***
Louisiana DOT	2	-	Utah DOT	2	**
Maine DOT	1	-	Virginia DOT	5	***
Maryland DOT	11	-	Washington DOT	9	***
Massachusetts DOT	5	-	Wisconsin DOT	3	**
Michigan DOT	5	**	Wyoming DOT	2	-

2.2.1 Sustainable Practices in Tennessee Department of Transportation

For the text mining analysis under this section for Tennessee reports and documents, the project team used seven TDOT publications. These included the following:

1. Sustainable Tennessee Agenda, A Project of Tennessee Environmental Council;
2. Advancing Sustainable Transportation in Tennessee, provided by Ben Bolton;
3. Tennessee Environmental Conference: Sustainability at Today's TDOT;
4. Sustainable transportation in Tennessee: strategies for energy and environmental solutions;
5. TDOT 25-year long-range transportation policy plan: plan summary;
6. Financially Sustainable Transportation (provided by Mr. Toks Omishakin), and
7. Sustainability and transportation in Tennessee (provided by Alan Jones).

As mentioned previously, prior to analyzing the data, text cleaning procedures were completed. Figure 3 depicts the word cloud of the TDOT documents. It should be noted that we have excluded some words not directly related to sustainability (i.e. year, program, state) to provide more accurate outcomes. Based on the results, it can be inferred from word size that most documents contain words related to energy, environment, policy, fuel, emissions, reduction, cost, water, public and work.

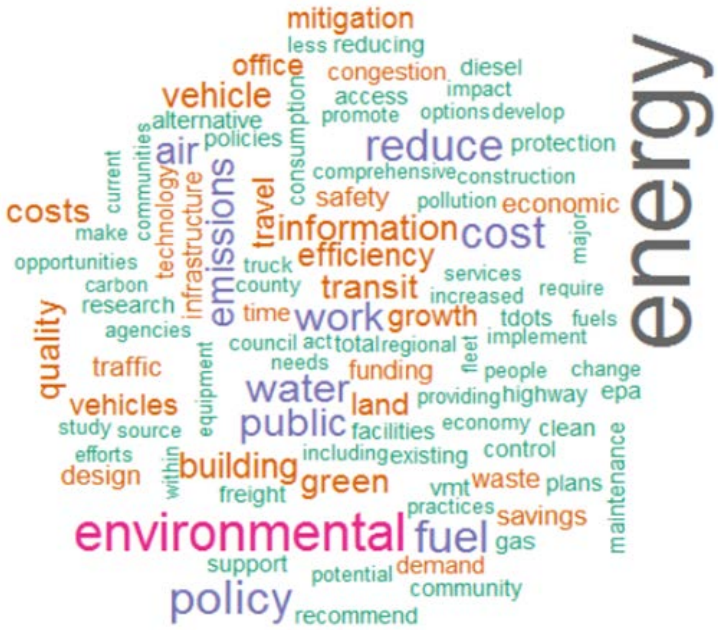

Figure 3: Word Cloud of Tennessee DOT Documents

Although the word-cloud does not provide detailed information regarding phrases or their context in the documents, it provides some insights regarding the general topics. As a result, we conducted a more advanced analysis called topic modeling, which is a well-known technique in the text analysis field that attempts to automatically identify and extract topical keywords mentioned in documents to derive hidden patterns in the data. Based on the keywords identified in frequency analysis (Figure 3), an inclusion dictionary is then manually constructed to define more appropriate thematic concepts. Similar words are then assigned to each of the different categories in the inclusion dictionary. When combined with natural language processing algorithms and statistical techniques, the inclusion dictionary provides a rigorous mechanism for extracting key thematic concepts. In this study, factor analysis is used as the main statistical procedure used for topic extraction. Qualitative Data Analysis (QDA) software was used to search and find keywords in the documents. Table 2 shows the results of factor analysis and identify key "topics" and the corresponding "text phrases" in seven TDOT documents. The statistics shown in Table 2 are defined as:

- EIGENVAL- Eigenvalue of extracted words that are related to the keywords in some way. A higher numeric value indicates a stronger relationship.
- %VAR - Percentage of variation calculates the percentage of disparity among keywords;
- FREQ - Frequency of keywords provides the total count for all of the selected keywords;
- CASES - Number of cases; in Table 2, each of the seven TDOT documents is considered one case; the total number of documents in which the keywords are in;
- %CASES - Percentage of cases; in this example the percentage of the total number of documents in which the keywords are found.

Based on the Eigenvalue results in Table 2, the top five keyword topics found in TDOT documentation refer to Bicycle/Pedestrian Travel Modes with an Eigenvalue of 8.26; Biofuels and Renewable Energy with an Eigenvalue of 4.03; Landfills, Recycling and Waste Management with an Eigenvalue of 3.92; Fuel Prices with an Eigenvalue of 3.50, and Collision Notification and Traffic Control with an Eigenvalue of 3.40.

The similarity plot of phrases is used to identify phrases containing similar words used in a similar context and not just keywords, that when matched with other documents indicate strong similarity between the documents. Figure 4 shows the similarity plot for sustainable practices in Tennessee. Based on the plot, the most similar phrases contain the following words:

1. Energy related phrases containing words such as fleet management, flexible work schedules, renewable, buildings, and communities;
2. Safety related phrases containing words such as freight and alternative travel (i.e. bicycle, and transit);
3. Emission related phrases containing words such as fuel, vehicles, climate, vehicle miles traveled (VMT), biofuel, light-duty vehicle, and asphalt, and
4. Waste management related phrases containing words such as waste, water, pollution, landfill, mowing and wildlife.

Table 2: Key Topics in TDOT Documents

NO.	KEY TOPICS	KEYWORDS/TEXT PHRASES	EIGENVAL	% VAR	FREQ	CASES	% CASES
1	Bicycle; Pedestrian	Bicycle; Pedestrian; Waling; Bike; Rail; Bicycling; Transit; Public Transit; reduce VMT; Bus	8.26	0.81	170	7	100.00%
2	Biofuels; Renewable Fuels	Biofuels; Renewable Fuels; Biodiesel; Fleets; Petroleum; Petroleum consumption	4.03	0.68	57	5	71.43%
3	Landfills; Material	Landfills; Materials; Recycling; Waste; Water; Raw Materials; Recycled Pollution; Pollutants; Waste Management; Recycling Centers	3.92	0.76	187	6	85.71%
4	Fuel Price	Percent Increase; Fuel Price; Fuel Economy; Revenue; Fuel Maintaining; Fuel Efficiency; Vehicle; fuel Prices; Funding	3.50	0.74	251	7	100.00%
5	Collision; Collision Notification	Collision Notifications; collision; Adaptive Cruise; Traffic Flow; Buses; Land; speed; Trucks	3.40	0.68	68	5	71.43%
6	Mow; Reduced Mowing	Mowed; Reduced Mowing; Public Awareness; Naturalized Mowing; Public Funds; Wildflower Program; Low Cost; Sustainable Landscaping; Save Money; Mowing costs; Mowing; Good	3.33	0.79	90	5	71.43%
7	Telecommuting; Flexible Hours	Limited Telecommuting; Flexible Hours; Reduced Fuel consumption; Reduce Energy consumption; Mobile Source Emissions; Commute; congestion; Reduced; Protect	3.24	0.79	137	7	100.00%
8	Hybrid Vehicles; Hybrid	Hybrid Vehicles; Hybrid; Public Transportation; Battery; Percent Increase; Electric; Waste Management; Efficient Vehicles; Vehicle Technology; Fleets	3.16	0.69	46	2	28.57%
9	Cleaning; Tunnel Cleaning	Cleaning; Tunnel cleaning; Tunnel; Maintenance of Traffic; Treatment; Cost Savings; Save Money; Materials; Build; Schedule; Life	3.08	0.73	108	6	85.71%

10	Heating; Cooling	Heating; cooling; Heat; Improving; cooling systems; Energy Efficient; Saved; Water Heating	3.05	0.68	101	4	57.14%
11	Stream Mitigation; Wetland	Stream Mitigation; Wetland; Mitigation; Waters; Wetlands; Aquatic; Clean Water; Aquatic Resources	2.93	0.63	96	5	71.43%
12	Light duty Diesel; Light Duty Gasoline	Light Duty Gasoline; Light Duty Diesel; Heavy Duty Gasoline; Diesel; Truck	2.89	0.67	86	7	100.00%
13	Access and Mobility; Good Stewart	Access and Mobility; Good Steward; Public Funds; Effective; Efficient	2.84	0.66	71	6	85.71%
14	LED Lights; Traffic Signals	Led Lights; Traffic Signals; Replaced; Diesel Vehicles; Asphalt; Hybrid Vehicles; Biodiesel; GHG emissions; Recycled	2.81	0.70	35	3	42.96%
15	Transit Oriented; Smart Growth	Transit Oriented; Smart Growth; Options; Emission Reductions; Planning; Technical Assistance; Land	2.67	0.69	2.36	6	85.71%

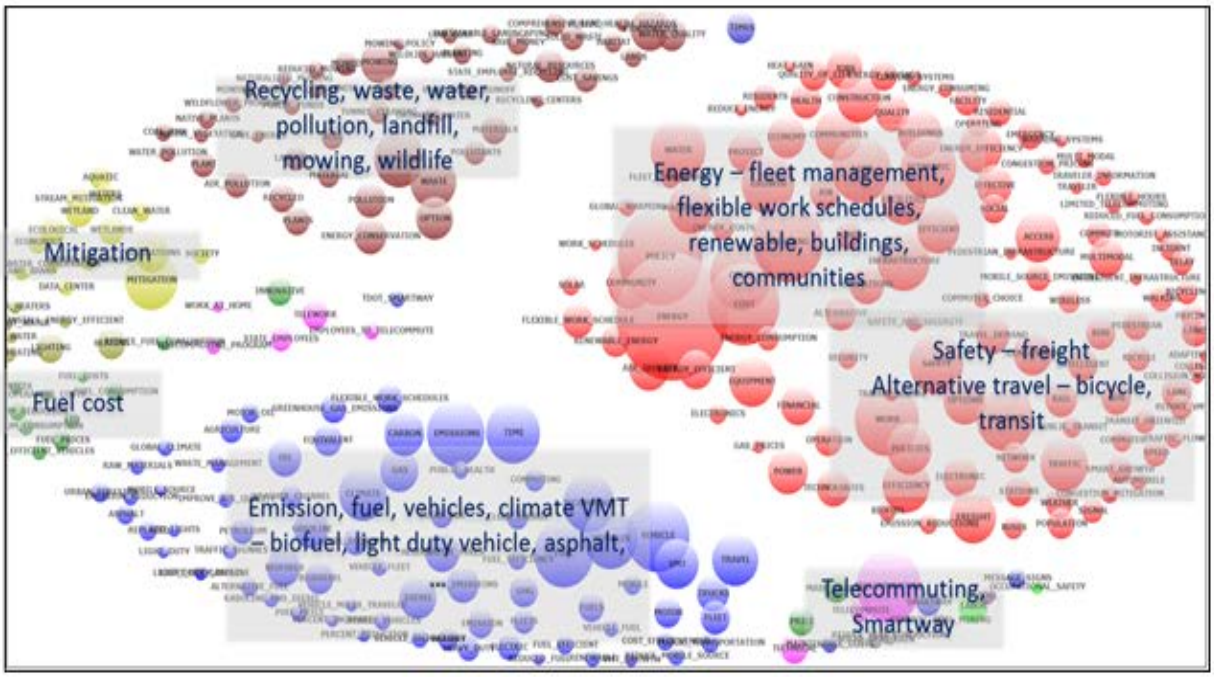

Figure 4: Similarity Plot of the Phrases in TDOT Documents

2.2.2 Sustainable Practices in Adjacent DOTs

In this section, the project team analyzed the documents published by three DOTs adjacent to the State of Tennessee - Kentucky, North Carolina, and Virginia. Various text mining techniques (i.e. word cloud analysis, topic modeling and similarity plots) were used to analyze the following four documents:

1. Virginia DOT: Department of Veteran Affairs Strategic Sustainability Performance Plan;
2. Kentucky DOT: Sustainable practices and related performances at state highway agencies;
3. North Carolina DOT: Greening North Carolina Travel and Tourism: Tips for Sustainable Practices in Tourism, and
4. North Carolina DOT: Green Ports Strategies.

Figure 5: Word Cloud of Adjacent DOTs

Figure 5 provides the word-cloud of the adjacent DOTs. The results indicate that documents contain information on energy, green, water, information, environment, recycling, reduction, waste, and renewable. In our attempt to obtain deeper insights, we used a topic modeling technique. The results are summarized in Table 3. Based on the results for documents retrieved from adjacent DOTs, the following most prevalent topics are found: Energy Usage and Efficiency with an Eigenvalue of 4.45; Fuel Types with an Eigenvalue of 3.34; Alternative Fuel Vehicles with an Eigenvalue of 2.99; Hybrid Vehicles and Climate Conditions with an Eigenvalue of 2.82, and Energy Reduction with an Eigenvalue of 2.76.

Table 3: Key Topics in Adjacent DOT Documents

NO.	KEY TOPICS	KEYWORDS/TEXT PHRASES	EIGENVAL	% VAR	FREQ	CASES	% CASES
1	Energy Usage; Energy Efficient Lighting	Energy Usage; Energy Efficient Lighting; Energy Efficiency; Costs; Energy Costs; Energy Efficient; Air Conditioning; Air Pollution; Parking Lot	4.45	1.31	159	4	80.00%
2	Fuel Type; Hybrid Electric	Hybrid Electric; Fuel Type; Fuel Vehicle; Natural Gas	3.34	1.39	7	2	40.00%
3	Alternative Vehicles; Light Duty Vehicles	Alternative Vehicles; Light Duty Vehicles; Fuel Vehicles; Alternative Fuel Vehicles; Natural Gas; Alternative Fuels; GHG	2.99	1.32	41	4	80.00%
4	Plug in Electric; Climate Conditions	Plug in Electric; Climate Conditions; Hybrid Vehicles; Home To Work; Public Transportation	2.82	1.23	17	2	40.00%
5	Reduce Energy	Expected to Reduce; Reduce Energy; Energy Intensity; Building Energy; Percentage; Reductions; Percent; Reduction	2.76	1.22	184	5	100.00%
6	Low Flow; Gallons of Water	Low Flow; Gallons of Water; Reduce Water; Water Usage	2.65	1.27	12	3	60.00%
7	Health and Safety	Reduction Targets; Health and Safety; Health Care; Water Quality; Safety; Cost Effective	2.57	1.12	55	5	100.00%
8	Plug In Hybrid; Emission	Plug in Hybrid; Emission; Charging Infrastructure; Charging Station; Low Emission; Charging Stations; Electric Vehicles; Hybrid Vehicles	2.55	1.16	44	4	80.00%
9	Economic Benefits; Noise Pollution	Economic Benefits; Noise Pollution; Greenhouse Gas Emissions; Land; Solid Waste	2.49	1.15	36	4	80.00%
10	GHG Emission Reduction; GHG Reduction Targets	GHG Reduction Targets; GHG Emission Reduction; Reduction Goals; GHG Emissions; Reduction; Energy And Water; Reduction Target	2.43	1.08	67	4	80.00%
11	Costs And Benefits; Climate Change Impacts	Costs and Benefits; Climate Change Impacts; Climate Resiliency; Climate Adaptation; Climate Change; Climate; Climate Change Adaptation	2.42	1.12	102	3	60.00%
12	Fueling Stations; Flex	Fueling Stations; Rec Fuel Vehicles; Alternative; Cost Effective; Alternative	2.38	1.04	49	4	80.00%

	Fuel Vehicles	Fuels; Fuel					
13	Fossil Fuel; High Energy	Fossil Fuel; High Energy; Fuel Cell; Energy Intensive	2.30	1.01	13	3	60.00%
14	Bus; Reducing Energy	Bus; Reducing Energy; Energy Conservation	2.26	1.04	12	3	60.00%
15	Alternative Modes	Alternative Modes; Bicycling And Walking; GHG Reduction; Public Transportation; Reduction Strategies	2.21	1.05	10	2	40.00%

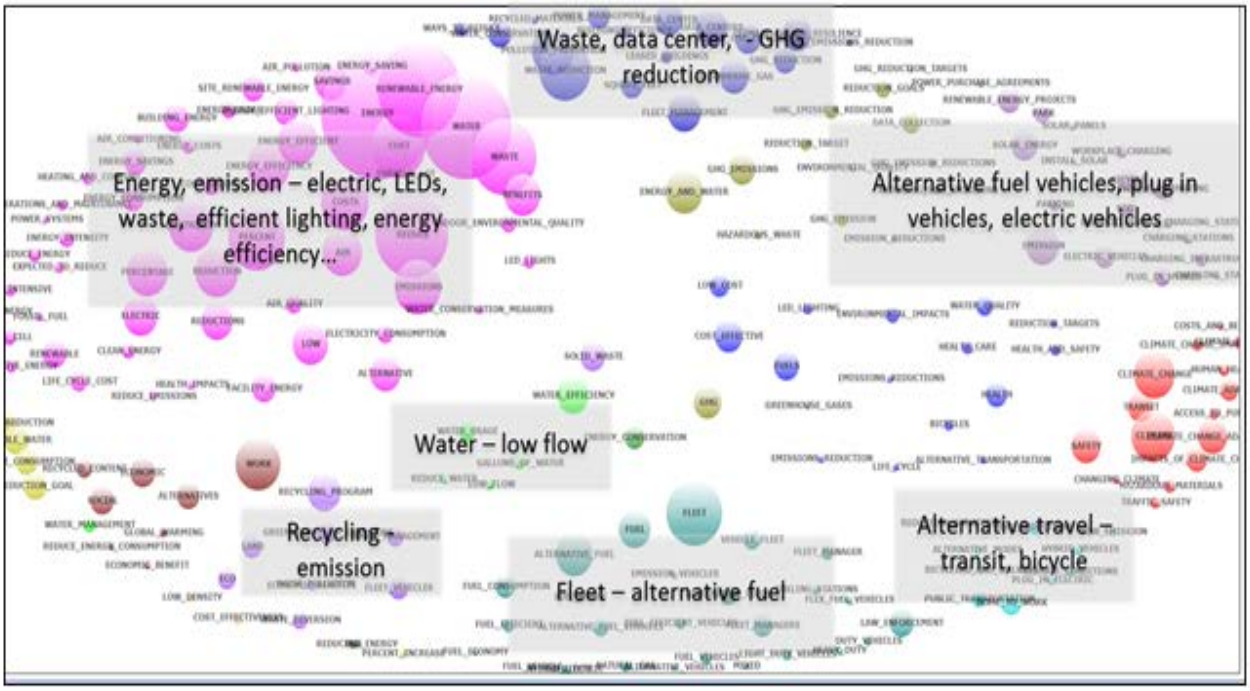

Figure 6: Similarity Plot of the Phrases in Adjacent DOT Documents

Figure 6 represents the similarity plot of phrases for the documents of adjacent DOTs. Based on the results, the main topics of phrases contained in the documents include:

1. Energy and Emissions, with words such as electric vehicles, LEDs, waste, efficient lighting, and energy efficiency;
2. Alternative Fueled Vehicles, with words such as plug-in vehicles and electric vehicles;
3. Waste or Pollutants, with words such as data center and greenhouse gas (GHG) reduction;
4. Alternative travel, with words such as bicycle and transit.

2.2.3 Sustainable Practices in Other DOTs

In this section, we analyze the reports and documents published by other DOTs in the United States. The documents from state DOTs that were chosen are considered mature in their evolution and iteration, which made the reports highly related to sustainability with details provided on their strategies and impacts utilizing specific performance measures. From the various reports reviewed, eight reports are considered highly related to sustainability. These include:

1. California DOT: Caltrans Strategic Management Plan;
2. California DOT: Road Map to Achieving Executive Orders;
3. Colorado DOT: Sustainability program;
4. Oregon DOT: Sustainability Progress Report;
5. Texas DOT: Development of a Transportation Sustainability Index for Urban Communities;
6. Texas DOT: Strategic plan;
7. US DOT: Strategic Sustainability Performance Plan, and
8. Washington DOT: Regional Greenhouse Gas and Vehicle Miles Traveled Reduction Strategies

Figure 7 provides the word-cloud of the most frequently cited words found in other DOTs reports and documents. Based on the results, these documents most frequently cite concepts relating to maintenance, station, energy, water, buildings, vehicles, emissions, data, reduction, equipment and facilities.

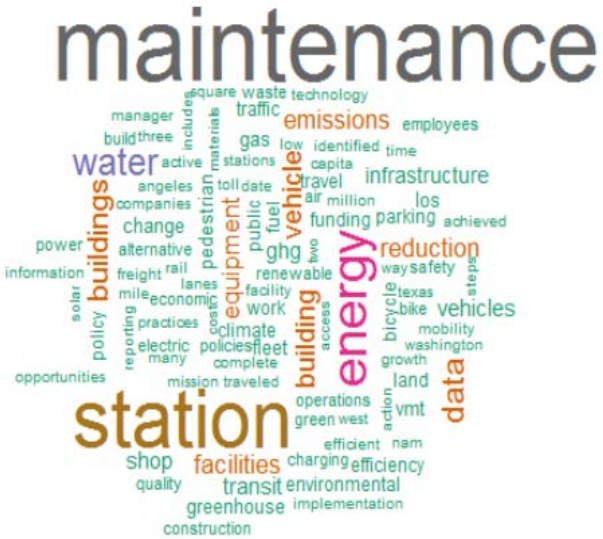

Figure 7: Word Cloud of Other DOTs

Table 4: Key Topics in Other DOTs

NO.	KEY TOPICS	KEYWORDS/TEXT PHRASES	ELIGENVAL	% VAR	FREQ	CASES	% CASES
1	LEDs, replace, incandescent; replace, diesel	LED Replace, Incandescent; Replace, Diesel; Annual, GHG Reduction; Light Reduction; Low Flow Toilets; Replace HMA; Low Flow Fixtures; Sign Lighting; Traffic Lights; Facility Lighting; Energy Reduction; Low Flow; Roadway Lighting; Pedestrian _Signals; Calculating GHG Emission	7.21	1.37	105	7	58.33%
2	Transit, bicycles	Bus Rapid Access; Bike on Transit; Rail access; Park and ride Facilities; Bus Rapid; Light Rail access; Local Bus	7.04	1.44	35	1	8.33%
3	Transit Oriented Developments; Energy Consumed	transit oriented developments; energy consumed; average speed; Bike lane; low income; low emission; walking distance; water consumption; mode split; vehicle miles; vehicle hours; VMT per capita;	6.59	1.29	88	12	100.00%
4	Access to Public; Vehicle Miles Traveled Reduction	Access to Public; Vehicle Miles Traveled reduction; Reduce Vehicle Miles-Travelled; Vehicle Miles Traveled Benchmarking; Reduction of Greenhouse Gas Emissions; Emissions Reductions; Affordable Housing; Vehicle Travel; Strategies to Reduce; Vehicle Miles Traveled; Capita Vehicle Miles Traveled	3.80	0.67	98	9	75.00%
5	Misc.: Plug in Hybrid Electric; Rubberized Hot Mix Asphalt	Plug in Hybrid Electric; Hybrid Electric; Safe Routes to School; Power Purchase; Gas and Electric; Bay Bridge; Air Conditioning; Light Duty; Vehicle Miles; Rubberized hot Mix asphalt; Hot Mix asphalt; Warm Mix asphalt	3.37	0.68	83	8	66.67%

To extract the most cited topics in the documents, topic modeling analysis was used. Table 4 depicts the top 5 topics in the documents based on keywords. The most frequently cited topics are related to Energy Reduction and Conservation (e.g. light-emitting diode (LED) lighting, and GHG reduction) with an Eigenvalue of 7.21; Alternative Transportation (e.g. bicycle, and light rail) with an Eigenvalue of 7.04; Transit Oriented Developments (TOD) with an Eigenvalue of 6.59; Public Access to transit options and VMT Reduction with an Eigenvalue of 3.80, and Hybrid or Electric Vehicles and Asphalt Mixtures that reduced energy consumption and were environmentally friendly with an Eigenvalue of 3.37.

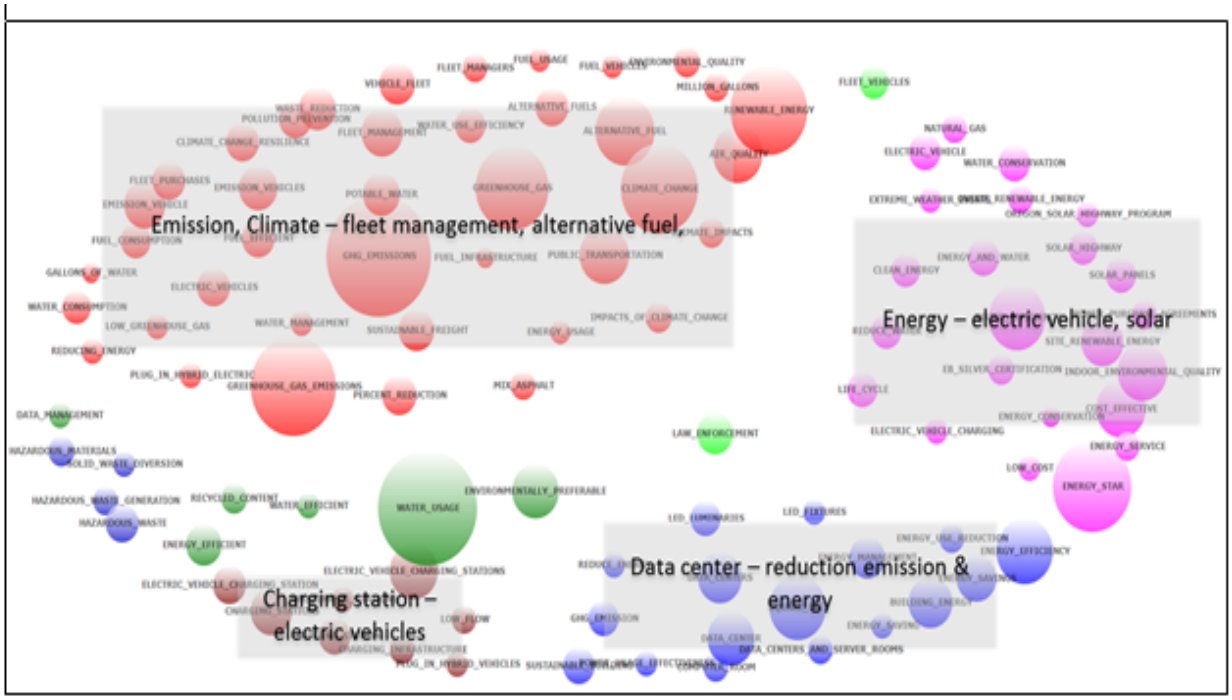

Figure 8: Similarity Plot of the Phrases in Other DOT Documents

The similarity plot of phrases for the other DOTs is provided in Figure 8. Based on the results, it can be observed that the main topics discussed by other DOTs are:

1. Emission Reduction and Climate phrases with words such as fleet management and alternative fuel;
2. Energy phrases with words such as electric vehicles and solar energy;
3. Charging Station phrases with words such as electric vehicles, and
4. Data Center phrases with words relating to emission reduction and energy.

2.2.4 Smart Cities

Project team members continued their text mining activities to include the perspectives of cities who competed in the U.S. Department of Transportation's Smart Cities Challenge. By expanding on the concept of the internet of things (IoT), which examines the processes that allow a network of connected devices (e.g. vehicles, and home appliances) to interact and exchange data into large data ecosystems, we used text mining techniques (i.e. word cloud, keyword identification and similarity plots of phrasing) on documents written by the finalists of the U.S. Department of Transportation's (USDOT) Smart City Challenge. In particular, by using data, applications, and technology, the participant cities were asked to propose and develop ideas for a connected and integrated, first-of-its-kind smart transportation system for quick, cost-effective, and efficient movement of people and goods, thus making it very relevant to the scope of the present study. In particular, we analyzed the seven Smart City Challenge Finalists' vision narratives, including Austin (Texas), Columbus (Ohio), Denver (Colorado), Kansas City (Missouri), Pittsburgh (Pennsylvania), Portland (Oregon), and San Francisco (California). The word-cloud of the documents is shown in Figure 9. It can be observed that the most frequently identified words in the seven vision narratives include data, smart, mobility, system, vision, transit, technology, public and traffic, as well as information, connected and infrastructure.

Figure 9: Word Cloud of Smart Cities Documents

In order to gain more precise information, the team used topic modeling to extract the most frequently cited keywords. As seen in Table 5, the top five key topics in the seven smart cities finalist documentation include Population Growth and the Economy with an Eigenvalue of 16.41; Public and Private Partnerships with an Eigenvalue of 4.47; Department of Transportation-Federal Highway (DTFH) Grant Opportunities with an Eigenvalue of 4.30; Charging Stations for Electric Vehicles with an Eigenvalue of 4.12, and Architectural Standards with an Eigenvalue of 4.00.

Table 5: Key Topics in Top 7 Smart Cities

NO.	KEY TOPICS	KEYWORDS/TEXT PHRASES	EIGENVAL	% VAR	FREQ	CASES	% CASES
1	Population Growth; Economic	Growth; Economic; Jobs; Neighborhoods; Growing; Employment; Residents; Population; Income	16.41	0.83	463	7	100.00%
2	Public and Private	Private; Sector; Partners; Public; Community; Organizations	4.47	0.75	809	7	100.00%
3	DOT (funding)	DTFH; RA; Notice; Funding; Department; Opportunity	4.30	0.90	348	7	100.00%
4	Charging Stations; EV	Charging; EV; EVs; Stations; Electric; Grid; Energy; Met; Electrification	4.12	0.84	515	7	100.00%
5	Architecture & Standards	Standards; Architecture; CVRIA; National	4.00	0.65	250	7	100.00%
6	UB; Mobile PDX	UB; POX; Mobile; Portland; Zones; TriMet; Demonstration; Priority	3.71	0.86	608	7	100.00%
7	Avenue BRT; Leverage Federal	BRT; Leverage; Federal Avenue; Cota; Investment; Funds; Project	3.46	0.65	459	7	100.00%
8	Ride; Bike Share	Ride; Bike; Car; Sharing; Services; Share; Service	3.16	0.71	735	7	100.00%
9	San Francisco	Francisco; San; Municipal; Agency; Meeting	3.11	0.60	405	7	100.00%
10	Performance; Goals	Performance; Goals; Measures; Objectives; Identified; Plan	3.07	0.67	340	7	100.00%
11	SMARTPGH; Pittsburgh	SMARTPGH; Pittsburgh; CMU; Consortium	2.98	0.64	271	4	57.14%
12	Connected Vehicles	Vehicles; Automated; Connected; Autonomous; Vehicle; Automation	2.84	0.77	856	7	100.00%
13	Business Models	Models; Strategic; Partnering; Business; Opportunities	2.79	0.63	299	7	100.00%
14	Delivery; Freight	Delivery; Freight; Logistics' Commercial	2.66	0.58	208	7	100.00%
15	Smart City	Smart; City; Mo; Kansas; Proposal; Challenge; Vision	2.57	0.62	2710	7	100.00%
16	Secure; Low-Cost	Secure; Cost; ICT; Low; Efficient; Communications; Devices; Information	2.51	0.63	567	7	100.00%
17	Risks; Mitigation	Risks Mitigation; Risk; Institutional; Engineering; Technical; Policy	2.48	0.54	290	7	100.00%
18	Climate Change; Safety, Efficiency	Curate; Change; Safety; Efficiency; Sustainability	2.45	0.58	335	7	100.00%

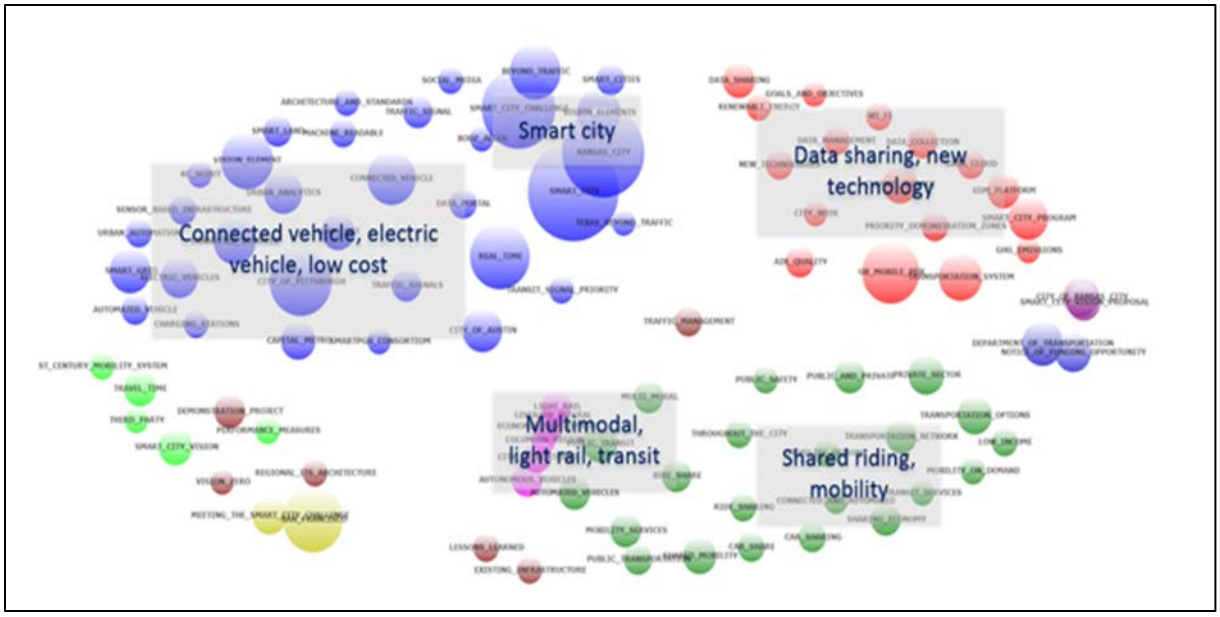

Figure 10: Similarity Plot of the Phrases in Smart Cities

Figure 10 provides the similarity plot of the phrases in the smart city documents for the top 7 cities. Based on the results, it can be inferred that the most frequently cited phrases deal with the following:

1. Smart cities;
2. Connected Vehicles phrases with words such as electric vehicle and low cost;
3. Data Sharing and New Technology;
4. Multimodal Transit phrases with words such as light rail, and
5. Shared Riding and Mobility.

2.2.5 Tennessee Smart Cities

Three cities from Tennessee (Nashville, Memphis, and Chattanooga) participated in the US DOT Smart City Challenge. Thus, we also analyzed vision narratives from of the participants in Tennessee. The results of the word cloud, key topics and similarity plot of phrases are found below.

As seen in Figure 11, the word cloud of vision narratives submitted by the Tennessee Smart Cities reveals the most cited concepts majorly relating to data and smart. Other words associated with the Tennessee Smart Cities include transit, metro, system, public, as well as infrastructure, information and traffic.

Table 6 highlights key topics found in documents from Tennessee's Smart Cities: Nashville, Memphis, and Chattanooga. The top five keyword topics include DTFH Grant Opportunities with an Eigenvalue of 5.14; Reduction and Improved Safety with an Eigenvalue of 3.60; Metropolitan and Davidson County with an Eigenvalue of 3.08; Strategic Choices and Elements with an Eigenvalue of 3.02, and Paratransit Service with an Eigenvalue of 2.67. Note that few of the words and relevant topics are common between the narratives of TN Smart Cities participants and TDOT sustainability-related documents. For example, the topics of transit/metro and traffic/congestion are more frequently cited in both contexts (see Table 2 and 6).

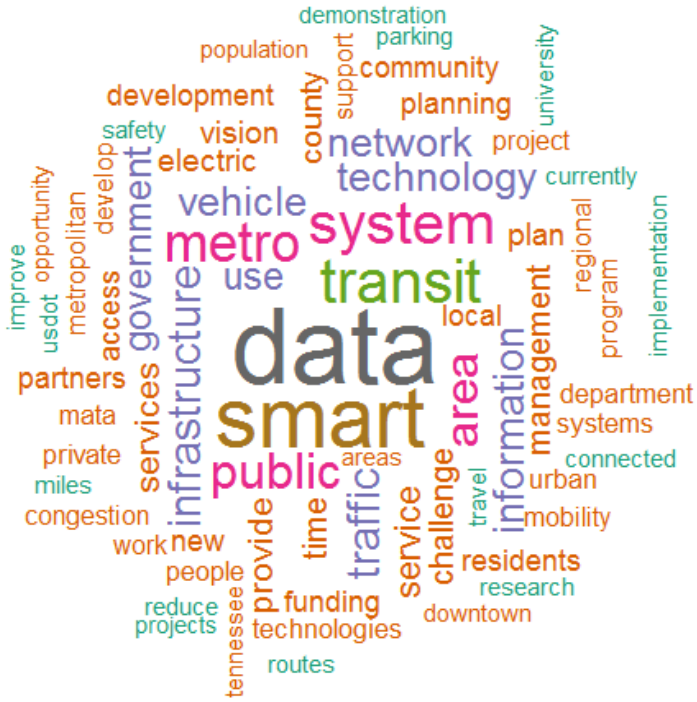

Figure 11: Word Cloud of Tennessee Smart Cities Documents

Table 6: Key Topics in Documents from Tennessee's Smart Cities

NO	KEY TOPICS	KEYWORDS/TEXT PHRASES	EIGENVAL	% VAR	FREQ	CASES	% CASES
1	DOT (funding)	Notice; DTFH; Opportunity; Plan; Chattanooga; Smart	5.14	1.80	638	3	100.00%
2	Improve Safety & Mobility	Reduce; Improve; Objective; Increase; Emissions; Safety; Change; Mobility; Sector; Study; Movement	3.60	0.99	246	3	100.00%
3	Davidson County; Metropolitan	Davidson; County; Metropolitan; Government; Nashville	3.08	1.08	448	3	100.00%
4	Element; Choices	Element; Choices; Strategic; Involved; User; Delivery; business; Architecture; Roadway; Analytics; Citizens; Grid; Land	3.02	1.04	236	3	100.00%
5	Med Route; Paratransit	Free; Route; Paratransit; Service; Bus; MATA; Routes	2.67	0.88	269	3	100.00%
6	Charging Stations; EV	Charging; Stations; EV; Electric; Grid	2.50	0.68	95	3	100.00%
7	Special Events	Events; Special; Conditions; Related	2.39	0.79	78	3	100.00%
8	Lyft; Uber	Lyft; Uber; Partnership	2.26	0.73	99	3	100.00%
9	Challenge; Memphis	Challenge; USDOT; Smart; City; Memphis	2.25	0.78	688	3	100.00%
10	Fiber Optic; Communication Network	Fiber; Optic; Network; Ep & Communications	2.19	0.77	201	3	100.00%
11	Airport	Airport; Shelby; FEDEX; Control	2.16	0.70	59	3	100.00%
12	Real-Time info	Time; Real; Information; Provide; Travel	2.13	0.72	341	3	100.00%
13	Population	Population; Total; Mid; Characteristics; Growing;	2.09	0.66	121	3	100.00%
14	Air Quality	Air; Quality; Congestion; Grant	2.00	0.68	103	3	100.00%
15	Risk; Vision	Risks; Risk: Vision; Security; Deployment	1.97	0.66	136	3	100.00%
16	Authority	Authority; Carta; Established	1.94	0.64	64	3	100.00%
17	Multimodal; Options	Multi; Options; Expand; Utilize; Setter	1.92	0.69	115	3	100.00%
18	Data	Data; Portal; Collected	1.89	0.64	260	3	100.00%
19	Distribution; Logistics	Distribution Logistics; Employment; Industry; Location	1.86	0.65	94	3	100.00%

20	Autonomous; AVs	Autonomous; AVs; Parking; Pilot; Test; Emerging; Ride	1.85	0.80	144	3	100.00%
21	Pedestrian	Pedestrian; Bicycle	1.85	0.68	41	3	100.00%
22	Streets; Neighborhood	Streets; Neighborhoods; Priority; Economy; Growing; Goals; Change		0.72	107	3	100.00%

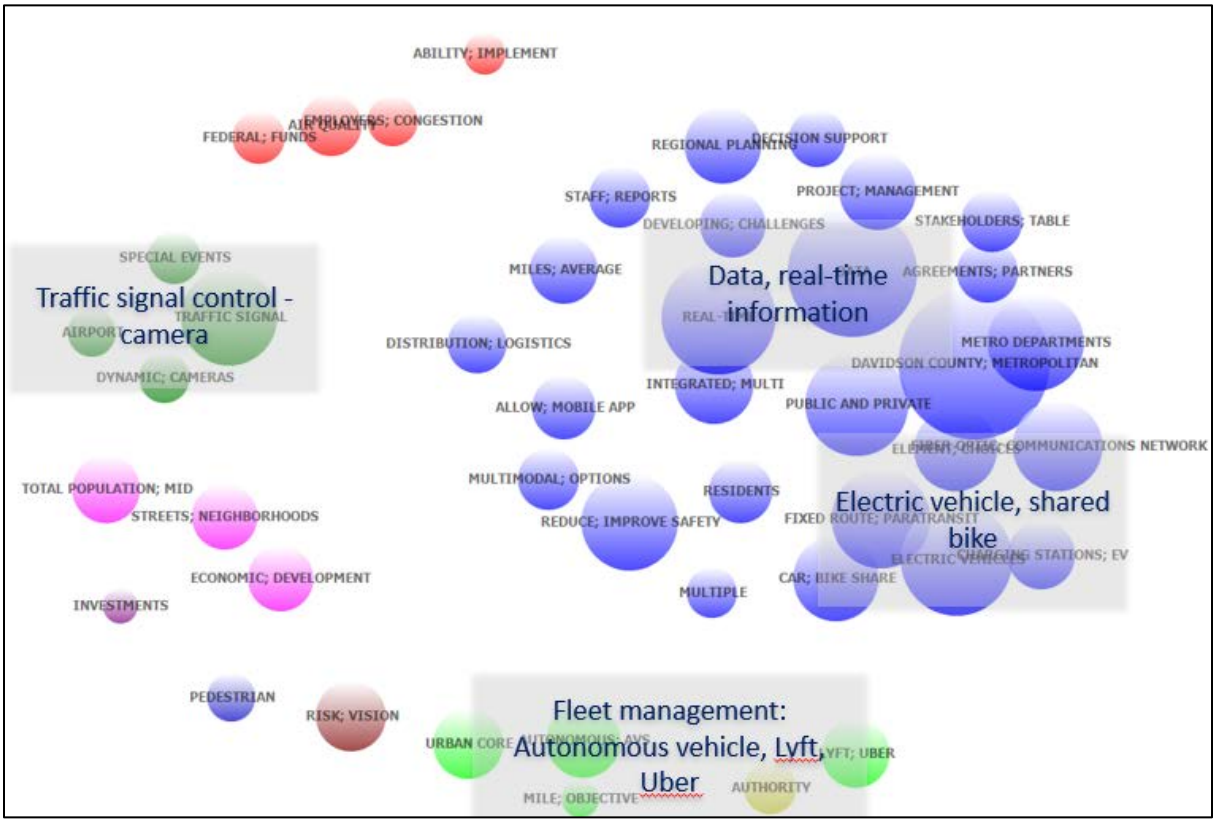

Figure 12: Similarity Plot of the Phrases in Tennessee Smart Cities

Finally, Figure 12 provides the similarity plot of the phrases in the Tennessee smart city documents for Nashville, Memphis and Chattanooga. Based on the results, it can be inferred that the most frequently cited phrases deal with the following:

1. Data phrases specific to real-time information;
2. Electric vehicles and Bike Sharing;
3. Fleet Management phrases with words relating to autonomous (automated) vehicles, and on-demand transportation (i.e. Lyft and Uber), and
4. Traffic Signal Control and Camera.

2.3 Successful Sustainable Strategies

The text mining results have provided insightful information regarding the most frequently used words in sustainability-related documents, the key topics found in the documents based on keywords, and the similarity of phrases across all documents analyzed. Given the lower specificity of text mining results, the findings should be interpreted in terms of "general information" on the attitudes contained in the retrieved documents. Finally, to create a catalog of successful strategies, we conducted a review of sustainable practices across the United States. Table 7 provides a summary of the strategies and their context-specific impact.

Table 7: Successful Sustainable Practices across the United States

State	Sustainable Strategy	Impact
US DOT	Deploy operations and management best practices for energy consuming and emission generating equipment, e.g., upgrading motors, boilers, HVACs, and chillers, compressors, and lighting.	Emissions: 34% reduction (Building & fleet) since 2008
	Reduce business air travel and ground travel, e.g., maintaining travel budget restrictions, installing technologies to facilitate remote meetings, telework or flexible work schedules	Emissions: 31% reduction (commuting & business air travel) since 2008
	Clean and renewable energy, e.g., install renewable on-site and retain corresponding renewable energy certificates (REC)	Energy: 15% of electric energy from renewable sources, including 3.75% from new sources
	Fleet management, a greater percentage of alternative fuels and increase the share of fuel-efficient, lower-emission vehicles, zero emission vehicles	Emissions: 26% reduction in fleet petroleum use in 2015 compared with 2005 Energy: 233% increase in alternative fuel use in 2015 compared with 2005
California DOT	Sustainable pavement: replace hot mix asphalt (HMA) with cold-in-place (CIP), rubberized hot mix asphalt (RHMA), and warm mix asphalt (WMA); Alternative fuel: replace gasoline with E85, or replace diesel with B5 and B20; Fleet strategies: HEVs, PHEVs, and BEVs; Road lighting: LEDs; Solar installations; Water: low flow in toilets or urinals; Indoor and Outdoor light reduction; Data center upgrade; Multiple travel: bicycle and transit; Carpool or vanpool;	Emissions: 10% reduction by 2015 and 20% reduction by 2020 against 2010
	Sustainable strategies, e.g., replace HMA with rubberized hot mix asphalt or WMA	Emissions: 61% reduction from construction of pavement and

		structure
	Installation/replacement of high-pressure sodium light fixtures with LED fixtures along the highway	Energy: 35-60% energy savings
Colorado DOT	Sustainable pavement, e.g., use recycled asphalt shingles and reclaimed asphalt paving (RAP)	Economy: savings of around $1.6 million in binder alone
	Encourage use of low-fuel consumption or electric vehicles, encourage carpooling, provide telecommuting or flexible work schedule	Economy and emission: qualitative
	Using recycled waste and wash water to produce a salt brine liquid deicer	Economy: CDOT Region 5 saved $394,030 in FY11
New York DOT	Renewable energy, e.g., solar installations	Economy: Saving 214 million kilowatt hours of electricity Energy: Producing at least 1.4 million kilowatt hours of electricity
Oregon DOT	Solar Highway Program	Energy: Offsets over one-third of the energy needed for freeway illumination at the site
	Increase the use of alternative fuels and vehicles in fleet	Economy and energy: qualitative
Texas DOT	Provide walkable community	Safety: 86% reduction in 'walking along the roadway' crashes
	Sustainable pavement, e.g., use recycled asphalt shingles (RAS) and reclaimed asphalt paving (RAP) in WMA and HMA	Economy: saving 50$ to 150$ million each year Emission: qualitative (Use of 90% WMA, 20% RAP and 2% RAS avoids approximately 113,300 tons/year of CO2 emissions)
Washington State DOT	Vanpool, carpool; car-share services; guaranteed ride home services; transit pass subsidies; employer outreach	Emissions: 3,801-ton reduction & additional 10% by 2014; Safety: 7.5 million reduction of VMT per year (based on home-work trips only) & additional 13% by 2014

	Add 15.2 miles of infill sidewalks; install new bicycle and pedestrian bridges; extend and connect non-motorized facilities in underserved communities; implement an active transportation marketing campaign; and complete crucial gaps and remove hazardous crossings along the trail system	Safety: reduction of VMT by 44 million
	Develop regional complete streets policy and encourage development of policies at the local level; increase alternative travel mode	Emissions: 58,269-ton reduction per year. Safety: An additional 91 million VMT reduction from 2006.
	Providing transit, non-motorized facilities and tolling	Emissions: 9% reduction from 2040 baseline.
	Improvements to future fuel efficient vehicles and low carbon fuels	Emissions: 25-43% reduction from 2040 baseline.

2.4 Summary

We performed three different text mining operations (i.e. word cloud analysis, keyword topic review, and similarity plot of phrases) on sustainability-related documentation from five entities or groups of entities: 1) TDOT reports; 2) documents of DOTs adjacent to Tennessee, 3) other DOT documents, 4) Smart City finalist vision narratives, and 5) vision narratives from three Tennessee cities who participated in the Smart City Challenge.

The comparison of the word clouds for the five entities indicates a few similarities. For example, the documentation for both TDOT and the Adjacent DOTs cited energy as one of the most frequently identified words. Other shared words include environment, water, and reduction (in problems). The Other DOT word cloud did contain the terms energy, water, and reduction, but these terms were not highlighted as the most frequently cited; the term maintenance was the most frequently cited word. Likewise, both the Smart City finalists and Tennessee Smart City participants had both the words "data" and "smart" highlighted as the most frequently found words. Other words shared by the Smart City finalists and Tennessee participants include transit, system, public, infrastructure and traffic.

The topic modeling analyses shed light on key thematic concepts most frequently cited in the retrieved documents. A few similarities do appear between the various entities. For instance, TDOT and the Adjacent DOTs reference biofuels and fuel types as one of the top five topic areas. TDOT and Tennessee Smart City participants share key concepts related to safety. TDOT's key topic of interest seemed interested in collision notification and the Smart City participants cite improved safety as a key topic. Both Adjacent DOTs and Other DOTs reference energy conservation/efficiency and reduction, as well as, hybrid, electric or alternative fueled vehicles as key topic areas. Finally, both the Smart City finalists and the Tennessee participants identified US Department of Transportation-Federal Highway Administration as their potential funding source because they were applicants to the solicitation. However, this highlights the need for funding sources when applying for innovative sustainable strategic initiatives.

Similarity plot analysis was conducted to understand the contexts in which key concepts and themes were often cited by different entities, similarity plot analysis was conducted. The sustainability-related documentation of the five entities (TDOT, Adjacent DOTs Other DOTs, Smart City finalists and Tennessee Smart City participants) contained phrases relating to energy conservation and emissions reduction. Similar words used include fleet management, electric or plug-in vehicle, and bio and alternative fuels. The Smart City finalists used phrasing directly related to Connected and Autonomous/Automated Vehicles (CAV) and the Tennessee Smart City participants used emerging (Shared) Transportation Management Companies (i.e. Lyft and Uber). Waste management related phrases containing words such as waste, water, pollution, greenhouse gas (GHG) was used by TDOT and Adjacent DOTs. Three entities (i.e. Other DOTs, Smart City finalists and Tennessee participants) used phrasing directly related to data centers, data sharing or real-time information.

Finally, a review of successful sustainable practices across the United States provided insights into the specific actions of USDOT and state DOTs. The resulting sustainable strategies include deployment of management best practices, reduction in travel, use of clean and renewable energy sources, fleet management, and developing sustainable pavement practices. The impacts of using these sustainable techniques were quantified and include reductions in emission (by 34% in one case), a reduction of energy usage (by 15%), and an increase (of 23%) in alternative fuel use. The use of sustainable strategies also includes monetary savings. For example, Colorado DOT saved $394,030 by using recycled waste and wash water to produce a salt brine liquid deicer; and Texas DOT reportedly saved $50 to $100 Million each year using recycled asphalt shingles (RAS) and reclaimed asphalt paving (RAP) in warm mix and hot mix asphalt.

3.0 ANALYSIS OF TRANSFERABILITY

In this section, project team members analyzed the transferability potential of sustainable practices and projects from one context to another. These contexts include socio-demographic distribution, hierarchical clustering and geographical similarities. Additionally, we completed a text analysis study on a review of the literature related to transferability of transportation knowledge and practices.

3.1 Socio-demographic Distribution

One way to explore the feasibility and transferability of strategies practiced at other DOTs to TDOT is to conduct descriptive analysis of key sociodemographic/exposure factors. Although sustainability related documents were not available for most of the DOT states, clustering analysis was conducted on all the 50 states of United States which will help us to identify and rank the similar states to Tennessee. Thus, descriptive statistics analysis on all the 50 states of United States is performed on the commonly observable sociodemographic and exposure-related attributes. These statistics are then compared to that of Tennessee for examining transferability (similarity). The descriptive statistics used include:

- Mean, which is the central tendency of the data;
- Standard Deviation (SD), which quantifies the amount of variation or dispersion of a set of data values;
- Minimum (Min), which is the least (smallest) value of a data set, and
- Maximum (Max), which is the greatest (largest) value of a data set.

The specific variables used to determine transferability and feasibility of strategies from all other DOTs to TDOT include population[1], area[2] (square miles), median household income[3], all ages in poverty[4] (percent), gross domestic product (GDP)[5], population density per square mile[6], air pollution in parts per million[7], gasoline consumption per capita[8], vehicle miles traveled (VMT)[9], public road length in miles[10], mean travel time to work in minutes[11], average road length, which is the total length of all roads (e.g. arterials and local) divided by state geographic

[1] https://en.wikipedia.org/wiki/List_of_states_and_territories_of_the_United_States_by_population
[2] https://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_area
[3] https://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_income
[4] https://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_poverty_rate
[5] https://en.wikipedia.org/wiki/List_of_U.S._states_and_territories_by_GDP
[6] https://simple.wikipedia.org/wiki/List_of_U.S._states_by_population_density
[7] https://www.americashealthrankings.org/explore/annual
[8] http://www.statemaster.com/graph/ene_gas_con_percap-energy-gasoline-consumption-per-capita
[9] https://www.bts.gov/statistical-products/surveys/vehicle-miles-traveled-and-vehicle-trips-state
[10] http://www.ipsr.ku.edu/ksdata/ksah/trans/15trans3x.pdf
[11] https://www.indexmundi.com/facts/united-states/quick-facts/all-states/average-commute-time#table

area (mile/area), VMT divided by population (VMT/population), fatality per 100 million VMT[12], rainfall in millimeters[13], and percentage of forest cover[14] in the state.

Presumably, a high level of similarity between the mean statistics of other states to that of Tennessee will indicate a higher transferability potential of a sustainable practice from another state to Tennessee (i.e. increase in the ease of project transfer). The results are found in Table 8. The variables with a differential of ten percent or less include population, GDP, air pollution, mean travel time to work, average road length, and fatality per 100 million VMT.

Table 8: Statistics Summary of Variables Used in the Transferability Analysis

Variable	Date	All-Mean	All-SD	All-Min	All-Max	TN
Population	2017	6205833.9	7051230.7	583223	38431393	6497269*
Area (square miles)	2000	74445.3	96933.17	68	665384	42144
Median Household Income (dollars)	2015	52766.1	9269.76	37047	74149	44621
All Ages in Poverty (percent)	2014	14.88	3.07	9.2	21.9	18.2
GDP (dollars)	2017	361927.3	459940.5	31092	2602672	328770*
Population Density (per square mile)	2013	200	266.16	1	1218	160
Air Pollution (PPM)	2017	8.67	1.7	5	12.5	9.1
Gasoline Consumption (per capita)	2001	10.03	3.34	0.97	15.91	11.469
Vehicle Miles Travel	2009	60693.5	63336.3	3557	335539	76670
Public Road Length (mile)	2016	81465.2	55633.3	1507	313596	95637*
Mean travel time to work(minutes)	2013	23.81	3.45	16.9	32	24.3
Average road length (miles/miles^2 i.e., area)	-	2.09	3.03	0.02	22.16	2.269291
VMT/population	-	10352.1	2011.9	5479.8	16455.1	11800.3
Fatality per 100 million VMT	2017	1.14	0.3	0.52	1.89	1.25
Rainfall (millimeter)	2000	941.8	371.7	241	1618	1376*
Forest cover (percentage)	2016	36.28	24.35	0.5	89	52.9*

*Figures are totals for Tennessee. N = 50 states

[12] https://www.iihs.org/iihs/topics/t/general-statistics/fatalityfacts/state-by-state-overview
[13] https://www.currentresults.com/Weather/US/average-annual-state-precipitation.php
[14] https://en.wikipedia.org/wiki/Forest_cover_by_state_and_territory_in_the_United_States

3.2 Hierarchical Clustering

One of the approaches widely used to determine transferability is clustering. In this project, we used the SPSS software, which is a statistical tool. States were classified into similar groups. In particular, cluster analysis (a.k.a. segmentation analysis or taxonomy analysis) is an exploratory analysis that attempts to identify similar structures within a dataset. In this approach, given a specific sample size (N) to be clustered, a similarity statistical distance matrix (N X N) is created. The statistical distance matrix quantifies the distance between two statistical objects.

The basic process of hierarchical clustering is to:

1. Assign each object into its own cluster so that each cluster contains one item (i.e. N items equals the same number of clusters); the distances (similarities) between the clusters equal the distances (similarities) between the items they contain;
2. Find the closest and most similar pair of clusters and merge them into a single cluster;
3. Compute distances (similarities) between the new clusters and each of the old clusters.
4. Repeat steps 3 and 4 until all items are clustered into a single cluster of size N.

Calculating the similarity of the clusters can be done in multiple ways: single-link, complete-link, and average-link clustering. In single-link clustering, the distance between one cluster and another cluster is considered to be equal to the shortest distance from any item in one cluster to any item of the other cluster. If the data consist of similarities, we consider the similarity between one cluster and another cluster to be equal to the greatest similarity from any item of one cluster to any member of the other cluster. In complete-link clustering, the distance between one cluster and another cluster is considered to be equal to the longest distance from any member of one cluster to any member of the other cluster. In average-link clustering, the distance between one cluster and another cluster is considered to be equal to the average distance from any item of one cluster to any item of the other cluster. Average and complete link clustering are considered most effective. In the present study, we performed clustering analysis using Average link method using all the presented variables in the Table 8 and the results are shown in Figure 13.

The horizontal axis of the Dendrogram represents the distance or dissimilarity between clusters. The vertical axis represents the objects and clusters (states). The main interest is in similarity and clustering. Each joining (fusion) of two clusters is represented on the graph by the splitting of a vertical line into two lines. The vertical position of the split, shown by the short horizontal bar, provides the distance (dissimilarity) between the two clusters (states).

Based on the results, it can be observed that Tennessee is in the same cluster with North Carolina, Wisconsin, Alabama, Arkansas, Kentucky, Mississippi, South Carolina, Louisiana, West Virginia, Florida, Maine, and Texas. Therefore, it is expected that transferability of sustainability strategies from these states to Tennessee can be more feasible and efficient than from other states. However, this does not take into account the micro-factors that influence transferability of strategies and those (observed and unobserved) factors must also be taken into account.

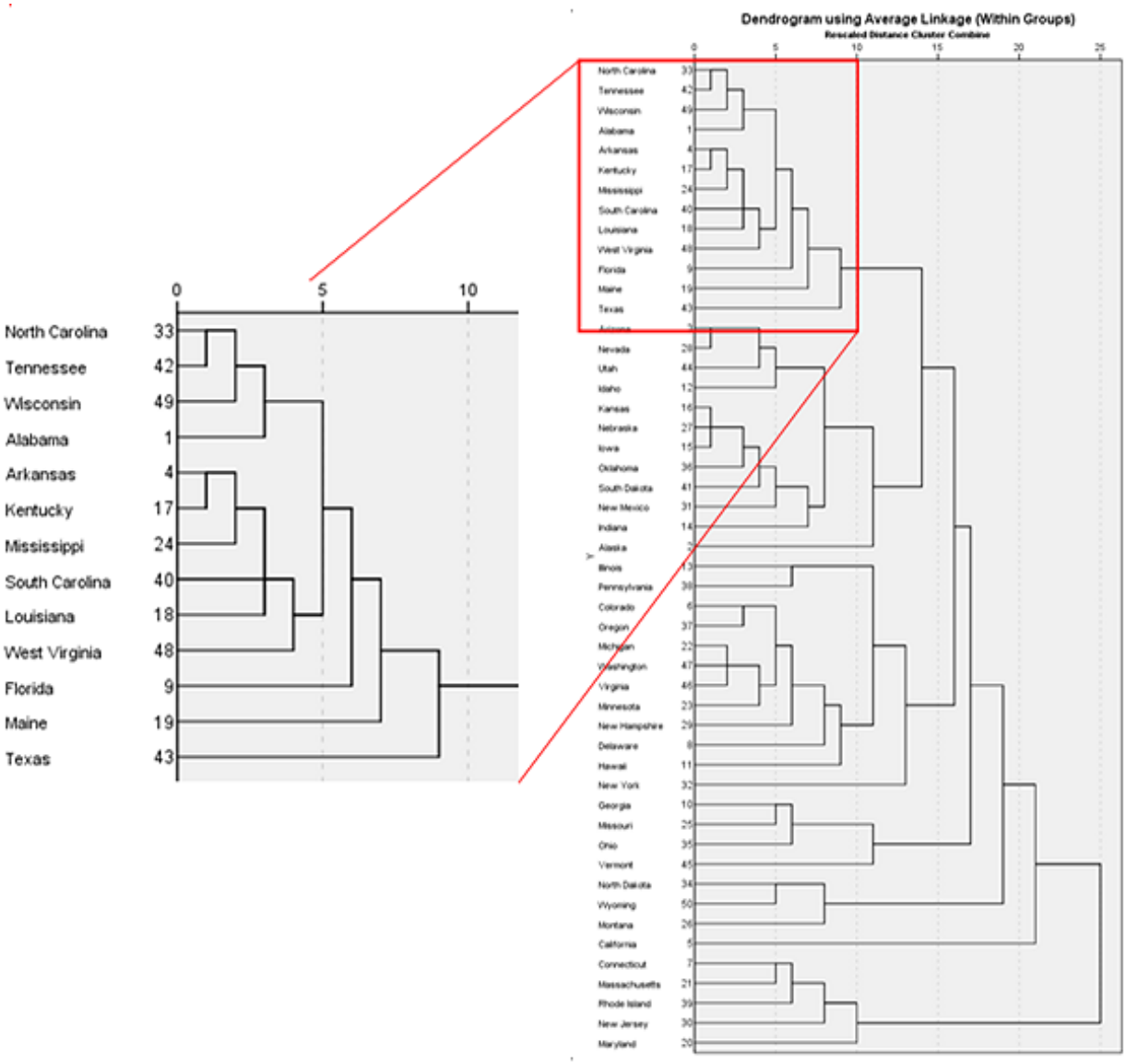

Figure 13: Results of Average Link Clustering

3.3 Transferability Framework for TDOT Sustainability Initiatives

One of the objectives of the research for the Green Generates Green project is to identify cost-effective sustainability initiatives that can be transferred to TDOT with relative ease. Chapter 6.0 DEFINING NEXT STEPS provides specific examples of sustainability actions that can be applied to each TDOT division. These recommendations are based on the 2017 TDOT Division Manager Survey during the interview discussions, and the sustainability actions identified through a detailed literature review. The choice of which mechanisms to use in identifying the ease in which specific sustainability programs could be applied to TDOT (i.e. the implementation rating) is based on six factors: Funding, Proven Technology, Costs, Benefits, Project Control and Barriers.

The initial framework described clarifies how the impacts of strategies may depend on the context in which sustainable strategies are implemented. The six-part evaluation tool has been developed to determine the ease of applying sustainability practices of other departments of transportation to the Tennessee Department of Transportation. The categories are defined loosely as EASY or MODERATE. Initiatives that are difficult to implement are not included. The ease-of-implementation framework contains the following factors:

1. Funding. Political considerations often influence where resources are allocated either statewide or nationally, as well as the difficulty in obtaining funds. Existing available funding through an application process is considered the easiest to obtain. Funding requiring a match or multi-tiered evaluation process is considered moderate to obtain, and funding requiring special legislative action, such as an earmark or state authorization; tax increase or bond issue would be considered difficult.

2. Proven Technology. Existing technology with a well-defined track record is considered easy to integrate as many of the nuances of integration have been identified. Newer technologies with limited data regarding their deployment are considered moderately difficult to transfer, and the newest technologies, either in the planning stages or without any track record are considered the most difficult to integrate into TDOT.

3. Costs. In this context, costs are not limited to financial outlay and expenses needed to update, improve or integrate technology over time. Costs do include “hidden” expenses, such as the disruption to workflow caused by employees learning new protocols or the expense of training. These costs are included descriptively and not quantifiably into the Technology Transfer Framework. As such, low cost protocols are considered easier to integrate, as they require few changes in existing strategies, can be integrated at the office level, can be budgeted for at the office level, and require no specialized training. Moderate cost technology transfer is considered options that require budget approval and protocol implementation at the division level, require some training that could be conducted online, and involve changes to existing strategies that require a change in thought processes and behavior of employees. Technological

transfers that involve approvals and budgeting at the TDOT or state levels involve training lasting that can last multiple days and change existing protocols substantially have known costs and strategies that are considered difficult to implement.

4. Benefits. This variable includes known cost savings over time (i.e. time savings and employee cost savings), as well as quantifiable environmental savings (i.e. reduction in waste, and use of recycled materials). Unquantifiable benefits that can be clearly identified are also included in the application of known benefits. Ease of implementation is determined by a cost-benefit ratio over time. For example, is the benefit exceeds the cost of technology implementation over a two-year period, the technology is considered easy to implement. If it takes more than two years but less than five years to receive financial benefit the technology is considered moderately difficult and if benefits do not outweigh costs over a period of five years or more the technology transfer is considered difficult to undertake. Relevant time periods of two, five and more than five years were determined using various articles from Investopedia.

5. Project Control. Project control allows for TDOT to predict, understand and constructively influence the time and cost outcomes of technology transfer including project delivery and meeting cost and time milestones. Sustainability implementation projects that are managed at the office or division level are considered easy to implement; projects that require management at the division or TDOT level are considered moderate in their ease of implementation, and projects that cannot be managed by TDOT personnel directly are considered difficult to implement.

6. Barriers. There are potential barriers to the implementation of sustainable design into TDOT protocols and projects. Depending on the nature of the barriers and the means to mitigate the barriers can make implementation of sustainability technology easy, moderate or difficult. Barriers relating to TDOT personnel, supervisors or other division leaders may be based on low awareness of potential and/or existing sustainability programs and policies and can be remedied through in-house education regarding the tools for implementation. This type of barrier is considered easy to overcome. Barriers toward the implementation of sustainability policies can be considered moderate to manage if the barriers come from non-TDOT sources, such as state, community or local leaders. The most difficult barriers include those created by legislative or regulatory prohibitions and those with a lack of state defined standards.

Table 9 provides one example of transferability framework as it is used for connected and automated vehicle (CAV) efforts. As previously mentioned, the USDOT launched the Smart City Challenge program to share ideas toward to a better transportation system. Among these proposals, to improve the safety, mobility, environment, and opportunity, seven top cities (i.e. Austin, Texas; Columbus, Ohio; Denver, Colorado; Kansas City, Missouri; Pittsburgh, Pennsylvania; Portland, Maine and San Francisco, California) proposed various CAV related strategies.

Table 9: Ease of Implementation Framework - Connected and Automated Vehicles

Criteria	Rating	Notes
Funding	Moderate	Under connected and automated vehicles (CAVs) driving environment, the agency can achieve substantial benefits in terms of safety, congestion reduction, and energy savings and emissions reductions. At the federal level, the National Highway Traffic Safety Administration (NHTSA) has studied the safety benefits of two CAV technologies – Left Turn Assist (LTA) and Intersection Movement Assist (IMA). Nationwide, they can prevent 592,000 crashes and save 1,083 lives annually. Therefore, TDOT and regions/cities can potentially fund the CAV projects through various financing mechanisms include CMAQ funds or even connected vehicle facility charges (to name a few sources of funding).
Proven Technology	Moderate	Various technologies can be used, based on the new Intelligent Transportation Systems architecture. These will include on-board wireless communication systems, on-board vehicle tracking systems, on-board alert and warning system, roadside wireless equipment that include Dedicated Short-Range Communications (DSRC) units. The development of apps for smart phones should be considered.
Cost	Difficult	Various methods and tools can be used to calculate the costs of implementing technology. Detailed cost information can be obtained from program plans. A cost-benefit analysis can be applied to calculate the return-on-investment before the implementation of the CAV program in various cities and regions. It is expected that the cost of technology will drop over time. Alongside the initial costs (purchasing CAVs, for fleets, deployment of initial equipment (DSRC RSUs, …) there may be hidden costs such as work force training related to specific technologies, designing experiments where volunteer drivers can be monitored to learn about how well and how much they drive when using CAVs. Consideration should also be given to life-cycle costs.

Benefit	Moderate	The benefits in terms of safety, congestion, energy and emissions can be calculated using performance measures. For example, reductions in near-misses, crashes, injuries, and fatalities could show substantial safety benefit, while the improvements in travel times and delays can indicate congestion benefits. The short-term and long-term benefits should be separated out.
Project Control	Moderate	TDOT can coordinate with the local public or private sector stakeholders to implement the projects as TDOT will provide an overall plan and establish new policies regarding CAVs. Also, different TDOT divisions will be involved in this project such as traffic operation, environmental, and maintenance divisions. They will have opportunities to coordinate and collaborate.
Barriers	Difficult	The barriers to deployment include:1) difficulty of installing vehicle-to-infrastructure (V2I) and I2V equipment as well as software development; 2) the general public retrofitting their vehicles with CAV on-board units can be costly; 3) the privacy of drivers will have to be protected as their driving behavior can be tracked under CAVs driving environment; 4) connected vehicles might not coordinate well with pedestrians if a vehicle is controlled by a driving assist system; 5) in most cases, the CAV technology is designed for normal driving conditions and it is unclear how the CAVs will perform in adverse or abnormal driving conditions, e.g., bad weather; 5) other barriers include AV certification, insurance and liability, maintaining security of the system, e.g., against cyber-attacks, and training a technology savvy workforce.

3.4 Summary

Socio-demographic comparison is used to analyze the transferability and feasibility of strategies at other DOTs to TDOT using quantifiable attributes, such as population, area, median household income, population density, etc. The most similar quantifiable attributes between other DOTs and TDOT included population, GDP, air pollution, mean travel time to work, average road length, and fatality per 100 million VMT. Based on a series of observed attributes, hierarchical clustering provided a comparison of Tennessee with all other states in terms of broad similarities/dis-similarities. As an example, significant similarities were observed among Tennessee, North Carolina, and Wisconsin - suggesting that "Green Generates Green" sustainable practices at the latter two states may be (relatively) easily transferred to Tennessee. However, the analysis presented in only a first step in transferability analysis and it does not take into account the micro level observed and unobserved factors that may influence transferability of specific strategies. Finally, an example of transferability is provided. Each of the seven top finalists of the Smart City Challenge proposed various Connected and Automated Vehicle (CAV) related strategies. Upcoming chapters of this Green Generates Green Final Report provide specific examples of sustainability actions that can be applied to each TDOT division. The ease with which specific sustainability programs could be applied to TDOT is based on six key factors which have been applied to CAV technologies in the example provided above.

4.0 PERFORMANCE MEASURES

We can use performance measures and tools such as cost-benefit analysis (CBA) and return-on-investment (ROI) to evaluate the success of a specific sustainable process or project component based on quantitative (e.g., traffic speeds or delay) and qualitative factors (e.g. social concerns, justice, and normative values). Improvement in an organization's performance cannot happen unless there is some way of communicating performance feedback based on a baseline of expected and current performance. Performance measures create a link between standard operating procedures and any changes made to these procedures. To calculate changes and improvement, a process needs to be measured. Generally, performance measurement methods are grouped into two types: 1) those that focus on the inputs that determine the results, and 2) those that relate to the outcomes of results. Team members reviewed a number of performance measures that include both types mentioned above, then linked sustainable goals and performance measures. Finally, this chapter reviews CBA and ROI tools, given that the sustainable actions should also be cost-effective, i.e., green practices that generate a good ROI.
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4.1 Types of Performance Measures Used Across Various Entities

The impact of sustainable strategies depend on the context in which sustainable strategies are implemented and the measures of performance used for assessment. For example, geographic factors such as terrain or climate may dictate the type of infrastructure that can be built, with implications for mobility, safety and energy and emissions. Additionally, political considerations influence where resources are allocated and how taxes or impact fees are determined. Equity concerns such as environmental justice or economic opportunity may be important considerations in certain contexts. Therefore, this section broadly reviews the performance measures proposed by different organizations or applied in different projects (Table 10), then provides a summary of performance measures based on sustainable goals (Table 11).

Table 10 reviews the general performance measures used by state DOTs and USDOT, federal agencies, metropolitan areas, other countries, and private entities. The performance measures used include quantitative variables (e.g. traffic speeds, crash rates, VMT, emissions, and noise) and qualitative elements (e.g. livable communities, ease of access, and public engagement). Finally, performance measurement elements can be classified broadly into different categories, such as social, economic, environmental, transportation, land uses, user concerns, and societal concerns, or business concerns.

Table 10: Review of Performance Measures

Organization/Project	**Performance Measures**		
Conventional Transport Indicators	Roadway level-of-service, Average traffic speeds, Average traffic delay, Parking convenience and price, Crash rates per vehicle-mile.		
Twin Cities metropolitan region	Six sustainability principles: More transportation choices, Protect natural resources, Promote equitable, Affordable housing, Value communities and neighborhoods, Enhance economic competitiveness and create positive fiscal impacts, Coordinate and leverage government policies and investment.		
	38 performance measures such as Job accessibility, Transportation accessibility, Housing and transportation affordability, Land use Mix, Walkability, Vehicle miles traveled, Transportation safety, Commute mode choice, Water quality, Air quality, Pollutants.		
Genuine Progress Indicator	<u>Economic</u>	<u>Social</u>	<u>Environmental</u>
	GDP, Personal Consumption, Household debt, Income inequality, Public and household infrastructure, Employment, transportation infrastructure.	Time use, Human health and wellness, Suicide, Alcohol, drug and tobacco abuse, Auto crashes and injuries, Family breakdown, Crime, democracy, intellectual & Knowledge capital.	Energy, agriculture, Forests, Parks and wilderness, Fish and wildlife, Water resource and quality, Energy use and air quality, Carbon budget, Municipal and hazardous waste, Ecological footprint.
US Department of Transportation	Environmental: Emissions, Greenhouse gas emissions, Energy, wetlands protection, Livable communities/Transit service, Airport noise exposure, Maritime oil spills, Fisheries protection, Toxic materials, Hazardous waste, Environmental justice		
Centre for Sustainable	Environmental and Health Consequences of transport: Fossil fuel energy, Gas emissions, Road injuries and fatalities		

Transportation	Transport activity: Motorized movement of people and freight, Light-duty passenger vehicles.		
	Land use, Urban form and accessibility: Urban land use per capita		
	Supply of transport infrastructure and services: Length of paved roads		
	Transport expenditures and pricing		
	Technology adoption: energy and emission intensity of vehicle		
	Implementation and monitoring		
World Business Council's Sustainable Mobility project	<u>User Concerns</u>	<u>Societal Concerns</u>	<u>Business Concerns</u>
	Ease of access, Financial outlay, Average door-to-door time, Reliability, Safety, Security	Impacts on the environment and on public health and safety, Greenhouse gas emissions, Safety, Noise, Land use, Resource use, Publicly-provided infrastructure, Equity impacts.	Profitability, Total market size, Private investment, Cash flow generation, Policy barriers/incentives.
European Union's Transport and Environment Reporting Mechanism	Transport and Environment Performance: Environmental consequences of transport, Transport volume and intensity.		
	Determinants of the Transport/environment System: Spatial planning and Accessibility, Transport supply, Price signals, Technology and utilization efficiency, Management integration		
Sustainable Transportation in Halifax Regional Municipality (HRM)	<u>Transport Activity</u>	<u>Social</u>	<u>Economic</u>
	Sustainable modes, Energy consumption, Greenhouse gas,	Access to basic services, Access to public transportation	Household transportation expenditure

	air pollutants, Transport facility space		
Strategic Urban Transport Assessment	Metropolitan multimodal travel and transport characteristics: Mode share, Vehicle km per capita, Household transport expenditures, Daily commute time, Transport capital investment, Fuel and annual car ownership taxes		
	Public transit system indicators and metrics: Operating ratio, System capacity, Cost per passenger served, Annual capital investment, Annual maintenance expenditure, Fleet maturity		
	Land use: Urban density, Population, Housing stress, Transit real estate strategy.		
	Transit accessibility to key amenities: Public health access		
	Qualitatively-oriented review categories: Transit investment, Bike and pedestrian network quality		
	Analyses particular to the corridor, Sub-regional and precinct scales: Transit service-levels, Walking and cycling performance, Station access mode shares, Jobs/housing balance, Car ownership		
	Transit project and investment economics: Benefit cost ratio, Net present value.		
Sustainability Assessment	Transportation System Effectiveness: Mobility and accessibility		
	Environmental Sustainability: Greenhouse effect, Air pollution, Noise pollution, Resource use.		
	Economic Sustainability: Economic efficiency, Affordability, Economic development		
	Social Sustainability: Equity, Public health, Safety and security, Accessibility		

Texas DOT	Congestion: Mobility, Reliability.		
	Safety: Crash rate, Incident detection and response		
	Economic opportunity: Mixed land use, Freight movement		
	Transportation Assets: Maintain highway system quality, Cost and impact of capacity expansion, Alternative travel		
	Air Quality: Human health, Greenhouse gas emissions.		
Regional Sustainable Transportation	Healthy Communities	Sustainable Natural Environment	Economic Vitality
	Pedestrians and transit, Access and mobility, Land use, communication, Consultation and public engagement	Environment and cultural heritage, Energy efficiency, Transportation demand management	Economic wellbeing, Fiscal sustainability and equitable funding
U.S. Environmental Protection Agency	Transit accessibility, Bicycle and pedestrian mode share, Vehicle miles traveled per capita, Carbon intensity, Mixed land uses, Transportation affordability, Distribution of benefits by income group, Land consumption, Bicycle and pedestrian, Average vehicle occupancy, Transit productivity.		

Table 11: Sustainable Goals and Performance Measures

Sustainable Goals	**Performance Measures**	**Sustainable Goals**	**Performance Measures**	**Sustainable Goals**	**Performance Measures**
Economic		**Social**		**Environmental**	
Accessibility quality	Access to markets and employment: Infrastructure density, Infrastructure quality	Equity / fairness	Transportation meets the basic needs of all people: Transport system diversity, Portion of destinations accessible by people with disability or constraint	Air pollution	Per capita emissions, Air quality standards
Traffic congestion	Traffic delay: Per capita total traffic delay	Mobility	Mode share, Daily average distance traveled, Average travel speed	Climate stability	Per capita emissions of greenhouse gases
Infrastructure costs	Public infrastructure, Household infrastructure	Affordability	Affordable access to basic services: Household spending on transport, Public or private investment in transport	Noise pollution	traffic noise exposure: Traffic noise levels

Customer cost	Money, Debt, Assets and Net Worth: Household Debt	Human health and safety	Per capita traffic casualty rates, Traveler crime rates, Human exposure to harmful pollutants, Portion of travel by walking and cycling.	Water pollution	Per capita fuel consumption, Management of used oil, Leaks and storm water.
Mobility cost efficiency	Easy access to all facilities: Percentage of household expenditures dedicated to transportation	Community cohesion	Land use mix, Walkability and bikeability, Quality of road and street environments	Hydrologic impacts	Per capita impervious surface area
Transportation safety	Safe transport to avoid costs of traffic crashes: Road fatalities, Seatbelt use, Impaired driving and speeding	Community livability	Subset of sustainability objectives that directly affect community members: Local environmental quality, Community livability ratings	Habitat and ecological degradation	Average size of road-less wildlife preserves, Preservation of high-quality wildlife habitat
Resource efficiency	Fuel consumption, Land consumption	Aesthetics	Roadway cleaning and litter removal	Non-Renewable Resources	Non-renewable resource consumption in the production, Use of vehicles and facilities

While Table 10 provides an overview of the types of performance measures used by various entities, Table 11 links the performance measures to sustainability-related goals based on broad categorical objectives: economic, societal and environmental; these are the three main pillars of sustainability. For example, the economic category has a sustainable goal of accessibility that uses access to markets and employment; infrastructure density and infrastructure quality as performance measures. In another instance, the societal category lists transportation mobility as a sustainable goal using the performance measures of mode share, daily average distance traveled, and average travel speed. Because specific performance measures are linked to specific goals, they can vary greatly based on their categorical objective.

4.2 Cost-Benefit Analysis

A cost benefit analysis is a systematic approach to assigning values to all inputs to calculate and compare the benefits and costs of a project in a given situation. The goal is to determine which option based on the inputs chosen provides the most optimal (highest) ratio of benefits to costs. Results may differ based on inputs chosen. In a cost-benefit analysis, both quantitative and qualitative components and inputs are assigned a monetary value. Cost benefit analysis is more comprehensive than ROI, as it attempts to quantify both tangible and intangible costs and benefits.

Tangible or quantifiable costs require Information on the level of staff expertise and training required to undertake the proposed project and its expected time frame are tangible costs. Cost types include direct project costs (e.g. staff, and office space); acquisition costs (e.g. purchase of technology); implementation costs (e.g. loss of productivity); and life ownership costs (e.g. operating costs, maintenance, upgrade/replacement of facilities, staff, training and support). Intangible or non-quantifiable costs are not easy to quantify but need to be recognized as they can impact the overall costs of the project under consideration. The cost-benefit analysis should acknowledge non-quantifiable costs, even if they are not factored into the calculations in the analysis.

In a cost-benefit analysis relating to sustainability objectives both the positive and the negative impacts of a new or changed policy, procedure or program are assigned monetary values and compared to other alternatives. An accurate cost-benefit analysis requires a complete understanding of the principles and process of the new or changed policy, procedure or program/action, as well as the specific context of its implementation. Requirements for the economic, environmental and societal evolution of the project need to be articulated and calculated as well. To this end, a number of tools have been developed to provide guidance on identifying and assessing the full range of costs and benefits associated with each proposed project (Table 12).

Table 12: Sustainability Rating Tools

Sustainability Rating Tools		Categories
Transportation & Infrastructure	BE2ST-in-Highways	Life cycle cost, Energy, Recycling, Hazardous waste, Water, Noise, Social carbon cost
	Envision	Project pathway contribution, Project strategy and management, Communities and efficiencies, Land-use and restoration, Landscapes, Ecology and biodiversity, Water resources and environment, Energy and carbon, Resource management, Transportation
	Green Guide for Roads	Mobility for all, Transportation efficiency, Safety, Energy and atmosphere, Materials and resources, Community impact, Innovation in design process
	GreenLITES	Sustainable sites, Water quality, Material and resources, Energy and atmosphere, Innovation
	GreenPave	Long-life pavement, Permeable pavement, Noise mitigation, Cool pavement, Recycled content, Reuse of pavement, Local materials, Construction quality, Reduce energy consumption, GHG emissions reduction, Pavement smoothness, Pollution reduction.
	Greenroads	Project requirements, Environment & water, Access & equity, Construction activities, Materials & resources, Pavement technologies
	I-LAST	Transportation, Materials, Water quality, Planning, Lighting, innovation and design.
	INVEST	Integrated planning, Economic development and land-use, Linking asset management and planning, Storm-water, Recycle materials, Construction waste management, Pavement management system, Road weather management program
	BRT Standard	Service planning, Infrastructure, Stations, Communications, access and integration
	Density-VMT Calculator	Building density, Vehicle miles traveled

	TOD Standard	Walk, cycle, Connect, Transit, Mix, Densify, Compact, Shift
Cities	Comprehensive Plans for Sustaining Places	Livable built environment, Harmony with nature, Resilient economy, Interwoven equity, Healthy community, Responsible regionalism
	STAR Community	Built environment, Climate and energy, Economy and jobs, Education arts and community, Equity and empowerment, Health and safety, Natural systems, Innovation and process
	Sustainable Communities	Agriculture, Economic development and tourism, Education, Environment, Governance, Housing, open space and land-use, Planning zoning building and development, Population, Public safety and emergency management, Recreation, Resource use, Volunteerism and civic engagement, Transportation
Planned Neighborhoods	BERDE for Clustered Residential Development	Management, Land-use and ecology, Water, Energy, transportation, Indoor environmental quality, Materials, Emissions, Waste, Heritage conservation, Innovation
	EnviroDevelopment	Ecosystems, Waste, Energy, Materials, Water, Community
	Green Land Development	Site design and development, Lot selection, Project team and mission, Innovative practices
	LEED for Neighborhood Development	Smart location & linkage, Neighborhood pattern & design, Green infrastructure & buildings, Innovation & design process
	Signature	Siting, planning & design, Construction, Long term management
Existing Neighborhoods	2030 Districts	Energy, Water, Transportation, Emissions
	Livability Index	Housing, Environment, Neighborhood, Transportation, health, Civic engagement, Equity & opportunity, Recreation & culture

All Neighborhoods	Living Community Challenge	Limits to growth, Urban agriculture, Habitat exchange, Human powered living, Net positive water, Net positive energy, Civilized environment, Healthy neighborhood design, Biophilic environment, Resilient community connections, Living materials plan, Embodied carbon footprint, Net positive waste, Human scale and humane places, Universal access to nature & place, Universal access to community services, Equitable investment, Just organizations, Beauty & spirit, Inspiration & education

Tools used to determine the performance of various sustainability actions appear to be concentrated in Transportation and Infrastructure (i.e. BE2ST-in-Highways, Envision, Green Guide for Roads, and GreenLITES). The majority of these tools seem to concentrate on quantitative inputs (e.g. energy costs, carbon cost, material costs, and VMT). The tools used by cities, planned, existing and all neighborhoods (i.e. BERDE for Clustered Residential Development, STAR Community, and LEED for Neighborhood Development) appear to have developed a process for providing a value to qualitative inputs (e.g. harmony with nature, interwoven equity, and healthy community). Applicability of these tools in Tennessee should be further explored.

4.3 Return-On-Investment

Throughout a project's life cycle, performance measurements provide indicators of needed project modification or remediation alternatives. One closely related technique to cost-benefit analysis is return-on-investment (ROI). ROI is a calculation of the most tangible financial gains or benefits that can be expected from a project versus the costs for implementing the project. Intangible calculations are not (typically) made in ROI. To calculate ROI, the benefit (or return) of a change is divided by the cost of the change. The result is expressed as a percentage or a ratio. As ROI calculates results based on hard data, it is easier to provide accurate results through time (i.e. time value of money).

Chapter 7.0 HIGH IMPACT STRATEGIES provides an example of tangible costs associated with Alternative Fuel station development. However, because the cost of each alternative fueling station varies significantly by the type of fuel and amenities offered, a true return-on-investment calculation could not be performed.

4.4 Summary

Performance measures, such as cost-benefit analysis and return-on-investment are used to monitor the success or failure of a specific process or project component. The measures of performance used for assessment are dependent upon both quantitative and qualitative attributes. Easily obtained numeric data include traffic speeds, crash rates, VMT, emissions, etc. But equity data such as environmental justice or economic opportunity is not as easy or clear cut to integrate into calculations. Performance measures such as cost-benefit ratio attempts to calculate soft data concerns and integrate them into a measurement that can discern the best alternative. Return-On-Investment utilizes hard data and can provide a well-defined result, but this result may lack important subtleties. Chapter 7.0 HIGH IMPACT STRATEGIES provides an example of cost-benefit analysis and uses a tangible costs scenario.

5.0 TDOT DIRECTORS' INTERVIEWS

In July and August 2017, the project team conducted a survey of fifteen Tennessee Department of Transportation (TDOT) Division Directors. The divisions surveyed included Aeronautics, Central Services, Construction, Environmental, Freight Logistics, Long-Range Planning, Maintenance, Materials and Testing, Multimodal, Roadway Design, Right-of-way, Strategic Planning, Strategic Transportation Investments, Structures and Traffic Operations.

5.1 Introduction

The purpose of the study is to obtain a baseline of current sustainability actions taken by TDOT personnel and compare these activities with those of other Departments of Transportation to define methods that could increase TDOTs ability to endure. This draft of the survey results represents one part of the overall research study and does not contain an analysis of other DOT's sustainability efforts.

Survey Methodology

After the survey was approved by Mr. Alan Jones of TDOT, Dr. Noltenius of University of Tennessee contacted all division directors via email and forwarded the April 12, 2017 email sent by Mr. Toks Omishakin (Deputy Commissioner, TDOT and Chief of Environment and Planning) to the division directors, requesting their participation in the survey. Phone calls were made to determine times and dates for the survey interview. The survey was administered July 1, 2017 until August 2, 2017. Thirteen of the 15 TDOT Division Directors or appointed respondents completed the surveys at the appointed time and date. Due to time constraints, two division directors were emailed the survey to be completed, and then returned to the project team. After each survey was completed, division directors were afforded the opportunity to edit, expand and clarify their responses.

5.2 Survey Results

The 22-question survey included five sections: Division Background Data, Policy Information, Cost-Benefit Information, Barriers to Sustainability and Sustainability Practices of Other Departments of Transportation (DOT).

5.2.1 Division Demographic Data

Survey questions 1-4 obtained basic demographic data about the respondents' role in the division, the number of full-time employees in the division, the number of employees directly managed by the division director, and whether or not the division provides training programs to encourage employee engagement in addressing sustainability issues.

The role of the survey respondents fell into two distinct categories with 13 respondents identifying themselves as division directors (87%) and 2 respondents identifying themselves as assistant directors (13%), who were able to respond to the survey on the director's behalf.

Five categorical responses were offered for the number of full-time employees in each division. The categories and number of responses are found in Table 13.

Table 13: Number of Full-time Employees reporting to TDOT Division Directors

# of Respondents	% of Respondents	Number of Employees
7	47%	1 - 25
3	20%	26 - 50
2	13%	51 - 75
2	13%	76 - 100
1	7%	More than 100
15	100%	Total Responses

The same categories were provided to determine the number of employees who were straightforwardly overseen or managed by the division director. The majority of division directors (14 or 93%) managed 1-25 employees directly. Based on further discussion, most managed five or fewer employees directly. One division director (7% of respondents) oversaw the activities of 51 - 75 employees directly.

The final question of the background data section asked if the division provided some type of training program to encourage employee engagement in addressing sustainability issues. Of the 15 responses received, eight responded "Yes" (53%) and seven responded "No" (47%). Further discussion indicated that TDOT did not have any specific training program or training strategy regarding sustainability education. Those division leaders who wanted to educate their employees did so by other means and organizations through webinars and workshops. These include:

- International Right-of-Way Association
- National Highway Institute
- Federal Highway Administration
- Various Smart Growth education activities

Three respondents discussed the need for in-house training that would include a series of educational opportunities that would build upon each other specific to certain themes. In addition, one respondent discussed the need for new hires to have exposure to sustainability concepts early in the employment process.

5.2.2 Policy Information

Survey questions 5 - 11 obtained information about policies, programs or methods currently in place regarding sustainability or the actions associated with the capacity to endure. When survey respondents were asked if the division had in place any written policies, programs or methods regarding sustainability or the actions associated with the capacity to endure, 12 division directors (80%) responded "Yes" and three or 20 percent responded "No". Written policies included excess land procedures and the Code of Federal Regulations, the division review of engineering drawings for preparation in bid letting that may include sustainable techniques, the division review of all permits that may require the clarification of sustainability aspects related to general permit requirements, the creation of a Road Diet Manual, and the Multimodal Access Policy.

When asked if there were any unwritten policies, programs or methods regarding sustainability actions, the same number of respondents answered in the same way, with 12 (80%) indicating "Yes" and three respondents (20%) indicating "No". The same division directors did not respond in the same manner to the two questions, but the numerical outcome is identical. Unwritten policies included paper recycling and reduction, general context sensitive solutions concepts, the encouragement of flexible work hours, and encouragement for employees to ride the bus, car pool, or use commuter rail. Four of the respondents mentioned that there may be a need to “formalize” the unwritten policies to provide consistency throughout the separate TDOT divisions. Division directors were asked the reason for the adoption of both written and unwritten policies and procedures. Seven specific categories were provided, as was an open-ended "Other" reason. Respondents were encouraged to indicate as many reasons as applicable, permitting multiple responses. Thirteen division directors responded; two did not. The results are found in Table 14.

Government regulation is the most often cited reason for the adoption of written and unwritten sustainability policies and procedures, with TDOT leadership initiatives and concerns about TDOT reputation or public relations benefit as the top three reasons. Of interest are the responses in the "Other" category. These responses included the adoption of policies because they "increased production and efficiencies"; the belief that "aspects of internal TDOT process delivery should include sustainability initiatives", and the concept of "Do it Right the First Time, Every Time" that includes cost and time savings from having to retrofit or re-work a project. Five division directors specifically stated that initiating sustainability policies and procedures into TDOT projects are the "Right Thing to Do" because sustainability practices are a part of good resource stewardship.

Table 14: Reasons for Having Sustainability Policies/Procedures in TDOT Divisions

# of Responses	% of Responses	Response
12	18%	Government Regulation Initiative
11	16%	TDOT Leadership Initiative
10	15%	TDOT Reputation or Public Relations Benefit
9	13%	Non-TDOT or other State Agency Request
8	12%	Cost Savings
6	9%	Natural Resource Limitations
6	9%	Other
5	7%	Employee Request
67	100%	Total Responses

NOTE: Multiple responses permitted; N= 13 respondents.

Division directors were asked if there was a specific person in the division responsible for overseeing the compliance of these or other sustainability initiatives. Ten responded "Yes" (67%) and five responded "No" (33%). Of those who responded "Yes" the responsible person was either the director or assistant directors as sustainability was a part of everyday performance. No director identified specific individual/s whose main purpose was to make careful examination of or initiate sustainability practices into projects.
The next question inquired if each division had implemented technological solutions that were considered "green" and economically viable. The definition of the question was given a wide interpretation. Twelve directors answered "Yes" (80%) and three respondents answered "No" (20%). Of those who responded affirmatively, the types of solutions included the following:

- Online documentation (e.g. printable not fill-able forms, manuals);
- Digital signature contract books that eliminates the need for printed books on approximately 500 contracts;
- Public outreach through the internet;
- Software used to communicate with Tennessee counties;
- Electronic plan submittal;
- Use of various online solutions (e.g. email, and video conferencing);
- Use of TDOT portal;
- TDOT divisions are currently participating in a state request to consider telecommuting as an option to reduce peak hour traffic and real estate footprint;
- Scanned and emailed invoice process and scanned reports, studies, etc.
- Consultants and contractors receive copies of TDOT sustainability standards and guidelines;

Of note is that the solutions described above are not necessarily utilized by all divisions, but some divisions were detailed about their technological solutions. These included the implementation and management of Community Transportation Planning Grants that "provide green solutions for bicycle and pedestrian master plans, transportation systems management and operations, corridor studies, complete streets, traffic flow and downtown pedestrian mobility studies, traffic signal timing optimization, etc." as well as one division that "recently evaluated and currently allow for the use of recycled concrete aggregate to be used for aggregate base course and are studying the use of ground tire rubber to be used to modify asphalt cements."

Other division-specific technologically green solutions include the use of Recycled Asphalt Pavement (RAP), Recycled Asphalt Shingles (RAS), and Warm Mix Asphalt (WMA) in asphalt mixtures, as well as the use of Fly Ash (Class F and Class C) and ground granulated blast furnace slag (GGBFS) in concrete mixtures. Also, one division is working to eliminate the use of painting systems on new steel bridges by utilizing weathering steel that provides a protective outer layer of weathered (rusty) steel which eliminates the need for future maintenance of a paint system. Additionally, it promotes the recycling of concrete and reinforcing steel from existing bridges as reinforcing steel can be recycled into new steel products, and existing concrete can be crushed and used as non-structural fill materials. Finally, one division actively supports the purchase of hybrid buses and other alternative fuel vehicles, and another supports the deployment of Intelligent Transportation System (ITS) projects across Tennessee, as these projects help manage traffic to maximize the existing roadway capacity.

Division directors were asked if their division-specific sustainability efforts were coordinated with any other TDOT departments or divisions. Most responded "Yes" (93%) with one exception who responded "No" (7%). The other TDOT departments or divisions cited include the following in order of frequency:

- Environmental Division (3 responses; i.e. 3 other TDOT divisions coordinate their sustainability efforts with this division);
- Construction Division (2 responses);
- Design Division (2 responses);
- Maintenance Division (2 responses);
- Strategic Transportation Investments (2 responses);
- Central Services Division (1 response);
- Long-range Planning (1 response);
- Local Program Development office (1 response);
- Multimodal Division (1 response);
- Regional Traffic Engineers Office (1 response);
- Traffic Operations Division (1 response);

Eight of the respondents remarked on the need to have in place some type of formalized method for integrating sustainability aspects of other divisions into procedures, documentation and other efforts – a comprehensive multidisciplinary approach to integrating sustainability concepts into final deliverables. Though most divisions were required to work with other departments in the project process, there was no impetus to do so outside of this requirement.

The final question regarding sustainability policies asked if directors coordinated their efforts with any Non-TDOT agencies, local governments or state or local departments. Thirteen directors responded "Yes" (87%) and two directors responded "No" (13%). Agencies outside of TDOT with which they coordinated sustainability initiatives include other state departments (e.g. Department of Environment and Conservation), federal agencies (e.g. Federal Highway Administration, US Army Corps of Engineers), and private groups (e.g. Keep Tennessee Beautiful, various local and state watershed protection groups).

5.2.3 Cost-Benefit Analysis

Survey questions 12 - 17 gathered information about the cost and benefits of integrating sustainability policies into program goals. This set of questions included information about whether or not sustainability initiatives were monitored or measured, how the initiatives were monitored, if sustainability actions provided benefits, if programs had been changed based on the measured results, if there was a method for identifying an unsuccessful sustainability initiative, and if the division addressed aspects of sustainability in the planning process or the beginning of a project.

When asked if the eventual outcomes of the sustainability programs and policies were measured or monitored, eight directors responded "Yes" (53%) and seven directors responded "No" (47%). Two respondents mentioned that they were unable to measure the outcome of some policies as their divisions provided only a part of an overall project. Those who responded "Yes" were asked to identify the types of indicators or measures used for monitoring outcomes of sustainability programs. Directors were encouraged to check as many indicators as were used as multiple responses were permitted. The results are found in Table 15.

Cost savings and time savings were the reasons most frequently cited as the indicators used to monitor sustainability programs. Physical resource reduction was listed by 23% of the respondents as well. Only two "Other" responses were recorded. One respondent reported that work force reduction was considered a measure of sustainability initiatives, and another cited that "Public feedback is used as a measure."

Table 15: Indicators Used to Monitor Sustainability Programs by TDOT Directors

# of Responses	% of Responses	Response
8	31%	Cost Savings
7	27%	Time Savings
6	23%	Physical Resource Reduction
3	12%	Energy Reduction
2	8%	Other
26	100%	Total Responses

NOTE: Multiple responses permitted; N=8 respondents.

The next question asked division directors if their sustainable policies, programs or methods generated benefits. All who answered the question reported "Yes"; two directors did not respond to the question. When asked to explain their affirmative answers, directors responded with more than 30 unique examples of benefits. Some of these include significant time savings with regards to issuing project work orders; reduction in waste and corrective actions and improvement of process efficiencies; the use of recycled materials that allow more options for greater purchasing competition and cost savings; more flexibility in employee work location and the resulting decrease in traffic, and “Though direct cost and environmental savings are difficult to calculate, research indicates savings through LED lighting, low-flush toilets, etc.”.

Directors were then asked for any examples, if this information was used to change program characteristics. Seven directors responded "Yes" (47%) and eight directors responded "No" (53%). When asked to explain how the cost-benefit information derived was used to change program characteristics, the directors indicated the following:

- When there is a culturally receptive change, the change in culture leads to support of e-Construction processes;
- There was improvement in the litter grant and adopt a highway participation;
- Sustainability initiatives were integrated during the design phase of new facilities or in the updating of existing facilities;
- QA/QC input and reports from reviewing plans will change our policy and guidelines as needed, and community relations group feedback is used to make program changes;
- Long time interstate closures have stimulated more focus on partnerships and multi-discipline traffic incident management training programs.
- We have integrated aspects of avoidance, minimization and mitigation into our projects;
- We use video conferencing technologies;

When asked how each director's division determines if a program is unsuccessful, the directors reported that an unsuccessful program would be indicated if all state, local, and federal guidelines had been met, but the project still could not be integrated; if the pre-determined baseline of production/efficiency could not be met; reduced incident clearance times, reduced secondary incidents, and improvements in travel time reliabilities; if the percent of construction projects were not completed by the original contract completion date or if the average percent difference in the final project construction cost were more than the contract award amounts or if there was a lack positive results and a loss of interest by partners in the program. Six division directors mentioned the need and reliance on public feedback to determine if a project is successful or not, but that there was no formalized method to receive, document and measure this feedback.

Finally, when asked if their divisions address aspects of sustainability in the planning process or the beginning of a project, eleven directors responded "Yes" (73%) and four directors responded "No" (27%). The most often cited reason for not addressing sustainability aspects in the planning process was that the division was not in a position to offer input at the beginning of a project.

5.2.4 Barriers to Sustainability

Two survey questions (Questions 18 – 19) asked about barriers to the initiation of sustainability policies or programs. The directors were asked "In your opinion, are there any barriers or difficulties encountered in implementing sustainability initiatives?" Thirteen directors responded "Yes" (87%) and two directors responded "No" (13%). When asked to clarify what could generate the most difficulty in implementing sustainable initiatives, multiple responses were permitted, and are found in Table 16.

The most frequently cited barriers to sustainability include low awareness of potential and/or existing programs, policies and procedures; the cost of implementation and legislative or regulatory prohibitions. The directors who selected "Other" were asked to clarify their responses. The results indicate some reasons that could be managed directly by TDOT. These include an individual or generalized resistance to change if there is not a clear understanding of the reason for the protocol change; the unfavorable concept of what constitutes "Sustainability" as the term is not well-understood and not well-defined; a lack of knowledge regarding the applicability of sustainable practices to the specifics of projects, and the need for TDOT to integrate into a new way of looking at the business of the DOT – to focus on the management and operations of the facilities as well as traditional road building.

One quote offers a clear understanding of barriers to sustainability: “At times educational disciplines and work environments do not encourage the inclusion of sustainability aspects into a final product or deliverable. Difficulty may arise because these aspects are often not quantifiable and require abstract thinking to understand their long-term benefits.”

Table 16: Barriers to Sustainability Expressed by TDOT Division Directors

# of Responses	% of Responses	Response
9	19%	Low Awareness of Potential and/or Existing Programs/Policies and Procedures
8	17%	Cost of Implementation
8	17%	Legislative or Regulatory Prohibitions
7	15%	Other
5	11%	Lack of Effective Implementation Tools and Methodologies
4	9%	Non-TDOT State, Community or Local Leaders
3	6%	TDOT Supervisors or Other Division Leaders
3	6%	Lack of State Define Standards
0	0%	Persons in Your Division
47	100%	Total Responses

NOTE: Multiple responses permitted; N= 13 respondents.

5.2.5 Sustainability Practices of Other Departments of Transportation

The final three survey questions (Question 20 – 22) asked division directors if they knew of any good examples and bad examples of sustainable practices at other DOTs, as well as any final comments they would like to make. Four directors were able to provide positive examples from other DOTs; these include:

- Multi-state cooperative efforts in the creation of a Monarch Butterfly Highway initiative to improve pollinator habitat along Interstate 35;
- Seattle, Washington's Road Diet manual;
- North Carolina DOT's Environmental Index;
- A list of five DOTs that had integrated sustainability actions beyond that required by federal law (i.e. Washington State DOT, Colorado DOT, Arizona DOT, Iowa DOT and Minnesota DOT);

Also, division directors were asked if they knew of any examples at other DOTs that were bad examples of sustainable practices. Three directors were able to provide examples from other DOTs that included one example where a higher percentage of recycled asphalt pavement (RAP) and RAS was used in hot mix asphalt and the pavement failed prematurely; the lack of funding or support for public transportation by some state DOTs, and state law that prohibits the purchase of land needed for future use (10 years or less).

The final survey questions asked each director's opinion on what revisions or changes should take place to make TDOT practices more sustainable with a capacity to endure. The following are the responses:

- Develop, promote and adopt the use of best practices.
- Designate a sustainability practice lead that can research initiatives, and coordinate with divisions possible initiatives;
- Need for awareness of the sustainability policies and programs already in place;
- Some recognition and publicity that TDOT is engaged in conservation efforts;
- The introduction of an emailed quarterly or monthly newsletter highlighting sustainability initiatives related to current or future projects or policies could provide impetus for other divisions/employees to integrate sustainability into their projects or policies;
- Extend current sustainability initiatives and policies further;
- Multimodal design guidelines could provide a foundation for a long-term multi-disciplinary integrated transit SYSTEM;
- Partnering TDOT divisions with entities in land management, public transit, economic development, etc.;
- Division leaders should have a method to communicate in order to foster a better understanding of what sustainability practices are being integrated;
- Sustainability education should begin with new employee orientation;
- Increase awareness of how each division can revise certain existing policies and procedures to be integrated into other division policies for comprehensive sustainability endurance;
- Open communication between TDOT divisions about initiatives/policies related to sustainability;
- More focus on the management and operations of our roadway facilities from end to end. This includes early in the project planning stage, through design, roadway construction, maintenance, and day to day activities.

5.3 Summary

The survey has revealed important insights that point to establishing a program that enhances TDOT's "capacity to endure." The input from TDOT division directors motivates the creation of a comprehensive program that can weave sustainability concepts into TDOT's fabric. The program can build on new initiatives and initiatives currently underway at TDOT. These include but are not limited to adoption of alternative and more efficient energy systems (hybrid and alternative fuel vehicles), application of intelligent transportation systems (e.g., incident management), smart growth strategies, maintenance (e.g., using recycled asphalt), and environmental stewardship (reductions in emissions).

Also, the survey has identified both general and specific requests mentioned by TDOT Division Directors. Generally, the directors mentioned the desire for dialog among different division directors, so they can collaborate on comprehensive sustainable strategies. Awareness and training for tools that can help TDOT staff evaluate the benefits and costs of sustainable actions and strategies that can hasten the diffusion of sustainable practices. Also, there is a need for written policies, planning, and outreach efforts (within TDOT and externally) to incorporate sustainability into the fabric of TDOT. Specific requests from various TDOT directors include the following:

- The desire for in-house training that would include a series of educational opportunities that would build upon each other specific to certain themes;
- The requisite for new hires to have exposure to sustainability concepts early in the employment process;
- The preference for each division to have a specific individual whose main purpose is to make careful examination of or initiate sustainability practices into projects as low awareness of potential and/or existing programs is the most frequently cited barrier to include sustainability into programs;
- The need for the formalization of administrative practices that are sustainable across all divisions (e.g. online documentation, digital signatures, public outreach through internet, emailed invoice and payment, electronic plan submittal, etc.);
- The desire to have in place some type of formalized method for integrating sustainability aspects of other divisions into procedures, documentation and other efforts – a comprehensive multidisciplinary approach to integrating sustainability concepts into final deliverables, and
- The requirement for a well-defined and consistent methodology to measure or monitor the eventual outcomes of the sustainability programs and policies.

The 2017 Division Directors survey provides a solid description of the current sustainability actions taken by TDOT leaders. Additionally, the survey provides a guide for future steps the directors would like to support. Most of the directors are aware of the need to integrate sustainability activities into day-to-day procedures and processes in order to create the capacity for TDOT to endure.

6.0 DEFINING NEXT STEPS

In March 2018, the project team presented the survey results to TDOT Division Directors. Directors were able to discuss and provide feedback or clarification regarding the survey results. At the meeting, a moderator from the Lipscomb University Institute for Sustainable Practice facilitated the ranking or rating of each sustainability-related priority. The methodology for the weighted metric included the listing of each director's request and the use of colored dots. Directors were asked to identify priorities that are easy-to-implement or short term (Greens dots), moderate-to-implement or mid-term (Orange dots), and difficult-to-implement or long-term (Pink dots). Each dot was assigned a numeric value (i.e. green dots are worth three points; orange dots are worth two points, and pink dots are worth one point). Table 17 shows the rankings based on the cumulatively added results. Appendix A contains details regarding the process used to determine results.

The results of the weighted metric sort objectives from most important to implement to least important to implement. The two primary strategic focus areas include **Greater Clarity or Focus** on what "sustainability" means (Issues ranked as numbers 1, 2, 4, 11 and 12 C), and **Core Strategic Actions** for TDOT personnel to undertake (Issues ranked as numbers 3, 5, 6, 7, 8, 9, 10, and 12A/12B). The top priorities identified by TDOT personnel are summarized below.

Table 17: List of Director Priorities

Ranking and Sustainability Area	# of Points
1. Common Definition of Sustainability	69
2. Best Practices from Other States	53
3. In-House Education	47
4. Designate a Sustainability Lead	44
5. Public Transit	38
6. Raise Awareness Internally	37
7. Integrate Benefit/Cost	30
8. Establish Sustainability Work Groups (especially for CAV)	27
9. Fleet Management	26
10. Smart Communities	26
11. More Collaboration	24
12. COMBINED: Move from Planning to More Practice, Connected/Automated Vehicles, Already have Some Policies & Most Use Them [Formalize It/More Needed]	23
13. Address Alternative Travel Infrastructure	19
14. More Sustainability Technology	19
15. Academic Research Needed to Sort Out Executable Strategies	18
16. Process the Negatives	17
17. New Hire Orientation	17
18. More Monitoring / Metrics	16
19. Address the Role of Energy	15
20. Water/Mitigation/Permeability	14
21. [Address] The Role of Efficiency	13
22. Mission: Internal Responsibility	12
23. Bike Infrastructure	11
24. Partner with {Transportation Policy] NGO's	11
25. Evaluate Uncertainty More	9
26. Mission: Good Transportation	6
27. [Secure] Outside Support	1

6.1 Greater Clarity and Focus

Greater Clarity and Focus includes defining sustainability, integration of best practices, designating a sustainability practice lead, developing a formalized collaboration process and the formalization of current sustainability actions.

1. Define Sustainability – (Ranked #1) Many state departments of transportation are moving to incorporate sustainability into their day-to-day operations. A definition of what sustainability means to TDOT provides clarity and a baseline of understanding for all TDOT employees.

2. Best Practices Applied to TDOT – (Ranked #2) There is a need to identify sustainability best practices utilized by other state DOTs that can be transferred to TDOT departments easily. This will allow directors to begin the process of sustainability integration.

3. Sustainability Practice Lead – (Ranked #4) In the survey, division directors indicated a need for a Sustainability Practice Lead who would be responsible for overseeing the compliance of sustainability initiatives.

4. Formalized Collaboration – (Ranked #11) Eight of the division directors remarked on the need to have in place some type of formalized method for integrating sustainability aspects of other divisions into their own projects, procedures, documentation and other efforts.

5. Formalization of Sustainability Policies - (Ranked #12 C) A number of directors indicated the following of unwritten sustainability practices, such as paper recycling and reduction, etc. Four of the directors mentioned that there is a need to "formalize" the unwritten policies to provide consistency throughout the separate TDOT divisions.

There are five sections identified in the Clarity and Focus portion of the report. This includes TDOT development of its own sustainability definition. The 1987 Brundtland Commission created one of the first well-known definition of sustainability "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED 1987). Since then, several state departments of transportation (DOT) have developed their own unique definition. For example, Florida DOT defines sustainability as "meeting the needs of the present without compromising the ability to meet the needs of the future" (FDOT 2000).

Global concerns about climate change, energy use, environmental impacts, and limits to financial resources for transportation infrastructure require new and different approaches to planning, designing, constructing, operating, and maintaining transportation solutions and systems. A series of Best Practices, specifically identified as easy or moderately difficult for

TDOT to implement, provides focus and clarity to implementing sustainability into the fabric of their day-to-day operations.

Division directors requested the assistance of a Sustainability Practice Lead who would be responsible for building and leading the initiatives of TDOT's sustainability plan and integrate TDOT's definition of sustainability into practice. This person would improve the performance of the triple bottom line (people, profit, and planet) of their efforts by developing customized solutions and organic growth strategies for each division that address their needs.

Directors requested the formalization of joint efforts between divisions, and of unwritten sustainability actions currently practiced. This report provides methods for TDOT personnel to formalize collaboration. More than half of the division directors requested a formalized method for integrating sustainability aspects of other divisions into their own projects to provide a comprehensive multidisciplinary approach to integrating sustainability concepts into final deliverables. There is also a section that provides methods for the endorsement of sustainability practices already in place and being practiced by TDOT personnel.

6.1.1 Sustainability Defined

The research team used Transportation Research Board National Cooperative Highway Research Program (NCHRP) Report 708: A Guidebook for Sustainability Performance Measurement for Transportation Agencies to collected and summarized definitions for "Sustainability" (NCHRP 2011). NCHRP Report 708 describes the underlying principles of sustainability as it relates to transportation, possible goals used to address those principles and performance measures used to address those goals.

NCHRP sustainability goals are based on three key sustainable transportation issues: economic, social and environmental. The research team further identified eleven additional sustainability goals, including safety, basic accessibility, equity/equal mobility, system efficiency, security, prosperity, economic viability, ecosystems, waste generation, resource consumption, and emissions and air quality.

To help define sustainability, the research team summarized the definition of sustainability used by other agencies and DOTs, including the Transportation Research Board Sustainable Transportation Indicators Subcommittee, California DOT, Colorado DOT, Florida DOT, Minnesota DOT, New York DOT, and Oregon DOT. The perspectives on sustainable transportation vary across DOTs.

The research team further explored the performance measures of sustainable transportation. Six key measures are identified as: emissions reduction and air quality, resource consumption, economic prosperity, waste management, safety and ecosystem preservation. To achieve these

goals, state DOTs have applied various sustainability strategies. Their corresponding benefits have been documented and can be found in Section 2.1.2. Best Practices.

State DOTs have suggested different definitions of sustainability, developed sustainable strategies, and investigated their impacts on the performance of the system utilizing various performance measures. Generally, state DOTs have explored the impacts of these strategies on economy, emissions, energy, water, safety, air quality and climate, ecology, land use, social and cultural aspects, and noise. A summary of sustainable strategies and their impact is included.

6.1.1.1 The Multiple Definitions of Sustainability

A study by Littman and Burwell (2006) has noted that the goal of the DOTs is providing adequate, efficient, and safe transportation mobility and service for the general public while considering the economic, social, and environmental consequences. The following indicators form the main categories of topics related to sustainability; they can help DOTs develop a comprehensive and balanced analysis of sustainability options (Table 18). Table 19 provides definitions for sustainability found in the National Cooperative Highway Research Program (NCHRP) Report Number 708.

Table 18: Structuring Sustainable Transportation Issues (Source: Littman and Burwell, 2006)

Economic Aspects	Social Aspects	Environmental Aspects
Accessibility quality	Equity / fairness	Air pollution
Traffic congestion	Impacts on mobility disadvantaged	Climate change
Infrastructure costs	Affordability	Noise pollution
Consumer costs	Human health impacts	Water pollution
Mobility barriers	Community cohesion	Hydrologic impacts
Accident damages	Community livability	Habitat and ecological degradation
Depletion of Non-Renewable Resources	Aesthetics	Depletion of Non-Renewable Resources

Table 19: Recommended Transportation Sustainability Goals in NCHRP 708 Report.

Sustainability goal	Definition
Safety	Provide a safe transportation system for users and the general public.
Basic accessibility	Provide a transportation system that offers accessibility that allows people to fulfill at least their basic needs.
Equity/equal mobility	Provide options that allow affordable and equitable transportation opportunities for all sections of society.
System efficiency	Ensure that the transportation system's functionality and efficiency are maintained and enhanced.
Security	Ensure that the transportation system is secure from, ready for, and resilient to threats from all hazards
Prosperity	Ensure that the transportation system's development and operation support economic development and prosperity.
Economic viability	Ensure the economic feasibility of transportation investments over time.
Ecosystems	Protect and enhance environmental and ecological systems while developing and operating transportation systems.
Waste generation	Reduce waste generated by transportation-related activities.
Resource consumption	Reduce the use of nonrenewable resources and promote the use of renewable replacements.
Emissions and air quality	Reduce transportation-related emissions of air pollutants and greenhouse gases.

The NCHRP report proposes a general approach for agencies to define the sustainability. As shown in the following Figure, four steps should be taken to develop a definition, including the review of sustainability principles, consideration of the context, and identification of goal related keywords (Figure 14). Together these will leave to a customized definition of sustainability. Ultimately, each of these steps applied in project development and infrastructure management affects sustainability and can be used as opportunities to develop and confirm sustainability goals and actions. The approach can also be used for entities within an agency (such as a district, department, or division) to define sustainability as it relates to them.

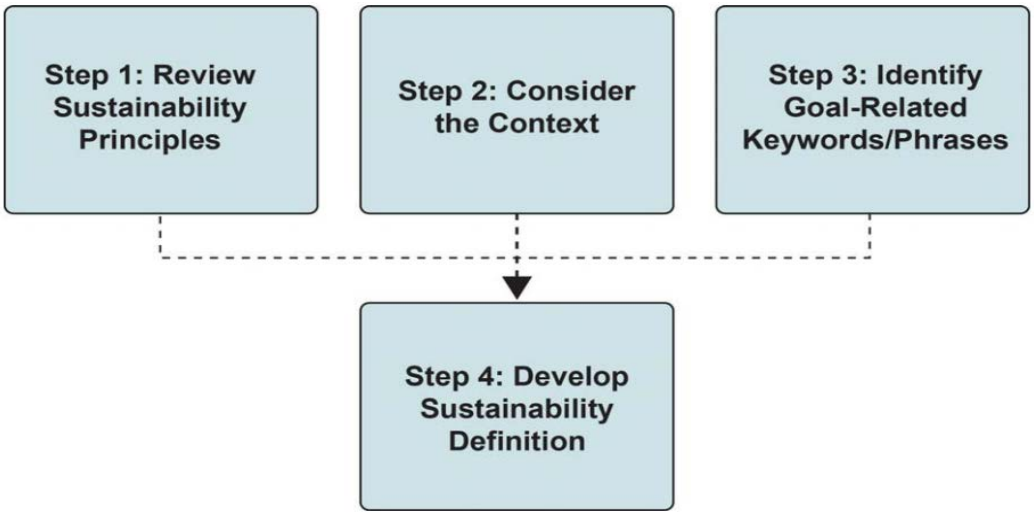


Figure 14: Steps to Defining Sustainability

One example of applying the steps to defining sustainability Include the following:

Step 1 – TDOT personnel review the principles of sustainability to develop an understanding of the subject. The principles of sustainability are varied (e.g. ecology, equity, and economy).

Step 2 – TDOT personnel identify the core issues of relevance (e.g. small urban areas; bus, bike, pedestrian facilities in addition to motor vehicles; focus on planning stage; and inclusion of stakeholders)

Step 3 – TDOT personnel identify goal related key words pertaining to each core issue. These key words are incorporated into the definition. Examples include accessibility, economic development, resource reduction, etc.

Step 4 – TDOT personnel develop a definition statement that integrates goal related key words. Sustainability is a complex concept with many nuances. In its simplest form sustainability means capable of lasting indefinitely (or for the long term). However, when specific objectives are added to the concept of sustainability, the various facets involved in a process being sustained become apparent. To assist TDOT in its development of a sustainability definition, the project team examined the sustainability definitions used by other departments of transportation. However, perspectives on sustainable transportation vary across agencies in the United States. In Table 20, the definition of sustainability by other DOTs is summarized.

Table 20: Definitions of Sustainability Used by Various Agencies (Source: NCHRP 708)

Agency	Definition
Transportation Research Board Sustainable Transportation Indicators Subcommittee	According to the definition, a sustainable transport system: • Allows the basic access and development needs of individuals, companies and society to be met safely and in a manner consistent with human and ecosystem health and promotes equity within and between successive generations. • Is affordable, operates fairly and efficiently, offers a choice of transport mode and supports a competitive economy, as well as balanced regional development • Limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and uses non-renewable resources at or below the rates of development of renewable substitutes, while minimizing the impact on the use of land and noise.
California DOT	Ensuring that environmental, social, health, and economic considerations are factored into decisions about transportation activities.
Colorado DOT	No official agency definition, but following general concept of the United Nations Brundtland Commission definition (i.e., meeting the needs of the present without compromising the ability to meet future needs).
Florida DOT	As defined in the 2025 Florida Transportation Plan: "Meeting the needs of the present without compromising the ability to meet the needs of the future."
Minnesota DOT	No official definition, although the agency's vision refers to a "safe, efficient, and sustainable transportation system."
New York DOT	A transportation system that supports a sustainable society is one that: • Allows individual and societal transportation needs to be met in a manner consistent with human and ecosystem health, with equity within and between generations. • Is safe, affordable, accessible, operates efficiently, offers choice of transport mode, and supports a vibrant economy. • Protects, preserves, and enhances the environment by limiting transportation emissions and wastes, minimizes the consumption of resources, and enhances the existing environment as practicable.
Oregon DOT	Using, developing, and protecting resources in a manner that enables people to meet current needs while providing for future generations to meet their needs, from the joint perspective of environment, economic, and community objectives.

6.1.1.2 Sustainability Strategies and Impacts

Sustainability strategies fall into three broad categories: economic feasibility, reduction in consumption (of energy, natural resources, etc.), and reduction in waste and wasteful behavior. These broad categories are divided further into specific strategies (e.g. increase use of alternative vehicles, use recycled asphalt in pavement, etc.). Many specific strategies have been used by departments of transportation and analyzed for their sustainable impacts. Table 21 provides examples of sustainability strategies and their impacts.

Table 21: Sustainability Strategies

Goal: Emission Reduction and Air Quality		
Agency	**Strategy**	**Impact**
US DOT	Deploy operations and management best practices for energy consuming and emission generating equipment, e.g., upgrading motors, boilers, HVACs, and chillers, compressors lighting, etc.	34% reduction (Building & fleet) since 2008
	Reduce air and ground travels	31% reduction in commuting & business air travel
	Fleet management by increasing the share of alternative vehicles	26% reduction in fleet petroleum use in 2015 compared with 2005; 233% increase in alternative fuel use in 2015 compared with 2005
California DOT	Sustainable pavement	10% reduction by 2015 against 2010; 61% reduction from construction of pavement and structure
Oregon DOT	Fleet management by increasing the share of alternative vehicles	Qualitative
Texas DOT	Sustainable pavement using recycled asphalt	113,300 tons/year of CO_2 emissions reduction
Washington State DOT	Improvement in alternative fuel vehicles fleet	25-43% reduction from 2040 baseline.
North Carolina DOT	Encourage green travel	Qualitative
Goal: Resource consumption		
US DOT	Clean and renewable energy, e.g., install renewable on-site and retain corresponding renewable energy certificates	15% of electric energy from renewable sources
California DOT	Installation/replacement of LED lights along the highway	35-60% energy savings
Colorado DOT	Encourage carpooling and AFV	Qualitative
New York DOT	Encourage renewable energy	Saving 214 million kilowatt hours of electricity; Producing 1.4 million kilowatt hours of electricity
Oregon DOT	Solar highway program	Offsets over 33% of the energy needed for freeway illumination
Virginia DOT	Fleet management and using AFV	Increased to use of alternative fuels to 13.3% of all fuels; Acquired AFV totaling 106% of covered vehicle acquisitions
Arizona DOT	Electrical energy efficiency and use	saved over 7 million KWh

Goal: Economic prosperity		
Arizona DOT	Bridge management system	Qualitative
Goal: Waste management		
US DOT	Recycling, composting and reuse materials	Qualitative
Colorado DOT	Using recycled waste and wash water to produce a salt brine liquid deicer	saved $394,030 in FY11
Goal: Safety		
California DOT	Adopting a "Toward Zero Deaths" practice	10% reduction in number of fatalities
Texas DOT	Provide walkable community	86% reduction in 'walking along the roadway' crashes
Texas DOT	Providing in-pavement LEDs	Improve the safety of intersection approaches
Washington State DOT	Reducing VMT by encouraging carpooling and car-share services	7.5 million reduction of VMT per year and 3,801 tons reduction in emissions
Washington State DOT	Improve the active transportation	VMT reduction by 44 million
Washington State DOT	Develop regional complete streets policy	91 million VMT reduction from 2006; 58,269 tons reduction in emissions per year
Arizona DOT	Highway safety plan	23 percent reduction in the number of fatalities in the first five years
Goal: Ecosystem		
US DOT	Climate resiliency plan	Qualitative
California DOT	Water conservation projects	10% reduction at facilities by 2015; 25% reduction in potable urban water use from 2013 to 2016
NY DOT	Preserving sensitive habitats and planting trees	Qualitative
Virginia DOT	Water use management	28% reduction in potable water use intensity in 2014 compared with 2007
North Carolina DOT	Storm water Pollution Prevention Plan	Qualitative

This chapter proposes a generally applicable approach to defining sustainability that TDOT can use. Defining "Sustainability" provides a cornerstone for changes in policies or procedures or adaption of new technologies. A TDOT-specific definition enables employees and state residents to have a common understanding of what Sustainability is as it relates to the actions taken by TDOT.

6.1.2 Best Practices

In broadest terms, the transfer of new sustainability technology requires detailed knowledge of the technology and its capability and applicability of being transferred to TDOT. The exact nature of technology transfer is difficult to pin down, partly because the term "technology transfer" has many different connotations. Within the context of this research, technology is information that is put to use in order to accomplish a sustainable objective, and transfer is the movement of technology via some communication channel from a state DOT to TDOT. In most cases, technology transfer will involve some changes in policies or procedures for TDOT.

This section of the final report provides specific examples of sustainability actions that can be applied to each TDOT division. These recommendations are based on the 2017 TDOT Division Manager Survey during the interview discussions, and the sustainability actions identified through a detailed literature review. The choice of which mechanisms to use in identifying the ease in which specific sustainability programs could be applied to TDOT (i.e. the implementation rating) is based on six factors: Funding, Proven Technology, Costs, Benefits, Project Control and Barriers. Details on how the six factors are used to calculate the ease of implementation are found in Chapter 3.0 ANALYSIS OF TRANSFERABILITY.

The initial framework described clarifies how impacts of strategies may depend on the context in which sustainable strategies are implemented. The six-part evaluation tool has been developed to determine the ease of applying sustainability practices of other departments of transportation to the Tennessee Department of Transportation. The categories are defined loosely as EASY or MODERATE.

Various practices can contribute to sustainable transportation. For example, sustainable options include using recycled materials in construction projects, retrofitting fleets to reduce vehicle emissions or investing in multimodal infrastructure to provide transportation options for the public. To this end, project team members have defined and selected sustainable practices that apply to 15 TDOT divisions (Aeronautics, Central Services, Construction, Environmental, Freight Logistics, Long-range Planning, Maintenance, Materials and Testing, Multimodal, Roadway Design, Right-of-way, Strategic Planning, Strategic Transportation Investments, Structures and Traffic Operations. The Sustainable Technology Transfer Framework was applied to each practice to determine the ease in which a policy or action can be applied. An example of the framework is found below in Table 22: Sustainable Technology Transfer Framework.

Table 22: Sustainable Technology Transfer Framework

Project Description

Criteria	Rating	Notes
Funding	Easy	Federal government offers funding to project sponsors using grants. The types of entitlement and discretionary funds are project type dependent - 75% to 90% of project cost is reimbursable.
Proven Technology	Easy	Funding application guidelines list the specific categories of proven technology that are eligible for funding.
Cost	Easy	Application contains worksheets to calculate exact project cost. Available information provides detailed information on project planning, the application process, eligibility requirements, project standards, cost effectiveness criteria, project tracking, etc.
Benefit	Easy	Available information provides a means to calculate sustainability cost savings.
Project Control	Moderate	TDOT Division does not have direct control over project though it can provide education on the application process and encourage eligible authorities/sponsors to apply.
Barriers	Moderate	Barriers to program application are outside of TDOT scope. These barriers include eligibility criteria and matching funding sources, as well as political barriers.

As seen in Table 23, each sustainability strategy is division specific, as well as categorized regarding type of sustainability strategy, such as RESOURCE, GUIDE, TOOL or POLICY. Resources materials are items that can assist TDOT personnel in implementing sustainability practices. Guides are general recommendations that provide a roadmap for implementation, and tools are task specific. Policies provide examples of formalized, approved actions that are mandatory. For example, a resource for the Environmental Division is the *Historical, Architectural, Archeological, and Cultural Resources Desk Reference* book; whereas a guide for the Maintenance Division is *Sustainable Pavement Management and Preservation Guidelines* or the *Sustainable Airport Manual* for the Aeronautics Division. Tools include Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS), which is a decision-support tool supporting the analysis of project alternatives for the Construction Division, and the INVEST TOOL for Sustainable Contractor and Acquisition Procurement. Policies include Fleet Acquisition and Management Policy for Central Services Division and Using Recycled and Reclaimed Materials Policy for Materials and Testing.

Table 23: List of Sustainability Actions & Strategies for TDOT Divisions

Division	Proposed Strategy
Aeronautics	**RESOURCE: Federal Aviation Administration VALE & AIP** FAA provides funding through Voluntary Airport Low Emissions Program to

	use Airport Improvement Program funds and Passenger Facility Charges to finance specific airport air-quality improvements. Currently, only the Memphis International airport has taken advantage of this program. TDOT can encourage other airports in Tennessee to participate in this program.
	GUIDE: SAM (Sustainable Airport Manual) SAM is a comprehensive guidance manual created by the Chicago Department of Aviation to incorporate and track sustainability in administrative procedures, planning, design and construction, operations and maintenance, and concessions and tenants with minimal impact to project schedules or budgets. TDOT can benefit by reviewing SAM and adopting appropriate practices.
	TOOL: Colorado Division of Aeronautics Tool Kit The tool kit provides tools, resources and guidance for general aviation airports to develop their own individually customized sustainability plans. TDOT can encourage other airports to develop their own sustainability plans.
Central Services	**POLICY: Fleet Acquisition and Management Policy** TDOT is currently purchasing alternative fueled vehicles, but may need a systematic method in their purchasing policy and guidelines for fleet replacement. USDOT has developed specific policies to achieve the goal of acquiring low emission vehicles via a comprehensive fuel-efficient vehicle purchasing, replacement and maintenance strategy. TDOT can incorporate the USDOT methodology into their fleet purchasing and replacement process.
	POLICY: Purchasing Recycled Materials USDOT has written a Sustainable Acquisition Policy Order that applies to all service contracts, leases, and purchases. TDOT can establish and implement policies to meet purchasing preference requirements for recycled content products.
Construction	**TOOL: Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS)** CA4PRS is a decision-support tool supporting the analysis of project alternatives for different pavement designs, construction logistics, and traffic operation options. It is developed to minimize traffic delay and reduce agency costs. TDOT can use the software to analyze scheduling, traffic, and costs for highway projects.
	TOOL: Sustainable Contractor and Acquisition Procurement - INVEST TOOL FHWA's INVEST is a web-based self-evaluation tool comprised of sustainability best practices, which cover the full lifecycle of transportation services, including system planning, project planning, design, and construction, and continuing through operations and maintenance. To accomplish this, the INVEST criteria are divided into four modules: System Planning for States (SPS), System Planning for Regions (SPR), Project

	Development (PD), and Operations and Maintenance (OM). Each module contains between 14 and 33 criteria and each criterion focuses on a topic area. TDOT can apply the INVEST tool to evaluate the sustainability of various new construction and rehabilitation of projects.
Environmental	**Environmental Analysis** **GUIDE: Preparing High-Quality NEPA Documents for Transportation Projects** NEPA Office. The purpose of the AASHTO handbook is to produce NEPA documents that contain sustainability actions. TDOT can use the reference to bridge the gap between the theory and practice of producing NEPA documentation. **RESOURCE: Historical, Architectural, Archeological, and Cultural Resources Desk Reference** Archeology office: This manual describes the analysis of historical, architectural, archeological, and cultural resources within the context of NEPA review and integration of sustainability into decision-making. TDOT can explore the desk reference to integrate sustainability language into archeological preservation efforts. **RESOURCE: Advisory Council on Historic Preservation** Historic Preservation office: Provides resources for integrating sustainability concepts into historic preservation. TDOT can use this resource toward the completion of Section 106 documentation. **TOOL: Texas Department of Transportation Hazardous Materials Toolkit** Hazardous Materials office: This toolkit provides sustainability tools to prepare materials associated with the management of hazardous materials during project development. TDOT can integrate hazmat and sustainability concepts into multiple projects. **GUIDE: Compendium of Next Generation Compliance Examples in Clean Air Act Programs** Air & Noise office: EPA publication is used to advance clean air goals and sustainability in rulemaking, permits, enforcement, and other functions. TDOT can couple state air control programs with this guide to become more efficient and effective. **GUIDE: How to Comply with Your Environmental Permit** Air & Noise office: This is a publication by the Environmental Agency of England that explains to permit recipients the sustainability practices that should be followed. TDOT can modify the document to assist state permit recipients into becoming more sustainability aware.

	Ecology and Permits **RESOURCE: Overcoming Barriers to Green Permitting: Tools for Local Governments** Workshop conducted by the Southface Energy Institute includes sustainable design during the entire permitting process. The Sustainable Design and Green Building Toolkit for Local Governments by EPA expands on the sustainability concepts in permitting. TDOT can attend the workshops and encourage sustainability into permitting. **Highway Beautification** **GUIDE: Rhode Island Highways-Best Practices Design Guide** Publication establishes beautification standards for design and management of infrastructure and buffer areas. The guide includes case studies of best practices. TDOT can utilize the best practices to create "beautification" corridors that integrate sustainability. **Environmental Comprehensive Inspections** **GUIDE: Implementation of Sustainability in Bridge Design, Construction and Maintenance** Publication provides a framework for sustainable design, construction and maintenance. TDOT can increase its incorporation of sustainable practices into its bridge maintenance program. **GUIDE: Iowa DOT Bridge Design Manual** Manual provides sustainable bridge design concepts for rehabilitation, reuse or the optimization of existing bridges. TDOT can utilize the concepts to form a framework for bridge optimization and reuse (e.g. pedestrians). **GUIDE: An Integrated Approach for Building Sustainable Roads** Publication provides a method to integrate sustainability into the planning, design, and construction of projects. It is intended to be compatible with TDOT's existing technical guidelines for project development processes. **Environmental Facility Compliance** **TOOL: Sustainable Facilities Tool (sftool.gov)** Toolkit provided by the General Services Administration assists with understanding federal requirements, project planning and development, procurement, operations and management, product search, etc. TDOT can explore the tool to discover gaps in their current process of facility

	compliance. **<u>Environmental Mitigation</u>** **GUIDE: A Strategy for Improving the Mitigation Policies and Practices of the Department of the Interior** Guide describes the key principles and actions necessary to successfully shift from project-by-project management to consistent, landscape-scale, science-based management of lands and resources. TDOT can use the tool to incorporate long-range regional project management into day-to-day operations.
Freight and Logistics	**GUIDE: Off-Peak Delivery Time** Off-peak delivery time guides can encourage night-time freight deliveries; these guides are used to reduce freight traffic during peak hours, saving both time and money. TDOT can create the guide to encourage public-private partnerships with industries that can accommodate off peak-hour shipments.
	POLICY: Left Lane Truck Restrictions The purpose of TDOT Rule 1680-2-5 is to implement Tennessee Code Annotated § 55-8-195 by establishing criteria for the designation and enforcement of lane restrictions for truck tractors and semi-trailers. These guidelines were last revised in 2005. TDOT can review and update these policies.
	TOOL: Expand the Smart Park Program Smart Park is a smartphone-based technology built by TDOT that provides real-time information on parking availability on two truck parking sites along I-75. The project team identified 11 potential sites. TDOT can expand this program to include additional sites along other interstate corridors.
	RESOURCE: Develop Public-Private Parking Partnerships This would allow for the construction or re-adaptation of additional parking spaces on the current or new right of way, such as closed weigh stations, and collaborative planning and rehabilitation of vacant urban parcels for use as parking areas. Sacramento uses park-and-ride facilities for overnight parking. TDOT can determine the availability of closed or underused public facilities and private land parcels.
Long-Range Planning	**POLICY: Extension of Plan Time Horizon** For transportation planning processes to integrate sustainability objectives, the forecast period for many projects could be extended to 40 years. Some planning organizations have begun to extend their planning horizons, most notably various metro areas and the state of California. TDOT can begin the transition of thinking of sustainability first by integrating longer planning horizons for some projects.

	POLICY: Inclusion of Sustainability Language USDOT has proposed the integration of sustainability language into purchases, processes and plans via the GROW AMERICA Act. TDOT can follow this example by highlighting policies that use terms relating to sustainability concepts and providing incentives to include sustainability terms into contracts.
	GUIDE: Complete Streets Environmental, societal and accident avoidance benefits outweigh costs associated with building comprehensive Complete Street segments. TDOT can replicate this model in other urban contexts by providing a series of how to guides specific for Tennessee municipalities.
	GUIDE: Alternative Fuel Infrastructure It is essential to reduce transport oil-dependence, mitigate its environmental impact and, deliver on the national strategy for low-emission mobility. TDOT can develop guidelines for the minimum requirements and tax benefits for the building-up of alternative fuels infrastructure, including publicly-accessible recharging locations for electric vehicles and re-fueling stations for natural gas and other alternative fuel vehicles.
	<u>Transportation Demand Management</u> **POLICY: Commute Trip Reduction Plan** Washington requires all counties with a population over 151,600 and each city or town within those counties containing a major employer (more than 100 full-time employees) to adopt and implement a commute trip reduction (CTR) plan, which includes flexible work hours and telecommuting. TDOT can create its own CTR plan.
Maintenance	**POLICY: Vegetation Management** A wide variety of vegetation management are considered sustainable and include slight changes to shoulder blading, mowing, brush mowing, and brush cutting. TDOT can make basic changes in methodology and policy that are considered sustainable.
	GUIDE: Sustainable Pavement Management and Preservation Guidelines Most often pavement maintenance decisions are made on a project basis where traffic volume and cost are the predominant factors. The FHWA has developed guidelines in its Sustainable Pavement Program to create a comprehensive program. TDOT can integrate the comprehensive approach into pavement preservation and management policies.
Materials and Testing	**POLICY: Replacing Hot Mix Asphalt with Warm Mix Asphalt** The immediate benefit to producing WMA is the reduction in energy consumption required by burning fuels to heat traditional hot mix asphalt. TDOT can benefit as the decreased production temperature reduces emissions from burning fuels, fumes, and odors generated at the plant and the paving site.

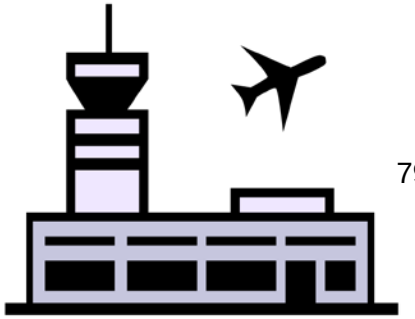
	POLICY: Using Recycled and Reclaimed Materials FHWA actively promotes asphalt pavement recycling and technology for highway materials in pavement construction in an effort to preserve the natural environment, reduce waste, and provide a cost effective material for constructing highways. TDOT can integrate these policies into their pavement policies.
Multimodal	**GUIDE: Statewide Comprehensive Public Transit Network** Colorado DOT and North Carolina DOT have developed statewide comprehensive connected public transportation networks that have integrated various modes across jurisdictional boundaries. TDOT can follow North Carolina's example. NCDOT has a Connected Statewide Network with 70 new routes, linking rural and urban areas with scheduled transit service by integrating the services of 100 urban and rural transit agencies
	POLICY: Sustainability Language Language used in a TDOT Multimodal plan and related documents may contain certain predispositions, e.g., toward automobiles or roadways over buses and transit systems or other more sustainable elements. TDOT can purposefully include sustainability terms into its plans.
Roadway Design	**TOOL: Sustainable Project Management - INVEST TOOL** FHWA's INVEST self-evaluates the use of best practices in contact management. TDOT can use this tool to optimize resources, reduce risk and waste and increase project effectiveness.
	POLICY: Sustainable Roadway Design Policy A study by Ferdinando Corriere and Angela Rizzo (University of Palermo, Italy) have drafted a methodology for integrating sustainability into Roadway Design Manuals and Policies. The authors identified ten steps to accomplish this task. The steps are a combination of items in the FHWA INVEST Tool and various tools used in Great Britain. TDOT can integrate some policy aspects into roadway designs.
Right-of-Way	**RESOURCE: North Central Texas Council of Governments Road Map to a Sustainable Public Right-of-Way** Document offers ten steps to improve the sustainability of the projects constructed within the public rights-of-way...it is a collection of ideas, examples, reference material, and memory joggers that may be used to create more sustainable public rights-of-way for both new construction and rehabilitation/revitalization projects. TDOT can use this resource to integrate sustainability into right-of-way seamlessly.
	RESOURCE: Ray C. Anderson Highway Right-of-Way The 18-mile-long Ray C. Anderson Highway, a segment of Interstate 85 in Troup County, Georgia provides a proving ground for sustainable technologies such as solar-powered electric vehicle charging stations, bio-swales, which are landscape elements designed to concentrate or remove debris and pollution out of surface runoff water, and a 7,000-square-foot

	pollinator garden. TDOT can integrate some of these concepts into their right-of-way designs.
Strategic Planning	**TOOL: Bartella Methodology** The methodology provides a means to identify strengths and weaknesses of TDOTs current strategic plan with regards to sustainability. A self-assessment tool was designed by Bartella to guide agencies through (1) identifying internal strengths and weaknesses (or gaps) in their planning frameworks and organizational structure and culture, (2) characterizing features of the external environment as opportunities or threats, (3) prioritizing areas for strategy development, and (4) developing strategies that link the internal and external environments.
	RESOURCE: National Sustainable Transport Planning - Concepts and Practices Danish researchers offer suggestions for integrating sustainability into TDOT as a comprehensive framework of approach. The aim of the document is to review how to integrate and define the concept of state sustainable transport planning. TDOT can use the resource to define TDOT sustainability.
Strategic Transportation Investments	**POLICY: North Carolina Strategic Investments Law** Passed in 2013, the Strategic Transportation Investments law allows the North Carolina Department of Transportation (NCDOT) to use its funding more efficiently and effectively to enhance the state's infrastructure. A formula is used to prioritize projects.
	RESOURCE: Invest Strategically in Transportation The Chicago Metropolitan Agency for Planning has developed a series of recommendations for investing strategically in transportation. These include a method to prioritize investments, find new revenue streams, and create costs and investment efficiencies.
Structures	**TOOL: National Bridge Investment Analysis System - NBIAS** The National Bridge Investment Analysis System (NBIAS) was developed to assess national bridge investment needs and the tradeoff between funding and performance. Newer editions of NBIAS include environmental trade-offs as well. The tool is based on an analytical framework developed by the Federal Highway Administration (FHWA) and subsequently adopted by the American Association of State Highway and Transportation Officials (AASHTO).
	GUIDE: Iowa Department of Transportation Sustainable Bridge Design Guidelines Iowa DOT has rewritten its Bridge Design Guideline Manual to include sustainability language. The IDOT manual provides sustainability assessment tools, sustainable processes for handling water used in construction, etc. TDOT can use the tool to determine if current practices

	are as sustainable as they could be.
Traffic Operations	**TOOL: Adaptive Traffic Control** Adaptive Traffic Control Systems enables traffic signals to adapt to actual traffic demand. In one case, ATCS system was shown to reduce travel time by 12.7 percent, reduce average stops by 31 percent, and decrease average delays by 21.4 percent. TDOT can utilize ATCS on congested corridors throughout the state and then highlight their intuitive.
	POLICY: Green Lights for Midtown The goal of the pilot project was to open up the streets and avenues in Midtown for pedestrians by reconnecting the street grid on 6th and 7th Avenues and closing off a portion of Broadway. The project resulted in traffic signals with up to 66% more green time; ravel time improvements on 6th and 7th avenues, and safer and simpler crossings for pedestrians
	RESOURCE: Connected and Automated Vehicles (CAV) Drivers who can receive information, alerts and warnings from surrounding vehicles can make more informed driving decisions. Specifically, they can avoid running into vehicles and perform safer lane change maneuvers. TDOT can identify high impact technologies, e.g., testing of truck platooning on roadways and creation of CAV testbeds for economic development and equality.
	POLICY: Telematics Telematics is the technology that helps in sending, receiving, and storing information from road vehicles. The technology is able to monitor and transmit information such as current vehicle speed against the speed limit of the road, road conditions, the braking, cornering, and accelerating habits of the driver. The California Department of Transportation began including telematics capability into its fleet of vehicles in 2015. TDOT can begin integrating telematics into its new fleet.
	TOOL: Intelligent Transportation Systems In intelligent transportation systems (ITS), transportation infrastructure is complimented with information and communication technologies with the objectives of attaining improved passenger safety, reduced transportation time and fuel consumption and vehicle wear and tear. With the advent of modern communication and computational devices and inexpensive sensors it is possible to collect and process data from several sources.

6.1.2.1 Aeronautics Division

The Aeronautics Division at TDOT is responsible for licensing public airports, monitoring compliance with federal grants and providing flight services for branches of state



government. It performs engineering services, aviation planning studies, airport improvement and project design consultation to local airports. It ensures the operational safety and efficiency of the state aviation facilities system. Services include air cargo and mail delivery; emergency helicopter dispatching, and crop dusting/hydro-seeding. Another important branch in aviation is forest and power line patrols. The Division has the responsibility of licensing 142 heliports and 74 public/general aviation airports. It also oversees grants to improve and rehabilitate these facilities. The Division's include Administration, Finance and Grant Management, Engineering and Program Development, Flight Services, and Planning and Programming.

Sustainability actions pertaining to the Aeronautics Division include using Federal Aviation Administration Funding to encourage the integration of low emissions technology (Table 24), the adoption of SAM (Sustainable Airport Manual) (Table 25), and case studies provided by the Colorado Division of Aeronautics (Table 26).

RESOURCE: Federal Aviation Administration VALE & AIP

The Federal Aviation Administration provides funding through VALE (Voluntary Airport Low Emissions Program) to use Airport Improvement Program (AIP) funds and Passenger Facility Charges (PFCs) to finance low emission vehicles (e.g. shuttle buses, maintenance vehicles), refueling and recharging stations, gate electrification, and other airport air-quality improvements, such as solar hot water. Eligible airports include Nashville International, Memphis International, McGhee Tyson, Lovell Field and Tri-Cities Regional TN/VA. Currently, the Memphis International airport has taken advantage of this program. Details of the programs are found at: www.faa.gov/airports/environmental/vale/

> *VALE grants have funded 105 projects at 51 airports and have reduced ozone emissions by 1,192 tons per year . . . equivalent to removing 66,550 cars and trucks off the road.*

The Passenger Facility Charge Program allows the collection of PFC fees up to $4.50 for every enplaned passenger at commercial airports controlled by public agencies. PFCs are capped at $4.50 per flight segment with a maximum of two PFCs charged on a one-way trip or four PFCs on a round trip, for a maximum of $18 total. Airports use these fees to fund FAA-approved projects that enhance safety, security, or capacity; reduce noise; or increase air carrier competition.

Table 24: VALE & Airport Improvement Program

Criteria	Rating	Notes

Funding	Easy	Airport sponsors can fund VALE projects using Passenger Facility Charges (PFCs) or Airport Improvement Program (AIP) grants. Both entitlements and discretionary AIP funds may be available for VALE projects; 75% to 90% of project cost is reimbursable.
Proven Technology	Easy	Funding for specific categories of proven technology includes Alternative Fuel Vehicles, Gate Electrification, Remote Ground Power, Ground Support Equipment, Geothermal Systems, Solar Thermal Technology, and Underground Fuel Hydrant.
Cost	Easy	Worksheets are available to calculate exact project cost. Available information provides detailed information on project planning, the application process, eligibility requirements (e.g., vehicle/equipment, fuel, ownership), program vehicle low-emission standards, emissions calculation methodology, cost effectiveness criteria, and project tracking)
Benefit	Easy	Available information provides a means to calculate emissions reeducation and cost savings.
Project Control	Moderate	TDOT Aeronautics Division does not have direct control over project though it can provide education on the application process and encourage airport authorities/sponsors to apply.
Barriers	Moderate	Barriers to program application are outside of TDOT scope. These barriers include eligibility and funding source. To be eligible for the VALE program, an airport must be a commercial service airport listed in the FAA's National Plan of Integrated Airport Systems (NPIAS) and located in an EPA-designated nonattainment or maintenance area for one or more of the criteria pollutants. Specific project eligibility varies between the two FAA airport funding programs (PFCS and AIP) in several important respects. Sponsors should consider these funding distinctions in planning their VALE projects and in selecting the most appropriate funding source or combination of sources to support them.

GUIDE: Sustainable Airport Manual

The Chicago Department of Aviation is the first in the nation to develop sustainable guidelines for design and construction at airports. The Sustainable Airport Manual (SAM) is as an integral part of Chicago's ongoing efforts toward implementing more environmentally sustainable initiatives across all airport activities. SAM is a comprehensive guidance manual created by the Chicago Department of Aviation to incorporate and track sustainability in administrative procedures, planning, design and construction, operations and maintenance, and concessions and tenants with minimal impact to project schedules or budgets. SAM not only guides the

implementation of sustainability initiatives at O'Hare and Midway International Airports, several other airports around the world utilize the concepts contained in the manual.

The manual has five sections: Administrative, Airport Planning, Design and Construction, Operations and Maintenance, Concession and Tenants. Aspects of each section are applicable to Tennessee Airports. A summary of each chapter follows, but because of the variation in sustainability practices, the Technology Transfer Framework only applied to Administrative actions. The other chapters of SAM are summarized below. The nearly 700-page document is at www.flychicago.com/community/environment/sam/Pages/default.aspx

Section 1: Administrative Procedures

The Administrative Procedures chapter clarifies the sustainability of airport-related administrative activities. Most of these activities are applicable to all TDOT divisions and are EASY to implement. Sustainability initiatives are applicable to meetings, document creation and electronic document transfers, as well as recycling and green procurement procedures.

Green meeting practices are intended to guide meeting hosts, planners, and attendees toward eco-friendlier meetings. A few extra efforts to incorporate environmental considerations into planning and conducting meetings will help to minimize the negative impact on the environment and educate all participants regarding sustainable meetings.

To reduce the volume of paper and facilitate the recycling of documents, a facility could start by producing only electronic copies. Using electronic distribution media for all documents whenever possible, such as; FTP sites, websites, emails, CDs, digital document libraries, memory sticks, etc. Additionally, airports could reduce the need for virgin materials, energy, and waste associated with the production of paper by promoting the use of recycled content paper. For example, the San Francisco International Airport has allocated paper use to each Airport Division at 80 percent of the previous year's consumption, requiring submittal of a special request if the allocation is prematurely exhausted.

Airports could reduce the environmental impact of products and services by developing a Green Purchasing Program. Introduce environmentally conscious purchasing into company practices. The policy needs to clearly define an objective and establish a sustainability claims verification procedure that can be replicated as necessary. Verification procedures may rely on product certifications (e.g. Green Seal, and ENERGY STAR). The Port of Seattle, the authority over Seattle-Tacoma International Airport, created an Environmental Strategy Plan to include a new strategic Environmental Purchasing Policy in 2009. The policy executes a contract for the purchase of sustainable office products and paper and focuses on saving money, increasing local products, and considering the life cycle effects of a given product.

Table 25: SAM Section One - Administrative Procedures

Criteria	Rating	Notes

Funding	Moderate	No federal funding is available to make changes in procurement structure or to motivate recycling or use of recycled materials. There is probable cost savings.
Proven Technology	Easy	Federal law allows for electronic signature and data transfer. The FHWA has endorsed e-Construction. There are lists of green materials that can be purchased (e.g. EPA.gov, BioPreferred.gov.)
Cost	Moderate	Updated computer hardware and software may be required. Document security will need to be monitored. There is cost and time related to employee training (i.e. learning how to review of the document from a digital version, and how to purchase from green vendors).
Benefit	Easy	Savings through reduction in paper consumption and printing. Possible savings through green purchasing.
Project Control	Easy	TDOT can encourage adoption, but airport authorities will have complete control.
Barriers	Moderate	Airport Authorities have historically required physical documentation and signatures to create a valid contract. Purchasing behaviors and vendor selection will need to be altered. Institutional mindset will need to be changed.

Section 2: Airport Planning

Summary - Airport planning is intended to address the conceptual planning of the airport's physical environment to facilitate implementation of design, construction, and/or operation and maintenance in a sustainable manner. Just like cost estimates and schedules, sustainability considerations and goals need to be integrated into the planning process for all projects, regardless of size and scope. The process of sustainable airport planning as described in this SAM Planning Chapter involves the creation of an overall plan outlining the measurable sustainability targets and goals for the project that, when finalized, will become part of the official plan for that project, function, or activity.

Section 3: Design and Construction

Summary - After the planning process, projects that move forward will enter the design and (usually) the construction phase. Design and Construction continues the process of incorporating sustainability into renovations and construction projects. By integrating sustainable design elements into the design process as early as possible, it is expected that the effectiveness of enhancing a project's sustainability is maximized while costs due to design and construction changes are minimized. Sustainability initiatives for Design and Construction con

include hundreds of different concepts, much of which may not be directly influenced by TDOT sustainability preferences. However, TDOT does have the ability to make suggestions to airport authorities, such as suggesting that requests for proposals (RFPs) for design services include language indicating that sustainability requirements must be incorporated as part of the design process for all projects.

Section 4: Operations and Maintenance

Summary - The Operations and Maintenance chapter is designed to certify the sustainability of ongoing operation of building operations, operational and maintenance procedures, system upgrades, minor space-use changes, and minor facility alterations or additions, and training and educational programs. Airport environmental concerns may include many things: noise, land use; social impacts, air quality; endangered and threatened species and wildlife, energy supply and natural resources, light pollution, solid waste impacts, storm water impacts, or construction impacts.

Section 5: Concessions and Tenants

Summary - The Concessions and Tenants chapter is designed to certify the sustainability of concession and tenant activities, including daily operations, as well as design and construction of tenant spaces within the terminals or other airport-related tenant spaces. Airport concessions provide an important passenger service amenity while providing significant financial benefits to the airport. Concessions include news and gifts, specialty retail stores, food and beverage, duty-free shops and many other services. SAM is designed to certify the sustainability of concession and tenant activities, including daily operations as well as design and construction of new facilities within the terminals.

Great Lakes goals of reducing energy consumption by 15%, diverting 50% of airport waste from landfill, and maintaining a ground fleet of at least 20% low emissions vehicles has resulted in savings of $775,000 per year.

TOOL: Colorado Division of Aeronautics Tool Kit

Colorado Division of Aeronautics developed the General Aviation Airport Sustainability Program and Tool Kit. This project provides tools, resources and guidance for general aviation airports to develop their own individually customized sustainability plans. Three Initial case studies explain in detail the General Aviation Airport Sustainability Program's abilities to encourage sustainability actions.

The tool kit and case studies provide a valuable resource as a reference for other airports when developing their own unique plans. The overall goal of the Airport Sustainability Program is to provide airports with a tool that will assist in addressing ways to improve sustainability within economic, social, operational, and environmental realms at their airports. This Airport Sustainability Plan provides the structure to ensure a balanced and sustainable approach to managing its operations and facilities. To formalize the reasoning and importance of creating and following the plan, the case studies assist airports in:

- Developing a Sustainability Mission Statement to guide the philosophy about sustainability at the airport;
- Establishing a Baseline Inventory;
- Identify Goals for the Focus Categories and Metrics to measure progress;
- Identifying Initiatives (implementation actions) that will achieve Goals, and
- Creating an Implementation Plan for the overall Airport Sustainability Plan and for measuring progress.

Denver International Airport currently recycles or reuses 21 different types of materials, including approximately 75 percent of collected aircraft deicing fluids resulting in environmental and cost savings of $ 1.1 million dollars. EcoStart motor controllers installed on escalators and moving walkways have reduced the power draw of the motors for a total savings of about 1.7 million kWh or $205,000 dollars per year.

Table 26: Colorado Division of Aeronautics Tool Kit

Criteria	Rating	Notes
Funding	Easy	General aviation airports in the State of Tennessee can be funded at three different levels: federal (i.e., FAA), state (i.e., TDOT), and/or local (e.g., counties, municipalities, authorities, associations, and private sector, as the airport sponsor). Federal funding eligibility applies to those airports that are identified in the National Plan of Integrated Airport Systems (NPIAS) which may be eligible to receive grant monies through the FAA's Airport Improvement Program (AIP). https://www.faa.gov/airports/planning_capacity/npias/
Proven Technology	Easy	Only proven technologies are funded with FAA grants; Research will need to be conducted regarding unproven technologies funded by other sources.
Cost	Moderate	The cost of utilizing the Tool Kit depends on the cost of project implementation.
Benefit	Easy	The Tool Kit saves time
Project Control	Moderate	The Tool Kit represents a truly complete approach to efficiently and responsibly operating the core business in an increasingly complex system while helping identify opportunities for innovation.
Barriers	Moderate	Utilizing the tool kits requires committed leadership example.

6.1.2.2 Central Services Division

The Central Services Division of TDOT provides coordination and general administration of staff services, forms, contracts and official documents. The office administers procurement procedures and inventory control. This division handles issuance of special permits for overweight/over-dimensional loads and is the purchaser of alternate fuel vehicles. It coordinates the annual budget for heavy equipment and vehicle purchases and operates the motor pool. The division assists with facilities and property management, surplus property removal and Printing and Distribution of TDOT's bid lettings. Various state departments of transportation provide sustainability examples. The easy-to-implement examples fall into two broad categories: Fleet acquisition- management (Table 27) and Purchasing of recycled materials (Table 28).

POLICY: Fleet Acquisition and Management Policy

Based on input from TDOT, the agency is purchasing alternative fuel vehicles. To streamline such purchases in the future, a systematic method is needed for their purchasing and fleet replacement. The US Department of Transportation (USDOT) has developed specific policies to achieve the goal of acquiring low emission vehicles. A fuel-efficient vehicle purchasing strategy prioritizes the buying or leasing of fuel-efficient vehicles, equipment, and components during new asset acquisitions and replacements. Optimal fuel performance with minimal GHG emissions is the primary goal. Life cycle costing is used to evaluate options based on capital costs, operating and maintenance costs, reliability, warranties, depreciation, and resale value alongside commitments to fuel efficiency. An output of the strategy is a vehicle purchasing policy. This policy is one of the most important outputs of a fuel-efficient vehicle purchasing strategy. The policy provides vehicle and equipment purchasing standards and procedures to ensure the best possible vehicle purchased. The USDOT policy informs purchasing practices by providing guidance or regulation on what should and should not be used by the fleet.

For example, the City of San Jose in California has developed a comprehensive and effective green fleet vehicle purchasing policy based on the USDOT directives. Additionally, the Dawson Creek green vehicle policy provides a strong example of a policy that ensures the fleets are effectively replaced over time. Other states with green fleet purchasing policies include North Carolina and Michigan. This could be used as a template for TDOT.

> *One green fleet vehicle can have an annual savings on fuel cost to be about $3,300 per year; this same vehicle can reduce emissions of around 6 metric tons of carbon dioxide each year.*

Table 27: Vehicle Fleet Acquisition and Management Policy

Criteria	Rating	Notes
Funding	Easy	US Department of Energy sponsors a Green Cities initiative that electric and hybrid electric vehicles into public and private fleet; EPA offers competitive grants to replace diesel engine vehicles. CMAQ grants are available.
Proven Technology	Easy	Overall, the vehicles have a history of proven technology; however certain elements within the vehicle (e.g. battery-life) may wear out and need replacement sooner than anticipated. Protocols for recycling worn out materials may not exist.
Cost	Moderate	Administrative costs associated with application and vehicles may be funded as 80/20 split.
Benefit	Easy	Clean Cities have a series of online tools to calculate savings: https://cleancities.energy.gov/blog/clean-cities-online-tools
Project Control	Easy	Depending on funding source, public fleets may be able to apply directly; private fleets may need a sponsor.
Barriers	Moderate	Required supporting facilities such as recharging, refueling, and maintenance facilities may not be federally funded.

POLICY: Purchasing Recycled Materials

The US Department of Transportation developed and released a Sustainable Acquisition Policy Order that applies to all service contracts, leases, and purchases. TDOT can establish and implement policies to meet purchasing preference requirements for recycled content products, ENERGY STAR qualified and FEMP-designated products, and Bio-preferred and bio-based products designated by USDA. The 40 Code of Federal Regulations (CFR) Part 247 requires a preference for recycled materials. It is not an absolute mandate as it "requires procuring agencies to procure designated items composed of the highest percentage of recovered materials practicable, consistent with maintaining a satisfactory level of competition, considering such guidelines. Procuring agencies may decide not to procure such items if they are not reasonably available in a reasonable period of time; fail to meet reasonable performance standards; or are only available at an unreasonable price" (USDOT 2010).

California DOT switched paper suppliers, which allowed them to purchase 30-percent recycled paper content while reducing costs by 20 percent and retrofitted 26,000 lighting fixtures with efficient light bulbs using 30 percent less electricity and lasting 6,000 more hours saving about $1.8 million dollars each year.

The Oregon Department of Transportation (ODOT) Sustainability Plan includes preferences for low-toxic and recycled products that are designed and manufactured in a sustainable manner, consistent with the principles of "green chemistry." Additionally, where daily or on-demand deliveries were being made, several ODOT facilities are now choosing a more coordinated delivery schedule. TDOT can mimic these efforts toward purchasing recycled materials and scheduling delivery of goods. Administrative offices of various departments of transportation have utilized recycled office supplies (e.g., paper, furniture, and pens) It is easier to buy green office products than ever before. The three largest office supply retailers, Staples, Office Depot and Office Max each carry thousands of reasonably priced products with recycled content and other environmental attributes. In this regard, TDOT can develop a plan of action for moving to such purchases.

Table 28: Green Purchasing

Criteria	Rating	Notes
Funding	Moderate	No grant money is available for purchasing green office supplies
Proven Technology	Moderate	No strong evidence supports all green goods match the quality of the same or similar non-green good. Individual product research needs to be conducted that includes examination of water and pollution involved in "green" product production.
Cost	Moderate	Green goods may be more expensive and not last as long in some cases
Benefit	Moderate	A cost-benefit review for each product may need to be conducted though some federal resources are available that have this information (e.g. ENERGYSTAR, PA's Environmentally Preferable Purchasing (EPP) Program)
Project Control	Easy	TDOT purchasing policies are at the discretion of the director
Barriers	Moderate	The need to justify any additional expense, lack of top management commitment, time and cost for reviewing quality sustainable purchasing

6.1.2.3 Construction Division

The Construction Division at TDOT awards highway and bridge construction, repair and enhancement bids, writes construction contracts, oversees construction contractors, and approves payment to contractors. Construction is responsible for the overall management of all aspects of the TDOT construction program to ensure that all construction complies with the approved plans and specifications and to ensure that construction proceeds safely and in accordance with established schedules and budgets. The Construction Division is responsible for preparing proposals and letting to contract all TDOT transportation highway and bridge projects. Also, the Division is responsible for the pre-qualification of all contractors who perform TDOT projects. This includes the division review of all engineering drawings and inclusion of aspects related to sustainable building practices, as well as the review of all permits and request for clarification of aspects related to sustainability. Examples of sustainable actions identify two software tools to support sustainable construction practices and sustainable contractor procurement tool (CA4PRS found in Table 29 and INVEST found in Table 30).

TOOL: Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS)

Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS) is a decision-support software tool supporting the analysis of project alternatives for different pavement designs, construction logistics, and traffic operation options. It is designed to help highway agencies and contractors develop construction schedules to minimize traffic delay and reduce agency costs. The software provides a set of applications facilitating the analysis of scheduling, traffic, and costs for highway projects (Figure 15).

The software's scheduling module estimates highway project duration (total number of closures), incorporating alternative strategies for pavement designs, lane-closure tactics, and contractor logistics. Construction Analysis for Pavement Rehabilitation Strategies or CA4PRS's traffic module (using the Highway Capacity Manual demand capacity model) quantifies the impact of construction work zone closures on the traveling public in terms of road user cost and time spent in queue. CA4PRS compares rehabilitation alternatives as "what-if" scenarios for the analytical criteria and its sub-parameters. CA4PRS can estimate working days and CPM schedules develop construction staging plans, supplement traffic management plans, and outline costs. The software can also analyze strategies for roadway widening and bridge/interchange replacement. CA4PRS yields additional benefits when its results are integrated with various traffic simulation modeling tools in quantifying the impact of work zone lane closures to the whole highway network, including local arterials and neighboring freeways. The use of CA4PRS is especially beneficial for transportation agencies when it is implemented during the planning and design stages of highway project development in order to balance schedule (construction production), inconvenience (traffic delay), and affordability (agency budget).

CA4PRS was used to select the most economical rehabilitation scenario for the I-15 Devore Project by CalTrans. The 4.5-km concrete reconstruction project, which would have taken 10 months using traditional nighttime closures, was completed over two 9-day periods using one-roadbed continuous closures and around-the-clock construction. Implementing continuous closures rather than repeated nighttime closures in this project resulted in significant savings: $6 million in agency costs and $2 million in road user costs.

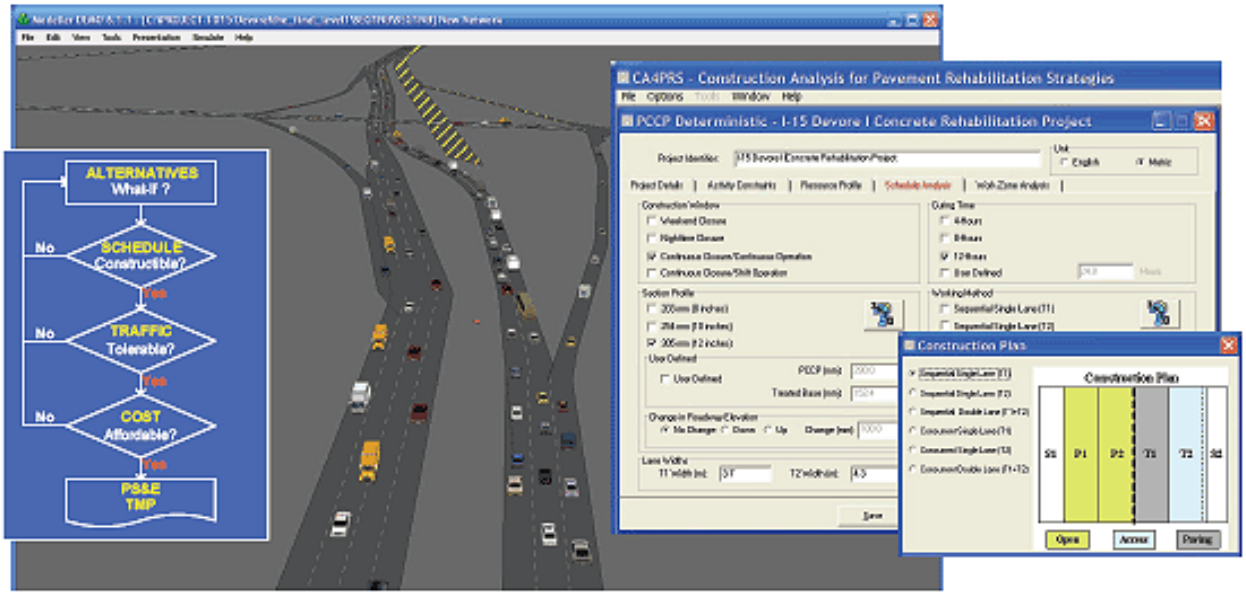


Figure 15: The CA4PRS Framework, Interface, and Traffic Simulation

Table 29: Construction Analysis for Pavement Rehabilitation Strategies-CA4PRS

Criteria	Rating	Notes
Funding	Easy	FHWA formally endorsed CA4PRS as a "Priority, Market-Ready Technologies and Innovations" product in 2008 for national wide deployment.
Proven Technology	Easy	Since 1999, the capabilities of CA4PRS have been confirmed on several major highway rehabilitation projects in states including California, Washington, and Minnesota. The software was validated on the 2.8-lane-km I-10 Pomona Project, which used fast-setting hydraulic cement concrete and was completed in one 55-hour weekend closure. The software was also used to develop a construction staging plan for the I-710 Long Beach Project, where 26 lane-km of asphalt concrete were reconstructed in a series of eight 55-hour weekend closures-two weekends ahead of schedule. Washington State DOT used it to analyze reconstruction of Interstate 5 through Seattle, and he Minnesota DOT used it to analyze the rehabilitation of I-394 and I-494.
Cost	Easy	All 50 state Departments of Transportation (DOTs) including Caltrans have an unlimited free license for the CA4PRS software for their internal use. Contact: IPIRA- Office of Technology Licensing University of California, Berkeley 2150 Shattuck Avenue, Suite 510 Berkeley, CA 94704-1347 Phone: (510) 643-7201 E-Mail: ca4prs@lists.berkeley.edu
Benefit	Moderate	Demonstrations have shown that CA4PRS is user-friendly, easy to learn, and valuable in any project phase. Its greatest value lies in its capability to provide information to the planner/designer to optimally balance pavement design, construction constraints, traffic operations, and agency budget for transportation agencies - especially during the planning and design of rehabilitation projects More recently, CA4PRS was used with traffic simulation models to select the most economical rehabilitation scenario for the I-15 Devore Project. The 4.5-km concrete reconstruction project, which would have taken 10 months using traditional nighttime closures, was completed over two 9-day periods using one-roadbed continuous closures and around-the-clock construction. Implementing continuous closures rather than repeated nighttime closures in this project resulted in significant savings: $6 million in agency costs and $2 million in road user costs. Alternative strategies enabled by use of CA4PRS led to an accelerated project process dubbed "Rapid Rehab" that was praised by professionals.
Project Control	Easy	TDOT Construction Division has control over how and when the software is used.
Barriers	Easy	FHWA provides training on software use. The software cannot account for all contingencies for all projects.

TOOL: Sustainable Contractor and Acquisition Procurement - INVEST TOOL

The Texas Department of Transportation (TXDOT) has effectively utilized the Project Development (PD) and Operations and Maintenance (OM) INVEST Tool modules in contracting for the Corpus Christi Harbor Bridge. FHWA's INVEST (Infrastructure Voluntary Evaluation Sustainability Tool) is a web-based self-evaluation tool comprised of sustainability best practices, called criteria, which cover the full lifecycle of transportation services, including system planning, project planning, design, and construction, and continuing through operations and maintenance. To accomplish this, the INVEST criteria are divided into four modules: System Planning for States (SPS), System Planning for Regions (SPR), Project Development (PD), and Operations and Maintenance (OM). Each module contains between 14 and 33 criteria and each criterion focuses on a topic area. These four sets of criteria comprise a comprehensive self-evaluation tool to aid agencies in evaluating the sustainability performance of their projects and programs. INVEST is focused on "above and beyond" sustainability efforts, as all projects are required to adhere to basic sustainability policies in order to receive federal funding.

TXDOT used INVEST during the procurement process for the Harbor Bridge Project in Corpus Christi. TxDOT's request for proposals required that bidders describe how their proposal would meet a "Platinum" rating on the INVEST Project Development module and a "Silver" rating on the INVEST Operations and Maintenance module. The sustainability score, along with price and other factors, was part of the total score for selecting among the bidders. This provided a strong incentive for bidders to achieve high sustainability at low cost. The winning bidder committed to a range of sustainability practices that will bring tangible benefits to the community. The scope of the comprehensive agreement includes the design, construction, finance, and 25-year maintenance of the project. The inclusion of maintenance in the contracting mechanism provides an incentive for the contractor to minimize life cycle costs, an important aspect of sustainability.

The winning bidder's sustainability plan included a number of sustainability practices. These included the use of LED lights, solar powered path lighting with solar brick pavers and solar markers on shared use paths, energy-generating wind sculpture, native vegetation in landscaping, benches and landscaped areas made from recycled materials, re-use of concrete from interchange bridges as crushed stone in landscape, and many others.

Using the Sustainable Contractor and Acquisition Procurement portion of the INVEST TOOL, TXDOT was able to procure a contractor willing to integrate sustainability concepts for the Corpus Christi bridge project for $973 million dollars. This is approximately 18% less than the anticipated cost of $1.15 billion dollars.

Table 30: FHWA INVEST Tool for Contractor and Acquisition Investment

Criteria	Rating	Notes
Funding	Easy	FHWA formally endorses INVEST as a free tool found on the FHWA website at: https://www.sustainablehighways.org/
Proven Technology	Easy	As of 2017, 34 case studies have been documented.
Cost	Easy	The tool is free, but there are costs associated with training and learning curve associated with tool use. A typical process for using INVEST first requires a point person to browse the tool and become familiar with how it works. This typically takes about a day. After that, the person will need to identify subject matter experts and have them gather supporting documents that they will each use to develop an initial score.
Benefit	Moderate	It can be difficult to capture the true value of sustainability. Benefits of the triple bottom line can be realized in several ways including cost savings, healthier environments, time savings to users and agencies as well as improved quality of life. No studies analyzing specific categories of cost or environmental savings though a generalized “benefit” report are accessible on the website.
Project Control	Easy	TDOT Construction Division has control over whether or not the INVEST tool is used.
Barriers	Easy	FHWA provides training on tool use. The tool cannot account for all contingencies for all projects.

6.1.2.4 Environmental Division

The Environmental Division at TDOT is responsible for the protection, preservation and enhancement of the environment with the implementation of transportation projects. Under the National Environmental Policy Act (NEPA), the division assists in transportation project development and decision-making process. Other specific responsibilities include analysis of air quality and noise impacts and for the avoidance of hazardous materials sites; preparing federal and state environmental documents, and assessing, preparing and acquiring environmental permits for transportation projects. The mission of the Environmental Division is to ensure the timely delivery of projects that comply with all environmental laws and regulations. The TDOT Environmental Division is comprised of six offices:

1) The Environmental Analysis Office includes the NEPA Section, Archaeology Section, Historic Preservation Section, Hazardous Materials Section, and Air/Noise Section. These sections are responsible for the preparation of environmental documents required for all transportation projects, along with the assessment of impacts on transportation projects and protection of historical and archaeological resources, analysis of air quality and noise impacts.

2) The Ecology and Permits Office is responsible for reviewing and analyzing project plans, addressing any impacts and acquiring all environmental permits needed for transportation projects.

3) The Highway Beautification Office encompasses a varied group of programs ranging from regulatory control and oversight of outdoor advertising to preserving, sustaining and enhancing the beauty of Tennessee landscape.

4) The Environmental Comprehensive Inspections Office is a new office created to oversee construction activities and Focus on highway and bridge construction projects. This office works with the state Tennessee Department of Environment and Conservation, as well as other regulatory agencies involved with activity oversight.

5) The Environmental Facilities Compliance Office has the responsibility of ensuring TDOT's facilities comply with environmental regulations. In addition, it investigates and remediates past disposal and spill sites by providing technical expertise and oversight.

6) The Environmental Mitigation Office is responsible for establishing compensatory mitigation to offset transportation project impacts to streams, wetlands, and species. These compensatory mitigation mechanisms include establishment of permittee-responsible mitigation sites and/or agreements with mitigation sponsors, development of advanced mitigation sites, and purchase of advanced credits from third party sponsors.

Sustainability examples for the Environmental Division and Offices are varied and plentiful. As such, no particular sustainability process is examined for ease into the fabric of TDOT Environmental responsibilities. Instead, a table reviewing valuable resources, guides and tools are included (Table 31). These resources have been collected to assist TDOT personnel in not only meeting the basic state and federal environmental requirements, but to actively engage in contributing to their sustainability.

Table 31: Sustainability Materials Relevant to Offices of TDOT Environmental Division

Department	Description
1) Environmental Analysis Sections	
NEPA	**GUIDE: Preparing High-Quality NEPA Documents for Transportation Projects** The purpose of the AASHTO handbook is to help practitioners bridge the gap between the theory and practice of producing high-quality NEPA documents. The handbook includes sustainability guidelines.
Archeology	**RESOURCE: Historical, Architectural, Archeological, and Cultural Resources Desk Reference** This manual describes the analysis of historical, architectural, archeological, and cultural resources within the context of NEPA review. The reference provides insight into methods of integrating sustainability and preservation concepts into decision-making.
Historic Preservation	**RESOURCE: Advisory Council on Historic Preservation** is an independent governmental agency provides numerous resources for integrating sustainability concepts into historic preservation directed toward the completion of Section 106 documentation.
Hazardous Materials	**TOOL: Texas Department of Transportation Hazardous Materials Toolkit** provides clear information on resources and tools to prepare materials associated with the management of hazardous materials during project development. Additionally, the toolkit encourages the participation in transportation projects that include the use and redevelopment of contaminated sites when appropriate.
Air & Noise	**GUIDE: Compendium of Next Generation Compliance Examples in Clean Air Act Programs** is an EPA publication that shows how state air control programs can use modern tools to advance clean air goals and sustainability in rulemaking, permits, enforcement, and other functions. **GUIDE: How to Comply with Your Environmental Permit** is a publication by the Environmental Agency of England that explains to permit recipients the sustainability practices that should be followed.
2) Ecology and Permits	
Permits	**RESOURCE: Overcoming Barriers to Green Permitting: Tools for Local Governments** is a workshop conducted by the Southface Energy Institute that provides improvements to encourage sustainable design during the entire permitting process. In addition, the **Sustainable Design and Green Building Toolkit for Local Governments** by EPA expand the concepts of including

	sustainability concepts in permitting.
3) Highway Beautification	
Design	**GUIDE: Rhode Island Highways-Best Practices Design Guide** establishes new beautification standards for design and management of infrastructure and buffer areas. The guide includes case studies of best practices.
4) Environmental Comprehensive Inspections	
Design	**GUIDE: Implementation of Sustainability in Bridge Design, Construction and Maintenance** develops a framework for more sustainable design and construction processes for new bridges, and sustainable maintenance practices for existing bridges. **GUIDE: Iowa DOT Bridge Design Manual** provides sustainable bridge design concepts for not only new bridges but also rehabilitation, reuse or the optimization of existing bridges. **GUIDE: An Integrated Approach for Building Sustainable Roads** provides an approach for practitioners to integrate sustainability into the planning, design, and construction of projects and is intended to be compatible with an owner's existing technical guidance for project development processes.
5) Environmental Facility Compliance	
Facilities	**TOOL: Sustainable Facilities Tool** (sftool.gov) is provided by the General Services Administration is an online toolkit that assists with understanding federal requirements, project planning and development, procurement, operations and management, product search, etc.
6) Environmental Mitigation	
Resource Management	**GUIDE: A Strategy for Improving the Mitigation Policies and Practices of The Department of the Interior** describes the key principles and actions necessary to successfully shift from project-by-project management to consistent, landscape-scale, science-based management of the lands and resource

6.1.2.5 Freight and Logistics Division

The Freight and Logistics Division at TDOT provides leadership on issues of rail, water and highway freight. The division serves as a liaison between TDOT and freight stakeholders in an effort to find opportunities to improve access for existing freight and appropriately prepare for the projected increases in freight as it moves in and out of the state. The primary focus areas for the division include water, short-line railroads, Section 130 rail program, rail inspection, highway freight and technology, freight advisory committees and the freight and state rail plan updates. Driving sustainable growth and reducing overhead costs is one of the TDOT's priorities; however, changes will need to be made of TDOT to connect growth, cost reduction and sustainability as it relates to logistics.

Transport services appear to be one of the biggest sources of CO_2 emissions. Freight and Logistics has the difficult task of balancing an industry that is indispensable for growth and employment. As a result, a more wide-range view on what can be done to improve the environmental performance of logistics can contribute to decreasing a negative environmental footprint. TDOT can support sustainability concepts and provide education about off-peak deliveries (Table 32); provide a review of current left lane truck restrictions (Table 33), make efforts to expand the Smart Park program in Tennessee (Table 34), and develop public-private truck parking partnerships (Table 35).

GUIDE: Off-Peak Deliveries (OPD)

Off-hour or off-peak deliveries have the potential to reduce peak-hour congestion by giving delivery drivers a wider delivery window and avoiding traffic delays. Businesses generally want to receive deliveries of goods during their normal work hours. Truckers schedule deliveries to meet the demands of receiving businesses. As a result, most truck traffic occurs during the most congested daytime traffic periods. Off-peak delivery (OPD) is a simple concept, but it can be challenging to implement because the benefits and costs are not always evenly distributed. Carriers generally like the idea because it can save them time and money, but receiving businesses often resist it because it can add costs. Communities will benefit from lessened congestion but may have concerns about nighttime noise. Sometimes special incentives are needed for businesses to participate. However, if enough businesses can adjust their schedules to accept deliveries when there is less traffic congestion, it could enable truckers to deliver goods more quickly and at less cost. TDOT could provide guidelines for businesses to adopt off-peak deliveries.

An Off-Peak Delivery Program should be designed in a manner that balances the benefits and costs to make it practical for carriers, receivers, shippers, customers and the community. Suggestions for guidelines can be found in *Off-Peak Delivery: A Pilot Project for the Chicago Region* (LaBelle 2015) and include:

- Location and industry type can affect participation. Businesses that are most receptive to off-peak deliveries are those that would likely be open during off-peak hours anyway (e.g. restaurants, bars, hotels, convenience stores, 24-hour supermarkets, big-box retailers and medical facilities). Carriers have a financial incentive to participate in off-peak deliveries as it saves time and money, but this incentive is diminished if only a few of their receivers are interested in participating as the carrier must make two separate trips (one in the day and one at night). Thus, larger establishments (more than 250 employees) and buildings with many businesses yield the greatest savings in terms of the number of truck trips and cost-effective implementation, as additional costs can be shared among more customers.

- Unassisted off-peak delivery may have more potential for some types of businesses. One type of off-peak delivery involves providing a setting for unassisted drop-offs. This requires some investment in physical improvements to create a secure area, but less ongoing staff expense. Unassisted deliveries have a greater potential for long term success. With unassisted off-peak deliveries, liability issues may decrease when receivers provide the driver with keys for the first set of double doors or install a virtual cage, which restricts drivers to an area marked off by sensors.

- Consolidated delivery centers should be considered for highly populated areas. These centers are facilities at which goods from multiple sources can be delivered, sorted, and consolidated to allow fewer deliveries to the final destination. Consolidation can allow more flexibility of delivery times to the center or to the final destination, allowing more trips to occur during off hours. This model has been used with success at the Atlanta Olympics and in pilot projects in Germany and the UK. During a pilot project in Bristol, UK, consolidated deliveries resulted in a 73% reduction in delivery movements and a 65% reduction in vehicle mileage (LaBelle 2015).

- Incentives may be necessary to persuade receivers and carriers to participate in off-peak deliveries. This can include a combination of one-time financial incentives, public recognition for outstanding service, or discounts from vendors for accepting off-peak deliveries. For example, in New York City, receivers were given $2,000 and carriers were given $300 per participating truck. Receivers could use the incentive to pay nighttime staff to accept the deliveries or for equipment to accept unassisted deliveries (LaBelle 2015). Businesses that allowed the vendors to have access to their establishment to deposit the off-peak deliveries could count the incentive as net profit. The Pier Pass Off-Peak program in Los Angeles port terminals eliminated the Traffic Mitigation Fee for containers entering or exiting the terminals during off-peak hours. The results of the Off-Peak program have been impressive. The initial goal was to shift 15-20% of all cargo movement to Off Peak within the first year, but after just 10 weeks Pier Pass reported that the program had shifted 30-35% of container cargo at all ports to Off Peak shifts on a typical day (LaBelle 2015).

TDOT may want to consider developing a pilot project to use to determine the feasibility of an off-peak delivery program or provide an example for other businesses to follow. This would mean identifying business participants and locations for the pilot program. Business types may be those that are normally open during off-peak business hours (e.g. health care, accommodations and food services industries that have more than 100 employees). Another possibility is to identify one large receiver, like a health care facility, to be a demonstration project as it would have the ideal scale and volume. Location could mean seeking out receivers in a particular corridor or area to implement off-peak delivery on a trial basis. Location could be determined by congestion, travel time reliability and truck citation density. Businesses that are most likely to participate in in program would be those densely located and where the program could substantially reduce peak period traffic volume. Table 32 provides information on the ease of developing guidelines for off-peak deliveries.

During a pilot project in Bristol, UK, consolidated deliveries resulted in a 73% reduction in delivery movements and a 65% reduction in vehicle mileage.

Table 32: Off-Peak Delivery Times

Criteria	Rating	Notes
Funding	Moderate	There is no well-established federal, state or local funding to perform a pilot study or write guidelines.
Proven Technology	Easy	Cities such as Los Angeles, Long Beach, New York and Chicago are already participating in off-hour delivery time programs.
Cost	Moderate	Costs may include special equipment and driver education and longer store hours to receive merchandise at off-peak hours.
Benefit	Easy	Reduced delivery times and associated lower transport operating costs; the city benefits from lower congestion and a reduction in emissions associated with stop-start driving.
Project Control	Moderate	TDOT Freight and Logistics Division does not have direct control over the project, but can provide assistance
Barriers	Moderate	The concept will have to be “sold” to city officials, retailers and freight delivers. This may prove problematic. Communication between all parties involved in nighttime deliveries is essential.

POLICY: Left Lane Truck Restrictions

The Freight and Logistics Division could review the current rules regarding legislative restrictions on left lane usage by freight. The purpose of TDOT Rule 1680-2-5 is to implement Tennessee Code Annotated § 55-8-195 by establishing criteria for the designation and enforcement of lane restrictions for truck tractors and semi-trailers. This policy was last revised in 2005. The complete contents of the TDOT rule can be found in Appendix B. TDOT can review and update these policies.

Legislation to require truck drivers to remain in the right lanes of highways could improve traffic flow and road safety, but these efforts may increase traffic jams and increase maintenance costs (Wilmot 2009). Generally, the ban is applied to trucks and other heavy vehicles weighing more than 10,000 pounds, but this definition is not consistent for all states as some states count axels. Researchers found that these benefits happen primarily on stretches of interstates with moderately heavy traffic (e.g. I-40, and I-75) and a relatively high percentage of trucks, but left-lane restrictions for trucks are not recommended for highways in urban areas, as it impedes vehicles from getting on and off the road. However, the majority of case studies show that lane restrictions reduce overall crash rates by about 10 percent (Wilmot 2009). Additionally, keeping trucks away from the left lane can cause problems, as well. Forcing all heavy vehicle traffic to drive along just two lanes accelerates road damage in those lanes. On an eight-lane highway, restricting trucks from using the two leftmost lanes would reduce the life of the pavement by 34 percent, or from 20 years to 13.6 years (Wilmot 2009).

Lane restrictions reduce overall crash rates by about 10 percent.

Table 33: Left Lane Truck Restriction Review

Criteria	Rating	Notes
Funding	Moderate	There is no known federal, state or local funding for researchers to perform a study or review current policies.
Proven Technology	Moderate	21 states have full or partial bans. Some research indicates a reduction in crash rates, increase in traffic flow, but also increases in maintenance costs.
Cost	Moderate	Costs may include access to specialized data or perform on-site research.
Benefit	Moderate	A complete and detailed understanding of the situation as it applies to Tennessee, which could provide a basis for legislation.
Project Control	Easy	TDOT Freight and Logistics Division does have direct control over the review process.
Barriers	Moderate	Researchers have provided conflicting research on the benefit and determents left lane truck restrictions. Conclusions are not pre-defined.

Truck Parking Shortages

Tennessee is home to seven interstate corridors; these corridors represent approximately 1061 miles of interstate highway (Hardin 2018). The main corridors in Tennessee are:

- **Interstate 24** spans 180 miles through the state from the Kentucky state line to Chattanooga. It passes through Clarksville, Nashville, Murfreesboro, and Monteagle.
- **Interstate 26** spans 54.5 miles in the state from Kingsport to North Carolina state line.
- **Interstate 40** spans 455.28 miles throughout the entire state, from the Arkansas state line to the North Carolina state line. It passes through Memphis, Jackson, Nashville, Cookeville, and Knoxville.
- **Interstate 55** spans 12.28 miles from the Mississippi state line to Arkansas via Memphis.
- **Interstate 65** spans 121.71 miles from the Alabama state line to the Kentucky state line, passing through cities like Columbia, Brentwood, Nashville, and White House.
- **Interstate 75** spans 161.86 miles from the Georgia state to the Kentucky state line. It passes near Chattanooga and through Cleveland, Charleston, Athens, Sweetwater, Knoxville, and Caryville, and
- **Interstate 81** spans 75.66 miles in Tennessee from Dandridge, Tennessee to the Virginia.

The American Transportation Research Institute (ATRI) conducted a survey in 2017 to identify critical issues in the trucking industry nationwide. The survey provided insight into both the changing and emerging priorities of the trucking industry. These critical issues from most important to least included (ATRI 2017):

1. Driver Shortages
2. Electronic Logging Device (ELD) Mandate
3. Hours-of-Service (HOS)
4. **Truck Parking**
5. Driver Retention
6. Compliance, Safety, Accountability (CSA)
7. Cumulative Economic Impacts of Trucking Regulations
8. Driver Distraction
9. Transportation Infrastructure, Congestion, Funding
10. Driver Health and Wellness

The growing scarcity of available truck parking (# 4) creates a dangerous and costly situation for truck drivers who are often forced to drive beyond allowable HOS rules or park in undesignated and, in many cases, unsafe locations (See reference regarding Jason's Law). The truck parking issue has gained greater attention since the ELD mandate was put into effect. Commercial drivers who were already using electronic logs were nearly twice as likely to spend more than 30 minutes looking for available parking as drivers who were using paper logs (ATRI 2017).

In order to provide available and more efficient parking, two easy-to-moderate sustainability strategies were explored: Expanding Tennessee's Pilot Smart Park Program (Table 34) and Developing Public-Private Parking Partnerships (Table 35).

TOOL: Expand the Smart Park Program

Smart Park is a relatively new (2016) smartphone-based technology that was built by the Tennessee Department of Transportation (TDOT). The tool provides real-time information on parking availability and a limited number of reserved truck parking spaces. The tool relies on the truck parking detector technologies integrated into a real-time truck parking information system for use by truck drivers (Golias, 2016).

The SmartPark pilot program is the brainchild of TDOT and the Federal Motor Carrier Safety Administration to help reduce trucker fatigue. Two parking sites along I-75 have been set up with monitoring equipment that will allow truck drivers to see on their smartphones in real time if spaces are available. The sites are located on the northbound side of I-75 at the rest area near the 45-mile marker south of Athens, TN and northbound mile marker 23 south of exit 25 in Cleveland, TN. The idea is that drivers will be diverted from one site to the other when spaces fill up. Users can also reserve parking spaces online ahead of time (Benton 2015). The communication conduit for the smart park located on the I-75 corridor sites is located underground to service 8 cameras and radar equipment that will inform truckers as to parking availability. In preliminary findings, data collected from the detection equipment indicated that the rest areas were operating close to capacity between 11 pm and 7 am most of the days of the week (Golias, 2016).

A total of 11 potential future SmartPark locations were identified. All of those rest areas met the following two criteria: 1) Another location exists that could be used to connect the selected location; and 2) Both locations should be in the same direction, be accessible from the same roadway and within 35 miles from each other (Golias, 2016). Some additional criteria were used in selection of the potential SmartPark locations, including pre-reconstructed sites with easily accessible truck parking spaces, single points of ingress and egress, separated truck and car parking areas, and ample lighting for nighttime operations. Locations that meet all the criteria include a rest area, located on I-40 in Jefferson County (East of Knoxville), and State Welcome Center in Cosby County (Golias, 2016).

> *Forty percent of commercial truck drivers spend an hour or more per trip searching for parking. Each of these drivers waste an estimated nine percent of driving time searching for parking...equaling $7,200 in lost wages annually due to parking shortages.*

ATRI designed the Truck Parking Information Management System (TPIMS) used by the Minnesota Department of Transportation and later expanded to the Mid America Association of State Transportation Officials (MAASTO) Truck Parking Information Management Systems (TPIMS). When fully deployed, the MAASTO - TPIMS will deliver real-time truck parking availability information to commercial drivers in eight Midwest states (ATRI 2017). Currently, the I-95 corridor study is underway and is providing test sites for real-time truck parking in Maryland and Virginia. I-5 in California has a working model of a parking detection and reservation system, and the Florida Department of Transportation received a grant for a Truck Parking Availability System (TPAS) under the Nationally Significant Freight and Highway Projects program.

Table 34: Expand the Smart Park Program

Criteria	Rating	Notes
Funding	Easy	Federal Highway Administration's (FHWA) Truck Parking Initiative; National Highway Performance Program; Surface Transportation Block Grant Program; National Highway Freight Program
Proven Technology	Easy	The technology is new as applied to truck parking; established technologies for car parking have proven successful
Cost	Moderate	Costs will include special equipment and facility construction, including maintenance costs, and paying Smart Park service provider fees.
Benefit	Easy	Optimize parking space usage, improve the efficiency of the parking operations and help smoother traffic flow; reduce driver fatigue
Project Control	Moderate	TDOT Freight and Logistics Division does not have direct control over the project, but can provide assistance
Barriers	Moderate	The concept will have to be "sold" to city officials, where the facilities will be located. State and local government cooperation.

RESOURCE: Developing Public-Private Parking Partnerships

According to US Department of Transportation's *Jason's Law Truck Parking Survey Results and Comparative Analysis*, most States report problems with truck parking shortages. Those States that did not report shortages were mostly rural (with the exception of Ohio). States report higher levels of shortages in public parking facilities than in private facilities, and states with the highest numbers of spaces are clustered along major corridors with high truck volumes (USDOT 2015). As seen in Figure 16, Tennessee has a total of 194 areas at which commercial trucks can park. Of these, 42 are public and 152 are private. When a buffer of 0.5 miles is added to the Interstate routes, 122 facilities are within one-half mile of the interstate. Of the 122, 103 are private and 19 are public facilities. The top five corridors cited by drivers and staff as having shortages are I-95, I-40, I-80, I-10 and I-81 (USDOT 2015). Additionally, more than 75 percent of truck drivers and almost 66 percent of logistics personnel reported regularly experiencing problems with finding safe parking locations when rest was needed, and 90 percent reported struggling to find safe and available parking during night hours (USDOT 2015). Rest areas in Tennessee are not suitable for commercial vehicles as no overnight parking is allowed; there is a two-hour parking limit (TDOT 2018).

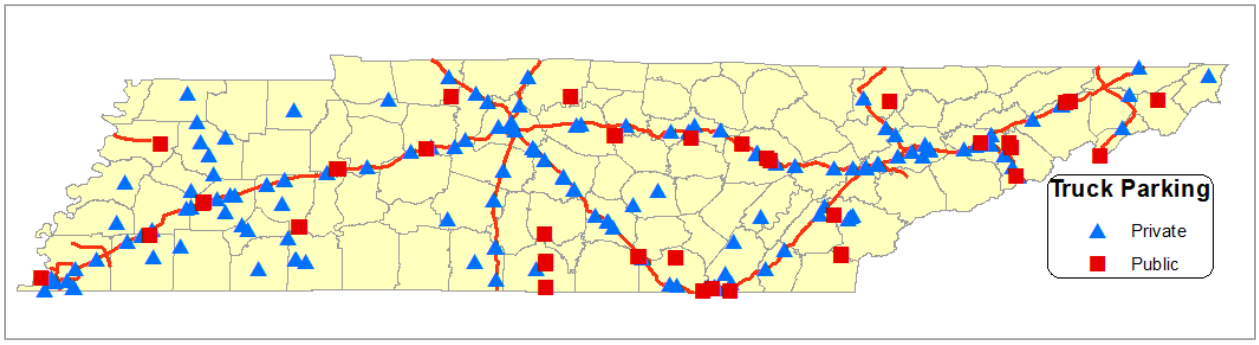


Figure 16: Map of Current Public & Private Truck Parking Facilities (Source: FHWA)

Almost half of the State DOTs reported unofficial and/or illegal parking on freeway interchange ramps and shoulders of highways. Similarly, State motor carrier safety officials also reported that most unofficial and or illegal parking occurs in these locations (USDOT 2015). Additionally, drivers use shopping areas, abandoned facilities or vacant lots to park. These options are generally found by word of mouth and have no official standing regarding safe or legal parking facilities. Drivers indicated that if parking was not found by mid-afternoon or early evening in either a rest area or private truck stop, the next suitable option is a well-lighted shopping area due to safety concerns. However, drivers stated they worried during their rest period they would be asked to leave or given a citation by law enforcement (USDOT 2015). Additionally, 53 percent of drivers regularly use a commercial truck stop for rest and 20 percent regularly use a rest area (Not an option in Tennessee). Other options used regularly include shipper/receiver location (20 percent), on/off ramp (8 percent), abandoned lot/isolated area (10 percent), and behind a shopping center (11 percent) (USDOT 2015).

Truck parking activity is driven by safety considerations and the associated need for adequate rest for drivers. Truckers have been killed when parking illegally. On March 4, 2009, Jason Rivenburg was killed while parked at an abandoned gas station, and Michael Boeglin was shot five times while sitting in his truck and his truck set on fire as he parked at a building that was abandoned and gutted by scrappers. Female truck drivers are also concerned about safety.

Illegal parking also takes place at abandoned or closed public facilities and vacant lots (e.g. schools) and privately-owned vacant lots and facilities (e.g. gas stations and retail businesses). The Mid-America Freight Coalition (MAFC) has identified three types of operation and policy solutions for this parking shortage (MAFC 2017):

1. Provide truck parking information through management systems that collect and distribute information about parking availability from detection and communication technologies or through social media applications, such as Tennessee's Smart Park Program.

2. Construction or re-adaptation of additional parking spaces on the current or new right of way, such as closed weigh stations, and

3. Collaborative planning and rehabilitation of vacant urban parcels for use as parking areas.

Solutions # 2 and # 3 will likely involve a public-private parking partnership.

One solution is to increase availability of parking by re-opening closed rest areas, weigh stations or other publicly-owned facilities or purchasing additional rights of way. However, available publicly-owned facilities or rights of way for parking may not always coincidental with areas of parking shortages, so opening closed locations may not have much impact on localized shortages (MAFC 2017). Other considerations include the cost of new rights of way as well as the availability and cost of amenities at re-purposed sites.

Another strategy is to develop a collaborative planning approach between state departments of transportation (DOTs), metropolitan planning organizations (MPOs), local governments, and private property owners to identify and readapt vacant urban sites and brown-fields for truck parking. This approach would provide additional capacity in urban areas where tightly scheduled delivery times and congestion place further demand on available spaces. The potential use of vacant industrial properties would require the purchase or lease of vacant paved sites of a minimum size, followed by the addition of appropriate assets like restrooms, lighting, fences, and access to highways, businesses, and ware-houses (MAFC 2017). Vacant industrial or commercial properties with large square footages of pavement or concrete would be ideal options. These sites are likely to be relatively low cost in terms of both land value and infrastructure construction and are more likely to have immediate access to arterial roads. This approach is also designed to avoid residential areas, hospitals, roads with clearance issues, areas with ordinances prohibiting truck parking, and potentially dangerous areas. The

methodology to determine the potential in the development of an urban truck parking areas is found in *Evaluation of Vacant Urban Land for Truck Parking* by Mid-America Freight Coalition.

The Atlanta Regional Commission has already conducted basic outreach to foster collaboration between stakeholders, private owners and public entities (i.e. state and municipalities) to address truck parking needs. In this assessment, participants were asked to identify any location that could be potential truck parking. These participants identified 11 locations, all but one of which were a vacant lot or building (ARC 2018). Law enforcement stakeholders were also asked to identify locations that could be potential truck parking. Thirteen locations were identified, which included vacant lots or vacant building locations, such as schools (ARC 2018).

A number of state DOTs and municipalities are in the process of using public-private partnership agreements to address truck parking issues. For example, California is using other parking facilities for overnight truck parking (e.g. park and ride facilities) in Sacramento, and the City of Baltimore is investigating tax incentives for private investment in parking facilities (ARC 2018). The state of Washington is providing low-interest loans or grants to commercial truck stops to increase capacity, and Oregon DOT is constructing state-owned lots adjacent to commercial truck stops and travel plazas and entering into agreements with these owners to lease or maintain the lots. Table 35 provides information on the ease of TDOT implementing a public-private parking partnership program.

Table 35: Development of Public-Private Parking Partnerships

Criteria	Rating	Notes
Funding	Moderate	Funding for public-private partnerships require state support, possibly through legislated initiatives, and private funds, which may be difficult to find.
Proven Technology	Easy	Various reports identify the need for accessible and available commercial truck parking on major corridors.
Cost	Moderate	Costs will vary depending on the type of facilities being constructed or re-purposed. One example stated the initial start-up costs will amount to $2.75 million, which will be used to purchase land, develop it, and construct a 6,000 square foot travel center, complete with gas/diesel islands, scales, and a restaurant.
Benefit	Easy	Optimized truck parking spaces can reduce traffic incidents, provide driver safety, provide efficient parking operations and assist in smoother traffic flow; reduce driver fatigue
Project Control	Moderate	TDOT Freight and Logistics Division does not have direct control over the project, but can provide assistance
Barriers	Moderate	The concept will have to be “sold” to state, city officials, and private funding agents where the facilities will be located. State, local government and private cooperation is required. This can be hard to do.

6.1.2.6 Long-Range Planning Division

The Long-Range Planning Division is responsible for the planning, development and management of statewide transportation studies and planning tools that help guide the policies and programs of TDOT and its various divisions. Specific responsibilities include developing the statewide long-range transportation plan, preparation of corridor studies, feasibility studies and metropolitan and rural transportation planning coordination. The mission of the Long-Range Planning Division is to play an active role in planning transportation strategies that improve safety, increase mobility, and encourage economic development in Tennessee. Sustainability examples include the extension of time horizons in parts of the state long-range plan (Table 36), and the inclusion of sustainability language within plan content (Table 37), providing guidelines for Complete Street initiatives (Table 38), guidelines for Alternative Fuel Infrastructure (Table 39), and Transportation Demand Management (Table 40).

POLICY: Extension of Plan Time Horizon

Federal regulations relating to transportation and air quality require states and metropolitan planning organizations to complete long-range transportation plans and programs for a 20-year forecast period. For transportation planning processes to integrate sustainability objectives, the forecast period for many projects could be extended to at least 40 years (TRB 2004). Some planning organizations have begun to extend their planning horizons, most notably various metro areas and the state of California. Adopting longer horizons and visioning techniques in the development of transportation plans may enhance the ability to plan processes that integrate sustainability objectives. Standard 20-year planning horizons could be extended to at least 40 years to incorporate sustainability concepts. In addition, public involvement could be expanded to enable plans that reflect a community's vision, have support from a broad constituency, and are therefore more likely to be implemented successfully. Furthermore, with an extended time horizon, a concept called "back-casting" could be encouraged. Back-casting involves working backward from a particular desired future, or set of goals, to the present. A handful of planning institutions (specifically in Canada) have begun implementing these practices, and their experiences can be valuable to other agencies. For example, Calgary is extending the boundaries of long-term planning. The basis of long-term planning in Calgary is the 100-year horizon of "Imagine Calgary", which is the city's vision document, developed through consultation with over 3,000 residents of Calgary. It is a statement of what the residents of the city would like the city to be like in a multigenerational timeframe. This document is supported by a series of 30-year target documents towards which it is practical for city operations to work. Budgets and operational activities are tied to a three-year business cycle using the Triple Bottom Line accounting method for budgeting and monitoring.

Project-based long-range plans develop and select specific projects to be undertaken over a long-term planning horizon to meet the state's transportation policies or goals. In order to extend the timing horizon of some, but not all projects, projects might be grouped by mode or category (e.g., bicycle/pedestrian, freight, and public transit). These groups could analyze for their inclusion into a plan with an extended time horizon. This would mean the creation of two plans. One of the difficulties of this approach is tying each project to fiscally constrained or fiscally realistic elements. For example, to identify project priorities, Indiana DOT estimated future project costs, developed new long-range fiscal forecasts, and then applied project priorities to estimated available funding for three time horizons (Volpe 2015). Research could be conducted to determine the applicability of extended time horizons for Tennessee's Long-Range Plan.

Table 36: Extension of Long-Range Plan Time Horizon

Criteria	Rating	Notes
Funding	Easy	Funding and staff to create a 20-year long-range transportation plan is already in place.
Proven Technology	Moderate	Currently, there is no research to indicate if a 30 or 40-year planning horizon is a proven method or benefit for sustainability planning.
Cost	Moderate	There may be additional staff costs with developing more than on plan or conducting research to determine the applicability of extended time horizons.
Benefit	Moderate	Currently, there is no research to indicate if a 30 or 40-year planning horizon produces cost savings or benefits.
Project Control	Easy	TDOT will have control over the projects included into the extended plan.
Barriers	Moderate	Legislative and institutional barriers may not allow for a 30 or 40-year plan for specific categories of projects. There may not be accuracy in calculating costs in the extended horizon.

POLICY: Inclusion of Sustainability Language

The US Department of Transportation has begun the process of weaving sustainability language into its purchases, processes and plans. The administration's proposed language for the next surface transportation reauthorization, the GROW AMERICA Act, will highlight policy changes using terms relating to sustainability concepts. The USDOT will review and monitor contracts for the inclusion of sustainability clauses, as well as determine the applicability of sustainable acquisition requirements, and sustainability language in construction projects. (USDOT 2014). Finally, USDOT will begin randomly sampling awarded contracts to verify if sustainability language is being followed in the Contractor Performance Assessment Reporting System (CPARS) (USDOT 2014). However, the USDOT is in the process of standardizing this type of language (USDOT 2014).

Language used in a TDOT long-range plan and related documents may contain certain predispositions, such as a predisposition toward automobiles or roadways over buses and transit systems or other more sustainable elements (Williams 2014). Not only should objective policy language be used throughout, but also sustainability terms should be included. For example, in September of 2007, the Ipswich, Massachusetts Planning Board began discussion of a proposed amendment to add language selectively to the 2003 Community Development Plan, which would actively incorporate a greater emphasis on sustainability, green design and resource efficiency (Ipswich 2008). The changes in policy language included references to long-term multi-modal planning, the increasing cost of not including sustainability policies, in particular, policies that are often introduced without due regard for the externalities being targeted by other policies, leading to inconsistencies and spill-over effects. Changing the language included in multimodal plans can change the mindset as language can exert a strong influence. Language identifies and communicates the concepts that shape thought and action. Author George Lakoff of the University of California at Berkeley has contributed work on the framing of language. (See Lakoff's "Don't Think of an Elephant," Chelsea Green Publishers, 2004). Some examples of language change include the following (Ipswich 2008):

- Change "natural resource management" to "regeneration of nature" or "natural resilience." "Management" reinforces a false sense that humans know exactly what to do and how nature is going to respond to actions and "Resource" conveys that nature is something to be used. Terms like regeneration and resilience better illustrate the end goal of re-establishing the capacity to adapt, flexibility, and ongoing processes that can evolve over time.
- Change "proper stewardship" to "proper interaction" or "healthy relationship," for the same reason as the above.
- Provide context for "sustainability," in that it means the ability to continue into the indefinite future by respecting the Earth's ecosystems and its limits.

Table 37: Inclusion of Sustainability Language

Criteria	Rating	Notes
Funding	Easy	Funding and staff to create a 20-year long-range transportation plan is already in place.
Proven Technology	Easy	The USDOT is actively engaged in including sustainability language into its plans.
Cost	Moderate	Not all directives have a well-documented cost if sustainability language is included in the long-range plan
Benefit	Easy	The mindset of successive generations will naturally include long-range sustainability thinking
Project Control	Easy	TDOT has total control over the language included in the Long-Range Plan
Barriers	Moderate	Not all will agree on definitions of certain terms; the language used will need to enhance, not alter, planning objectives

GUIDE: Complete Streets

Environmental, societal and accident avoidance benefits outweigh costs associated with building comprehensive Complete Street segments. TDOT can replicate this model in other urban contexts by providing a series of how to guides specific for Tennessee municipalities. TDOT already provides a *Community Transportation Planning Grant Fact Sheet* that highlights the efforts of Pikeville, Tennessee to draw visitors to its downtown central business district. However, the 2-page fact sheet does not provide cradle-to-grave instructions on how to build complete streets or determine an appropriate road segment for inclusion. The fact sheet states "certain roadways are not good candidates to become complete streets" but does not provide criteria on how to determine a good candidate (TDOT 2016).

The Knoxville Regional Transportation Planning Organization has developed Complete Streets Design Guidelines that includes information on how to design specifics (e.g. street speed, function, sight distance, pedestrian/bicycle requirements, road diets, signal and crosswalk placement). The guidelines include flexibility in design guides, land use and transportation connections, safety, liability and cost challenges, as well as a step by step process of implementation - from selling the vision, drafting supporting policies and resolutions, public participation to public financing and integrating "tag along" projects (KRTPO 2018).

The Nashville Metropolitan Planning Organization has developed an online resource that provides information on public outreach, studies that were performed to determine complete street candidates, design guides, and web surveys (NMPO 2018). Already, TDOT's Multimodal Division has published a multi-modal design guideline that include some aspects of complete streets. The High Impact Strategies section has further information on the Cumberland Avenue Complete Streets project in Knoxville, Tennessee, as well as a cost-benefit analysis. Table 38 provides a review of the difficulty of writing complete streets guidelines for Tennessee.

A cost benefit analysis of the Cumberland Avenue Corridor Complete Streets Project (Knoxville, Tennessee) indicates a cost of $42.5 million dollars, and a benefit of $89.4 million dollars. Details of the method used for calculation can be found in Chapter 7.0 HIGH IMPACT STRATEGIES.

Table 38: Complete Streets Guidelines

Criteria	Rating	Notes
Funding	Easy	Funding and staff to write guidelines are already in place.
Proven Technology	Easy	The USDOT and Smart Growth American have some guidelines and can offer assistance.
Cost	Moderate	Not all aspects of complete streets implementation have well-documented cost-benefit analysis.
Benefit	Easy	Not all aspects of complete streets implementation have well-documented cost-benefit analysis.
Project Control	Easy	TDOT has total control over the content of *the Complete Streets Guide for Tennessee Communities*.
Barriers	Moderate	Not all will agree on the content.

GUIDE: Alternative Fuel Infrastructure

It is essential to reduce transport oil-dependence, mitigate its environmental impact and, deliver on the national strategy for low-emission mobility. TDOT can develop guidelines for the minimum requirements and tax benefits for the building-up of alternative fuels infrastructure, including publicly-accessible recharging locations for electric vehicles and re-fueling stations for natural gas and other alternative fuel vehicles (ATV). Establishing adequate refilling/charging infrastructure is necessary to address "range anxiety," one of the prime concerns associated with consumer purchasing behavior and the use of AFVs. Range anxiety refers to the hesitancy of a consumer to buy an AFV due to concern of being stranded without access to refilling/charging infrastructure or being unable to complete a trip given the constraints of the vehicle. This is a particular concern with alternative transportation fuels requiring a discrete refueling infrastructure. Moreover, natural gas, propane, ethanol, and hydrogen vehicles need dedicated pumping stations.

To this end, at least three states have developed Guidelines for Alternative Fuel Infrastructure: Maryland, New Jersey and California. Maryland has specific guidelines for the type of station as "eligible projects must be sited within the state, have a fixed location and must be open twenty-four hours a day, seven days a week. . . publicly accessible natural gas, propane and hydrogen fueling infrastructure projects are preferred. . ." (Jones 2018). Maryland provides guidance on ways to review the candidates for infrastructure. This includes the following:

- Estimated annual gallons of petroleum displaced;
- Cost Sharing methodology;
- Letters of Support from project partners, residents, officials, property owner's, site hosts, etc.;
- Innovative technology, concepts, and partnerships;
- Geographic distribution of stations within State and in relation to other stations of that same fueling technology;

- Ability to complete project during specified timeframe;
- Thoroughness of signage plan and the operations and maintenance plan;
- Company's financials, including bonding and insurance, and
- Experience installing, operating and maintaining AFV refilling/charging stations.

The document expands on the previous concepts including specifications for each type of alternative fueling center (Jones 2018). The New Jersey guide is similar to that of Maryland, but California's guide offers very specific insights into AFV infrastructure, such as providing a plan to encourage off-peak charging through the deployment of time- of-use rates; takes into account the need for stricter electrical, fire and building codes, as well as health and safety codes (CEC 2018). The guidelines offer safety tips to address concerns about the possible presence of flammable, toxic or corrosive materials. There is also a chance of acid leakage with flooded lead-acid batteries. This also includes education about electrical dangers during charging and training of personnel in commercial repair garages and service centers, as well as emergency response training needs for local officials. Overall, there a few existing guidelines for TDOT to use as a template, but TDOT's publication of *Guidelines for Alternative Fuel Infrastructure* would help in the development of alternative fuel corridors in the state. More information about the interstate corridors with existing AF stations and gaps along these corridors is found in the High Impact Strategies section of this report. Table 39 provides a summary of the difficulty of writing alternative fuel infrastructure guidelines.

The average cost of a public fast charging electric vehicle stations is approximately $70,000 dollars. Each electric *vehicle can have an annual savings on fuel cost to be about $3,300 per year; this same vehicle can reduce emissions of around 6 metric tons of carbon dioxide each year. Further information about the gaps in Alternative Fuel Vehicle Service Stations and cost associated with these stations can be found in Chapter 7.0 HIGH IMPACT STRATEGIES.*

Table 39: Alternative Fuel Infrastructure Guidelines

Criteria	Rating	Notes
Funding	Easy	Funding and staff to write guidelines are already in place.
Proven Technology	Easy	A few states have already drafted guidelines that can be used as a template.
Cost	Easy	Costs of building stations is fairly well-documented.
Benefit	Easy	Benefits and savings using AFV is well-documented.
Project Control	Easy	TDOT has total control over the content of *Alternative Fuel Infrastructure Guide for Tennessee Communities*.
Barriers	Moderate	Not all will agree on the content.

Transportation Demand Management

Transportation Demand Management (TDM) is the flip side of infrastructure. It focuses on understanding how people make their transportation decisions and helping people use the infrastructure in place for transit, ridesharing, walking, biking, and telework (MobilityLab 2018). Figure 17 illustrates TDM options. These include Walking; Biking and Bikeshare; Rideshare, including vanpooling and carpooling; Paratransit; Carsharing; On Demand, Point-to-Point Private Transit, including taxicabs, Uber and Lyft; Public Transit, including rail and bus, and Telecommuting.

TDOT has the ability to encourage the use of existing strategies without much or any capital investment, such as walking or biking to work and either full or part-time telecommuting. Other programs may require start up and ongoing capital. These include ridesharing (i.e. vanpooling or carpooling), and car sharing options, including on-demand services such as taxis, Uber and Lyft, as well as public transit. However, TDOT does not have any control over who can use paratransit services, as this is a special transportation services for people with disabilities, often provided as a supplement to fixed-route bus and rail systems by public transit agencies.

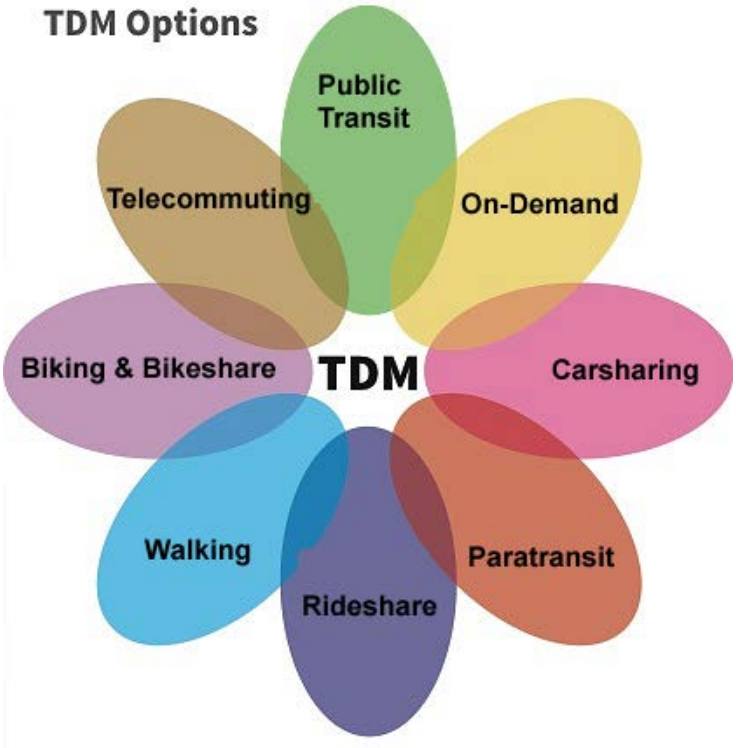


Figure 17: Transportation Demand Management Options

Low or no cost policies for TDOT could include a compressed workweek (e.g. 40 hours in 4 10-hour days), flexible work start and end times, telecommuting, or preferential parking for carpoolers. Other resources that may require ongoing financing that are used to make TDM attractive could include public transit passes, creation of an internal ride matching or carpooling resource; offer a limited number of free or subsidized rides to employees who walk, bike, bus or carpool to work with an Emergency Ride Home program (e.g. taxis, Uber or Lyft); replace subsidized parking with a monthly transportation allowance, which employees can apply towards whatever form of commuting they choose; offer cash-in-lieu of parking for employees willing to give up their spot or include work-related bicycle mileage or transit reimbursement in the same manner as mileage reimbursement for driving on work-related trips.

POLICY: Commute Trip Reduction Plan

Washington State requires all counties with a population over 151,600 and each city or town within those counties containing a major employer (more than 100 full-time employees) to adopt and implement a commute trip reduction (CTR) plan, which includes flexible work hours and telecommuting (WSDOT 2018). Washington State Department of Transportation (WSDOT) provides technical assistance to jurisdictions and employers to get their programs up and running. WSDOT maintains 17 years of CTR data that jurisdictions and other agencies use for planning. TDOT can create its own in-house CTR plan to showcase as an example, and then assist other employers that want to create their own CTR program. In Washington State more than 1,050 worksites and 530,000 commuters statewide participate in the CTR program. By 2009 three years after the programs started, people at CTR worksites across the state had reduced their weekday morning trips by about 30,000. CTR cut traffic delays by 8 percent in the Central Puget Sound Region, and rush-hour commuters saved about $59 each that year in fuel and time (WSDOT 2018). Vehicle emissions account for nearly half the harmful greenhouse gas released in Washington State. By driving 154 million fewer miles since 2007, CTR participants have prevented about 69,000 metric tons of GHG from entering the atmosphere each year. CTR participants also conserved about 3 million gallons of gasoline in the 2009-2010 biennium, which saved them together about $30 million each month (WSDOT 2018). Table 40 outlines the difficulty in implementing a CTR program.

The Commute Trip Reduction Plan in Washington State has reduced miles traveled by 154 million; prevented 69,000 metric tons of emissions from entering the atmosphere each year; conserved about 3 million gallons of gasoline and saved about $30 million dollars.

Table 40: Commute Trip Reduction Plan

Criteria	Rating	Notes
Funding	Moderate	TDOT will need to fund the program.
Proven Technology	Easy	The CTR has proven to be effective in Washington State. The California and Oregon Employer-Based Trip Reduction initiatives have also proven effective.
Cost	Easy	There are low cost expenses associated with implementing a commute or employer-based trip reduction plan. Depending on the size and scope of the CTR program, expenses can range from ~$25 - $100/employee.
Benefit	Easy	The advantages of CTR program savings in terms of time and emissions have been calculated.
Project Control	Moderate	TDOT Traffic Operations Division does not have direct control of whether or not the CTR program is put into place.
Barriers	Moderate	Barriers to program include the need to introduce new way of thinking at TDOT.

6.1.2.7 Maintenance Division

The Maintenance Division at TDOT is responsible for the administration of several statewide programs to ensure the cost-effective repair and upkeep of state roadways and highways. Specific responsibilities include establishing standard operating maintenance procedures and policies, winter maintenance operations, development of an annual roadway maintenance budget, emergency management planning, pavement management, interagency and city maintenance agreements, development of roadway maintenance contracts and facility maintenance.

The maintenance department is often the focus of environmental policies because maintenance itself is a key part of sustainability, as it improves operations and contributes to longer asset life. Sustainability examples include the use of non-invasive and low-maintenance plants for landscaping (Table 41) and pavement management systems (Table 42).

POLICY: Vegetation Management

TDOT manages vegetation along the highway right of way primarily for safety, both for motorists, pedestrians, and cyclists, for the protection of the road structure and highway features, for compliance with legal obligations and for good land stewardship. Based on this information unwanted vegetation can be defined as vegetation that obstructs safety features or creates unsafe conditions, limits sight distance, impedes drainage, increases fire hazards and compromises pavement and structure integrity. Unwanted vegetation also includes noxious and invasive weeds as well as hazard trees. A wide variety of vegetation management includes shoulder blading, mowing, brush mowing, and brush cutting. Basic changes in methodology are considered sustainable:

- Shoulder blade prior to the application of shoulder residual spray;
- Mow to a minimum height of 6 inches;
- Follow up brush cutting with herbicide applications;
- Mow noxious weeds prior to seed set to prevent spreading;
- Develop corridor tree management plans that will define trees on a TDOT corridor that need to be removed based on health, location, species etc., develop a time line for removal; a mitigation plan that reflects appropriate conditions for the area; and a disposal plan.

> *North Carolina DOT has witnessed a savings of about $2.3 million dollars annually since implementing vegetation management best practices.*

Table 41: Vegetation Management

Criteria	Rating	Notes
Funding	Easy	Grants for pest and weed management, and pollinators are available through the Sustainable Agriculture Research & Education (SARE) program, a part of USDA.
Proven Technology	Moderate	There is limited data on the types of plants that are most sustainable
Cost	Moderate	There is limited data on the cost-benefit ratio of vegetation management practices
Benefit	Moderate	There is limited data on the cost-benefit ratio of vegetation management practices
Project Control	Easy	All projects are under the control of the division director.
Barriers	Easy	Citizens may complain about median grasses not being trimmed or the removal of trees

GUIDE: Sustainable Pavement Management and Preservation Guidelines

Pavement management is the process of planning the maintenance and repair of a network of roadways or other paved facilities in order to optimize pavement conditions over the entire network. Most departments of transportation do not have any comprehensive guidelines for integrated sustainability. Most often pavement maintenance decisions are made on a project basis where traffic volume and cost are the predominant factors.

The FHWA has developed guidelines in its Sustainable Pavement Program. The document "Towards Sustainable Pavement Systems: A Reference Document" has complete descriptions of sustainability practices regarding pavement management and preservation. Of interest is the chapter on Maintenance and Preservation Treatments to Improve Sustainability. Pavement preservation is inherently a sustainable activity as it employs low-cost, low environmental-impact treatments to prolong or extend the life of the pavement by delaying major rehabilitation activities. There are a wide range of innovative surface treatments now available that can substantially prolong the service life of roads by restoring the skid resistance, filling pot holes and sealing the pavement. For example, durable micro-asphalts have been developed to give retained macro-textures similar to thin asphalt surfacing. Widely used on the continent and throughout the United Kingdom (UK) by many local authorities. Surface treatments such as mechanical re-texturing that can restore skidding resistance and extend the life of the surface course have been available in the UK for some time. Modern computer-controlled surface dressing sprayers can apply bitumen emulsion at rates that vary transversely across the lane width. This is a further example of the extent to which the surface dressing industry has embraced innovation resulting in improvements in quality over recent years.

Texas DOT has experienced a savings of about $50 million dollars each year since implementing pavement management and preservation guidelines.

Table 42: Pavement Management and Preservation Guidelines

Criteria	Rating	Notes
Funding	Easy	There is no funding
Proven Technology	Moderate	Some preservation techniques have been proven to extend the life cycle of transportation roadways.
Cost	Easy	Limited cost-benefit evaluations have been conducted. According to "Cost-Effective Pavement Preservation Solutions for the Real World", if a preservation treatment is applied at year 2, which extends the life of the pavement 3 years, the savings of $1,400 per mile per year.
Benefit	Easy	Cost savings can be quantified. Safety and other considerations have not been integrated into life-cycle costs/benefits.
Project Control	Easy	Under the control of the division director.
Barriers	Easy	Depending on the road type and location, different techniques are employed. These techniques are varied and there is no one right answer or consensus for type of best preservation treatment. This can cause conflict and doubt.

6.1.2.8 Materials and Testing Division

Division of Materials and Tests at TDOT is responsible for ensuring that all materials used in the construction and maintenance meet the appropriate legal specifications. This division monitors the state's highway network by performing field evaluations, performing laboratory tests, and analyzing a variety of data. The division coordinates pavement and materials research projects and maintains the department's Qualified Products List. It provides technical expertise and support to the entire department including the development of new specifications, geotechnical testing and consulting, and technician training and certification. Sustainability examples include the replacement of hot mix asphalt with warm mixed asphalt (Table 43), and the use of recycled asphalt shingles and reclaimed asphalt paving into asphalt mixtures (Table 44).

POLICY: Replacing Hot Mix Asphalt with Warm Mix Asphalt

Departments of transportation are using technologies that allow a reduction in the temperatures at which asphalt mixes are produced and placed. These technologies have been labeled Warm Mix Asphalt (WMA). The immediate benefit to producing WMA is the reduction in energy consumption required by burning fuels to heat traditional hot mix asphalt (HMA) to temperatures in excess of 300° F at the production plant (FHWA 2017). These high production temperatures are needed to allow the asphalt binder to become viscous enough to completely coat the aggregate in the HMA, have good workability during laying and compaction, and durability during traffic exposure. With the decreased production temperature comes the additional benefit of reduced emissions from burning fuels, fumes, and odors generated at the plant and the paving site. However, some of the technologies used to formulate WMA require significant equipment modifications.

California replaced hot mix asphalt with cold-in-place, rubberized hot mix asphalt, and warm mix asphalt in 2010. Since that time, there has been a 10% reduction in emissions by 2015, and an anticipated reduction of 20% 2020.

Table 43: Warm Mix Asphalt

Criteria	Rating	Notes
Funding	Easy	FHWA promotes the use of WMA and allows federal funding for road pavement using WMA
Proven Technology	Easy	According to FHWA, HMA is a proven technology that reduced pavement costs.
Cost	Moderate	Warm mix asphalt has an initial cost higher than traditional hot mix asphalt – it costs $4 ore per ton than hot mix asphalt because of the additives that are needed.
Benefit	Moderate	Warm mix asphalt uses less fuel and can be placed faster than hot mix asphalt; it is easier to transport and can be shipped over longer distances than hot mix asphalt, making it more cost-effective.
Project Control	Easy	TDOT will have total control over the use of WMA.
Barriers	Moderate	There are variety of additives and limited research into which additives produce longer-lasting results at specific locations; savings are not clearly quantified;

POLICY: Using Recycled and Reclaimed Materials

The Federal Highway Administration (FHWA) supports and promotes the use of recycled highway materials in pavement construction in an effort to preserve the natural environment, reduce waste, and provide a cost-effective material for constructing highways. In fact, the primary objective is to encourage the use of recycled materials in the construction of highways to the maximum economical and practical extent possible with equal or improved performance. As part of the FHWA recycled materials policy, the FHWA actively promotes asphalt pavement recycling and technology (FHWA 2016).

In order for asphalt payment recycling to be successful, the recycled asphalt pavements should be cost effective; environmentally responsible and perform well. In order to satisfy these requirements, the FHWA has identified the following specific objectives to encourage asphalt pavement recycling:

- Encourage the use of recycled material in the construction of highways to the maximum economical and practical extent possible with equal or improved performance;
- Promote the use of Reclaimed Asphalt Pavement (RAP) because the utilization of RAP can have the greatest economic, environmental, and engineering impact in pavement recycling.
- Specific goals include increasing the amount of highway construction and rehabilitation projects that use RAP and to increase the amount of RAP used in specific projects.

Table 44: Using Recycled and Reclaimed Materials

Criteria	Rating	Notes
Funding	Easy	FHWA provides funding for projects using RAP
Proven Technology	Easy	The use of RAP as an additive in hot mixed asphalt has been proven; the use of RAP as an additive in warm mixed asphalt has just begun
Cost	Moderate	In theory the use of RAP saves money when added to HMA;
Benefit	Moderate	In theory the benefits include reduction of asphalt waste in landfills;
Project Control	Moderate	TDOT Division will have control of the use of RAP in HMA/WMA.
Barriers	Moderate	The use of RAP in asphalt production is not uniformly consistent as there are multiple production mixture designs.

Colorado DOT encourages sustainable pavement practices by using recycled asphalt shingles and reclaimed asphalt paving for a savings of $1.6 million dollars in binder.

The savings from using warm mix asphalt (or other type mixture) is not necessarily easy to quantify; however, the California DOT has replaced hot mixed asphalt (HMA) with rubberized hot mix asphalt (RHMA), WMA or cold-in-place (CIP) recycling. California predicts a reduction in road construction costs of around ten to twenty percent. The use of recycled asphalt materials is more prevalent with Colorado DOT using recycled asphalt shingles (RAS) and reclaimed asphalt paving (RAP) to produce a savings of around $1.6 million in binder alone. Texas DOT also uses RAS and RAP in the production of HMA or WMA that has resulted in a saving of about $50 – $150 million dollars per year. Texas DOT has calculated that the use of 90 percent WMA, 20 percent RAP and 2 percent RAS results in the decline of approximately 113,300 tons of CO2 emissions per year.

6.1.2.9 Multimodal Division

The Division of Multimodal Transportation Resources at TDOT includes Public Transportation, Rail and Waterways, Bicycle and Pedestrian Programs, Rail Inspection and Safety, and the Section 130 Rail-Highway Grade Crossing Program. The Division administers state and federal grant programs for public transportation. The Division's Bicycle and Pedestrian Program provides coordination with TDOT resurfacing projects, awards the Multimodal Access Grants to local communities. Sustainability Examples include a Statewide Comprehensive Public Transit Network (Table 45), and the integration of language related to sustainability into plans and policies (Table 46).

GUIDE: Statewide Comprehensive Public Transit Network

A number of departments of transportation (Colorado, North Carolina,) have developed statewide comprehensive connected public transportation networks that have integrated various modes across jurisdictional boundaries. This enables residents to travel seamlessly across the state. This integration includes public bus (local, regional, interregional, intercity, bus rapid transit, trolley bus), vanpools, passenger rail service (light rail, commuter rail, and intercity rail), private shuttles and taxis, as well as human services and on-demand transportation services. The integrated services are operated by public, private or nonprofit entity. North Carolina DOT plan features a Connected Statewide Network with 70 suggested new routes, linking rural and urban areas with scheduled transit service. The NCDOT Public Transportation Division developed the Strategic Plan over a two-year period with help from the state's 100 urban and rural transit agencies (NCDOT 2018). NCDOT drafted the plan by developing 1) a comprehensive outreach and engagement effort; 2) an analysis of the statewide public transportation needs and gaps in service; 3) recommendations to meet the needs and close the gaps; 4) a roadmap to achieve the vision, and 5) short-term and long-range recommendations to improve North Carolinians' access to opportunities.

The annual savings is $9,370 for a person who switches their commute to public transportation, according to the American Public Transportation Association's (APTA) October Transit Savings Report. Individuals who ride public transportation instead of driving can save, on average, more than $781 per month.

Table 45: Statewide Comprehensive Public Transit Network

Criteria	Rating	Notes
Funding	Moderate	Funding to draft a plan is available through federal grants.
Proven Technology	Easy	No technology needed to draft a plan
Cost	Moderate	Approximately 2 years of costs associated with meetings, work hours, etc.
Benefit	Moderate	No research has been conducted measuring cost savings of comprehensive integrated statewide systems versus city or countywide systems. Benefits with Integrated statewide planning involves streamlined funding and mitigation of redundancies.
Project Control	Easy	TDOT will have control over plan development; plan execution will require coordination among other entities
Barriers	Moderate	Barriers include a need for coordination and possibly a change in leadership as a coordinating council may take the place of transit managers.

POLICY: Sustainability Language

Language used in a TDOT Multimodal plan and related documents may contain certain predispositions toward automobiles or roadways over buses and transit systems or other more sustainable elements (Williams 2014). Not only should objective policy language be used throughout, but sustainability terms should be included. For example, the Ipswich, Massachusetts Planning Board began discussion of a proposed amendment to add language selectively to its Community Development Plan, which would actively incorporate a greater emphasis on sustainability, green design and resource efficiency (Ipswich 2008). The changes in policy language included references to long-term multi-modal planning, the increasing cost of not including sustainability policies, and policies that are often introduced without due regard for the externalities being targeted by other policies resulting in inconsistencies. Changing the language included in multimodal plans can change the mindset as language has real power. Language identifies and communicates the concepts that shape thought and action. George Lakoff of the University of California at Berkeley has contributed work on the framing of language. (See Lakoff's "Don't Think of an Elephant," Chelsea Green Publishers, 2004.) Some examples of language change include the following (Ipswich 2008):

- Change "natural resource management" to "regeneration of nature" or "natural resilience." "Management" reinforces a false sense that humans know exactly what to do and how nature is going to respond to actions and "Resource" conveys that nature is something to be used.
- Change "proper stewardship" to "proper interaction" or "healthy relationship," for the same reason as the above.
- Provide context for "sustainability," in that it means the ability to continue into the indefinite future by respecting the Earth's ecosystems and its limits.

Table 46: Inclusion of Sustainability Language

Criteria	Rating	Notes
Funding	Easy	Funding and staff to integrate sustainability into multi-modal plans and guides is already in place.
Proven Technology	Easy	The USDOT is actively engaged in including sustainability language into its plans and programs.
Cost	Moderate	Not all directives have a well-documented cost if sustainability language is included in plans.
Benefit	Easy	The mindset of successive generations will naturally include sustainability thinking
Project Control	Easy	TDOT has total control over the language included in plans.
Barriers	Moderate	Not all will agree on definitions of certain terms; the language used will need to enhance, not alter, objectives.

6.1.2.10 Roadway Design Division

The Roadway Design Division at TDOT deals with the Design Standards and Policy, Contract Management, Aerial Surveying, and Consultant Management sections. The key responsibility of the Design Standards and Policy Section is to provide roadway design criteria and developing roadway design standards and training manuals. This section also reviews locally administrated projects for the Program Development Division for Quality Assurance and Compliance (Table 46). The Contract Management section performs the pre-qualification of consultant engineering firms, advertisement of consultant projects, oversight and payment of contracts, and provides pavement design, value engineering studies, plan sales, and file management. The Consultant Management section oversees consultant developed roadway projects. Federal Highway Administration published "An Integrated Approach for Building Sustainable Roads" (FHWA 2013). The guidebook is intended for any practitioner involved in project development, including the TDOT personnel, engineers, designers, and those involved in contractor oversight and management, such as the Roadway Design Division. The publication provides a well-documented method for integrating sustainability into the roadway design and construction proves. The INVEST tool is formally endorsed by FHWA for sustainable project development (Table 47), and a sustainable roadway design policy has been developed by Ferdinando Corriere and Angela Rizzo that could be a template for TDOT (Table 48).

TOOL: Sustainable Project Development - INVEST TOOL

Table 47: Sustainable Project Development INVEST Tool

Criteria	Rating	Notes
Funding	Easy	FHWA formally endorses INVEST as a free tool found on the FHWA website at: https://www.sustainablehighways.org/
Proven Technology	Easy	As of 2017, 34 case studies have been documented.
Cost	Easy	The tool is free, but there are costs associated with training and learning curve associated with tool use. A typical process for using INVEST first requires a point person to browse the tool and become familiar with how it works. This typically takes about a day. After that, the person will need to identify subject matter experts and have them gather supporting documents that they will each use to develop an initial score.
Benefit	Moderate	It can be difficult to capture the true value of sustainability. Benefits of the triple bottom line can be realized in several ways and in several different timeframes. This includes cost savings, healthier environments, time-savings to users and agencies as well as improved quality of life.
Project Control	Easy	TDOT Roadway Design Division has control over INVEST tool use.
Barriers	Easy	FHWA provides training on tool use. The tool cannot account for all contingencies for all projects.

The Arizona Department of Transportation (ADOT) became interested in using INVEST in 2010 while in the midst of updating two of their long-term planning documents (i.e. *Building a Quality Arizona* and *What Moves You Arizona*?) At the time, the State of Arizona was going through a period of rapid demographic change and population growth. Simultaneously, many members of the public were becoming more informed about the transportation planning process and demanding that transportation projects address more than just mobility and accessibility needs, but also include environmental, social, and economic components. ADOT used the INVEST tool to score the sustainability development for more than 50 individual transportation projects using the PD checklist and developed recommendations for improvements to agency practices based on the evaluation, as well as integrate recommendations and sustainability concepts into ADOT manuals and guides. Table 46 provides a summary of the ease-of-use of the INVEST tool.

> *Arizona DOT's use of sustainable practices has resulted in over $200 million in cost savings.*

POLICY: Sustainable Roadway Design Policy

A study by Ferdinando Corriere and Angela Rizzo have drafted a methodology for integrating sustainability into Roadway Design Manuals and Polices (Corriere 2012). The authors identified ten steps to accomplish this task. The steps are a combination of items in the FHWA INVEST Tool and various tools used in Great Britain. Each step is interrelated to the next step. Table 48 provides an illustration of its ease of implementation. The steps of the methodology are:

1. Sustainability Goals Defined. In this step, the project purpose, in terms of sustainability, which is to be achieved for each of the requirements identified in Steps 3 and 4 is defined.
2. Associated Benefits. In this step, the choices between different projects that cannot be based solely on technical elements but also in terms of the sustainable benefits associated with the project (e.g. environmental, and social) are defined.
3. Project Basic Requirements. In this step, the basic requirements to be incorporated into each element of the project are identified. These include any activities, procedures, analyses, studies, etc. that the project must include meeting federal and state requirements. At this point, sustainability elements may be added to each requirement.
4. Project Voluntary and Innovative Requirements. In this step, the project basic requirements from step 3 are expanded to include any extra voluntary (not mandatory) requirements that may have greater or lesser weight in terms of impact on sustainability. Any additional proven technological innovations can be added as well.

5. Approach and Methods. A review of any voluntary and innovative additions to the basic requirements is made. Back of the envelop cost/benefit review may be needed to meet time and cost restraints.
6. Key Performance Indicators. In this step, key performance indicators are identified, and benchmarks are developed.
7. Standard Requirements. For each additional voluntary and innovative requirement of the project, are measured against any basic regulatory and legislative requirement.
8. Current State of Research. Information regarding the state of research and anticipated benefit for each additional voluntary and innovative requirement is provided.
9. Case Studies, Examples and Calculations. Additionally, for each voluntary and innovative requirement, examples of calculation and strategies for the determination of success are developed.
10. Criteria for Evaluation. In the final step, criteria for inclusion into a project is developed. As each project is different, the criteria for inclusion may change.

Table 48: Sustainable Roadway Design

Criteria	Rating	Notes
Funding	Easy	This is a free study that can be accessed to make changes to current policy.
Proven Technology	Moderate	Though the INVEST tool has a number of documented successes, the methodology does not.
Cost	Moderate	The tool is free, but there are costs associated with training and learning curve associated with actual use of the methodology.
Benefit	Moderate	It can be difficult to capture the true value of this method as no complete case studies exist.
Project Control	Easy	TDOT Roadway Design Division has control over whether or not to use the methodology into Roadway Design Manuals and Polices
Barriers	Easy	There is no training for the use or integration of the methodology into practice. The methodology cannot account for all contingencies for all projects.

6.1.2.11 Right-of-Way Division

The Right-of-Way (ROW) Division at TDOT is responsible for the appraisal and acquisition of land needed for state highway construction and relocation of displaced families and businesses. This division is also responsible for the coordination and relocation of utility and railroad facilities necessary for highway construction projects, as well as the disposed of excess land. The headquarters offices oversee the administration of policy and procedures, and the regional offices oversee the daily operations. Utilities Office is responsible for the coordination of local utility and railroad relocation efforts for highway construction and issuance of utility encroachment permits. Appraisal Office is responsible for quality assurance in the process of estimating just compensation for property rights acquired for the construction of transportation facilities. Acquisition Office is responsible for the acquisition of real property required for state transportation needs. Relocation Office is responsible for the relocation and reestablishment of persons, businesses and farms displaced because of State or State-aid highway projects and the management of acquired improvements. Excess Land Office is responsible for the administration and disposal of surplus right of way for non-highway purposes. Engineering Office is responsible for providing engineering and technical advice, support and interpretive assistance as it relates to the interface between roadway design, construction and right-of-way appraisal and acquisition. Right-of-Way involves many sections (e.g. appraisal and acquisition, relocation of facilities, and excess land) on many levels (e.g. Chief Engineer, and regional engineers). There are hundreds of people responsible for the various aspects of right-of-way.

RESOURCE: North Texas Council of Governments Road Map to a Sustainable Public ROW

This document offers ten steps to "improve the sustainability of the projects constructed within the public rights-of-way…it is a collection of ideas, examples, reference material, and memory joggers that may be used to create more sustainable public rights-of-way for both new construction and rehabilitation/revitalization projects" (NCTCOG 2012). The 10 general principals of a Sustainable Public Right-of-Way (found below) can help put ROW into a sustainable framework and can be used to provide a valuable resource for TDOT. Table 49 provides a summary of its ease of use by TDOT.

1. Meet the needs of today without compromising the ability of the future;
2. Create environmentally friendly, economically feasible, and socially acceptable public rights of way;
3. Involve stakeholders and coordinate from start to finish;
4. Improve air quality;
5. Improve water quality;
6. Create pedestrian and bicycle friendly communities;
7. Improve performance and reduce lifecycle and maintenance costs;
8. Ensure regulatory compliance;
9. Promote economic development;
10. Provide safer and healthier neighborhoods;

Table 49: Sustainable Right-of-Way

Criteria	Rating	Notes
Funding	Easy	This is a free report that can be accessed to make changes to current policy.
Proven Technology	Moderate	Though the report provides a list of resources, there is no study that indicates the success or failure of utilizing the methodology outlined.
Cost	Moderate	The report is free, but there are costs associated with training and learning curve associated with actual use of the methodology.
Benefit	Moderate	It can be difficult to capture the true value of this method as no complete case studies exist.
Project Control	Easy	TDOT Right-of-Way Division has control over whether or not to use the methodology.
Barriers	Easy	There is no training for the use or integration of the methodology into practice. The methodology cannot account for all contingencies for all projects.

RESOURCE: Ray C. Anderson Highway Right-of-Way

The 18-mile-long Ray C. Anderson Highway, a segment of Interstate 85 in Troup County, Georgia provides an example of a sustainable right-of-way. For instance, there are solar-powered electric vehicle charging stations, beautifying bio-swales and a 7,000-square-foot pollinator garden (Hickman 2017). The highway boasts several restorative pilot projects. The bio-swales capture and filter polluted storm water runoff from the highway; the visitor center contains the pollinator garden that attracts bees, butterflies and other beneficial nature, as well as the photovoltaic electric vehicle charging stations (Figure 18). Other existing initiatives include an innovative tire safety check station that aims to boost safety and fuel efficiency by texting motorists "critical information" about their tire pressure as well as a small test patch of solar power-generating pavement (Hickman 2017). Most noticeable of all is the wheat grass farming taking place on the shoulder of the interstate. The wheat grass is a sod-forming, multi-functional perennial grain with superior carbon sequestering capabilities. There is a one thousand square-foot mini-farm along the highway for demonstration purposes, and a section of I-85 that will be repaved using experimental, nontraditional materials, such as asphalt that incorporates recycled tires. These "rubber roads" reduce noise pollution while extending the life of the pavement by 15 to 20 percent (Hickman 2017). Table 50 outlines the ease of adoption by TDOT Right-of-Way Division.

Solar arrays on less than 2% of the state's right-of-way could supply 30 million kilowatt hours of energy.

Table 50: Sustainable Highway Right-of-Way Design

Criteria	Rating	Notes
Funding	Moderate	There is not known federal funding for this type project, though public-private partnerships could be used.
Proven Technology	Moderate	The separate concepts of solar-powered electric vehicle charging stations, butterfly gardens and bio-swales have been proven effective, the comprehensive plan with all components have not been proven.
Cost	Moderate	There is an unknown cost for integrating all aspects of the Ray C. Anderson Highway on a Tennessee corridor.
Benefit	Moderate	It can be difficult to capture the true value of the greening of 18 miles of highway, though the goal is zero deaths, zero waste and zero carbon emissions.
Project Control	Easy	TDOT Right-of-way Division has control over whether or not to use the methodology.
Barriers	Easy	There is one example of the greening of right-of-way, but no training.

Figure 18: Solar Powered Electric Vehicle Charging Station on Ray C. Anderson Highway

6.1.2.12 Strategic Planning Division

Strategic planning and management calls for an on-going process where resources, results, critical issues, trends, and citizen needs are systematically reviewed to help evaluate and reset priorities for each TDOT division. The Strategic Planning Division assesses each TDOT division to ensure that each department's objectives align with TDOT's overall goals. As such, Strategic Planning Division can integrate sustainability into each department uniformly and cohesively.

TOOL: The Bartella Methodology

The Bartella methodology provides a means to identify strengths and weaknesses of TDOTs current strategic plan with regards to sustainability. Based on a national survey of State Departments of Transportation (DOTs) by Dr. Bartella, it was determined that strategic planning agencies are engaged in a variety of activities to address sustainability issues associated with transportation planning, design, and operations. However, state DOTs in general do not have sufficient policies or practices in place to evaluate and prioritize investment options that will promote sustainable development (Bartella 2012). For this research, a mixed-methods research design employing an expert panel and case studies of individual State DOTs was used to develop, test, and evaluate the value of a strategic planning tool that can help DOTs evolve more sustainable practices and be used to monitor progress over time. A self-assessment tool was designed to guides agencies through (1) identifying internal strengths and weaknesses (or gaps) in their planning frameworks and organizational structure and culture, (2) characterizing features of the external environment as opportunities or threats, (3) prioritizing areas for strategy development, and (4) developing strategies that link the internal and external environments (Bartella 2012). The main contribution of this research is to define a methodology for transportation agencies to develop or refine their organizational frameworks to be more oriented toward sustainability. Table 51 outlines the ease-of-implementation for TDOT Strategic Planning Division.

Table 51: Sustainable Strategic Planning

Criteria	Rating	Notes
Funding	Easy	This is a free report that can be used to make changes.
Proven Technology	Moderate	Though Bartella methodology has not been proven.
Cost	Moderate	The methodology is free, but there are costs associated with integrating its concepts into policies, training, etc.
Benefit	Moderate	It can be difficult to capture the true value of this method as no complete case studies exist.
Project Control	Easy	TDOT Strategic Planning has complete control over the changes made.
Barriers	Easy	There is no training for the use or integration of the methodology into practice.

RESOURCE: National Sustainable Transport Planning - Concepts and Practices

Though on a broader scale, ideas from "National Sustainable Transport Planning - Concepts and Practices" by Claus Hedegaard Sørensen (Denmark) offers a few suggestions for integrating sustainability into TDOT as a comprehensive framework of approach. The aim of the document is to review how to integrate and define the concept of 'national (in this case state) sustainable transport planning'. This is done via a selected literature review. A definition is provided, and it is suggested that three interlinked dimensions are of importance for transitions, thus a normative, an analytic and a governance dimension (Sørensen 2013). The definition of national (or state) sustainable transport planning is developed from current concepts in Sweden and Norway, which are somewhat advanced and have long traditions of recurrent, comprehensive, cross modal planning processes and integrated documents. Finally, three research topics for future research are proposed.

Based on the document, successful transition to include sustainability into strategic planning includes the need to organize strategic planning processes and apply knowledge tools to support the implementation of new policy goals and instruments for sustainability. The effectiveness of TDOT's non-comprehensive silo-like ad hoc approach should be questioned. Strategic planning principals and policies should be defined that stages the planning process of each division, providing fixed planning cadences and the conduct of 'strategic analyses that can be supported by an integrated state transport model to underpin critical decisions. This will involve the integration of some state and federal policy-makers.

The Danish research project, SUSTAIN (2012 to 2016) can provide a method for transitioning the current strategic planning method into one that is comprehensive across TDOT divisions. The scientific objective of SUSTAIN is to help establish sustainable transport planning as a coherent research topic across the social and technical sciences, while the societal objective is to promote future-oriented planning for a sustainable transport system in Denmark (Sørensen 2013).

There are multiple and different definitions of planning depending on the context. In the case of TDOT strategic planning, a comprehensive and somewhat general definition may need to be created to act as an umbrella for more context sensitive sustainability definitions used for each TDOT division. Inherent in these definitions is the concept that planning can never become a fully routinized, understood and predicted phenomenon because it deals with novel problems and circumstances. To develop a sustainability strategic plan, cross-disciplinary approaches may need to be addressed. These interlinked dimensions a normative approach, an analytic approach, and a legislative approach. The normative approach includes the fundamental ethical principles and value-orientations of sustainability. This includes the definition of what sustainable transport is, what the three pillars (environmental, economic, and social) imply in transport, and which goals to pursue. The analytic approach is used to determine whether an action is sustainable or not – the consequences of sustainability applied to infrastructure, transport service projects, plans, etc. The legislative approach identifies the system of governance that should promote and implement changes through policies, programs and plans.

This also includes the identification of public entities, private entities, and partnerships, as well as the development of key government institutions, and implementation of procedures, which promote integration of sustainability. Sweden and Norway are countries with explicit and easily identifiable national transport planning practices that can be used as a template for TDOT to develop a robust strategic plan that comprehensively integrates sustainability transportation throughout the state. Table 52 outlines the ease of use regarding the concepts in the "National Sustainable Transport Planning - Concepts and Practices" by Claus Hedegaard Sørensen.

> *Massachusetts DOT integration of sustainable practice into its departments has resulted in $2.9 million dollars in air pollution savings; $1.4 million dollars in sewer bill savings; $1 million dollars in water bill savings, and $5.9 million dollars in energy bill savings.*

Table 52: Sustainable Roadway Design

Criteria	Rating	Notes
Funding	Easy	This is a free study that can be accessed online.
Proven Technology	Moderate	Though the counties of Sweden and Norway are nationally known for their sustainable transport systems, the concepts outlined by Claus Hedegaard Sørensen have not been studied or put into practice.
Cost	Moderate	There are costs associated with training and learning curve associated with actual use of the methodology.
Benefit	Moderate	It can be difficult to capture the true value of this method as no complete case studies exist.
Project Control	Easy	TDOT Strategic Planning has control over all aspects of this methodology's use.
Barriers	Moderate	There is no training for the use or integration of the methodology into practice.

6.1.2.13 Strategic Transportation Investments Division

The Strategic Transportation Investments Division at TDOT provides strategic support for projects that addresses safety, congestion, and economic development needs across the state. This includes Expedited Project Delivery (EPD) whose goal is to address the immediate issues on the highway system and propose the proper solution. The Division conducts operational analysis of non-highway transportation projects as they affect the highway system. Investments relate to the work of this division in determining what new commitments (i.e. investments) TDOT will be making. This process includes the new "Needs Assessment Process" which determine the appropriate level of study and Project Prioritization, which uses technical data, schedule and cost to provide a prioritized list of major projects to assist in the development of the 3-year Multimodal Transportation program

POLICY: North Carolina Strategic Investments Law

Passed in 2013, the Strategic Transportation Investments law allows the North Carolina Department of Transportation (NCDOT) to use its funding more efficiently and effectively to enhance the state's infrastructure while supporting economic growth, job creation and a higher quality of life. This process encourages thinking from a statewide and regional perspective while also providing flexibility to address local needs. This law also established the Strategic Mobility Formula, which allocates available revenues based on data-driven scoring and local input, thus prioritizing projects. The Formula is used to prioritize projects contained in the NCDOT's State Transportation Improvement Program, which identifies the transportation projects that will receive funding during a specified 10-year period. NCDOT updates its State Transportation Improvement Program every two years. Table 53 provides the ease of implementation review for Tennessee.

The Strategic Mobility Formula funds projects in three categories: Division Needs, Regional Impact, and Statewide Mobility. Division Need projects receive 30 percent of the available revenue, shared equally over NCDOT's 14 transportation divisions, which are groupings of local counties. Project scores are based 50 percent on data and 50 percent on rankings by local planning organizations and the NCDOT transportation divisions (NCDOT 2018). Regional Impact projects receive 30 percent of available revenue. Projects on this level compete within regions made up of two NCDOT transportation divisions, with funding divided among the regions based on population. Data makes up 70 percent of the project scores in this category. Local rankings account for the remaining 30 percent. Finally, Statewide Mobility projects receive 40 percent of available revenue. The project selection process is based 100 percent on data (NCDOT 2018). Table 52 provides basic information on the difficulty in implementing the law.

The second 10-year plan developed under the 2013 Strategic Transportation Investments law – consists of 750 highway projects across North Carolina and is estimated to support at least 300,000 jobs. The data-driven approach to identify projects – called Strategic Prioritization – yielded a comprehensive State Transportation Improvement Program with about 1,200 projects funded across all 100 North Carolina counties and all modes of transportation. NCDOT identified ways to accelerate hundreds of projects, which allowed an additional 144 projects to be funded. This resulted in a total of 1,367 projects in the STIP at a savings of $14.5 million dollars.

Table 53: Strategic Investment Law

Criteria	Rating	Notes
Funding	Moderate	There is no funding available to draft a law or recruit stakeholders.
Proven Technology	Moderate	NCDOT has the legislative template and experienced leaders that could act as a guide for Tennessee's effort.
Cost	Moderate	Unknown costs.
Benefit	Moderate	In theory, the law allows the NCDOT to use its funding more efficiently and effectively to enhance infrastructure while supporting economic growth, job creation and a higher quality of life.
Project Control	Difficult	The passing of laws require legislative sponsorship outside of TDOT authority.
Barriers	Difficult	There is no guarantee the law will be passed or passed in such a way as to generate benefits.

RESOURCE: Invest Strategically in Transportation

The Chicago Metropolitan Agency for Planning (CMAP) has developed a series of recommendations for investing strategically in transportation. CMAP has the responsibility of addressing traffic safety, congestion, and economic development needs in the area, while integrating creative funding strategies that are sound practice. These investments could promote some feature of sustainability with each dollar spent. Table 54 provides an outline of the ease of implementation. The guidelines include methods to:

1. Prioritize Investments. To improve the efficiency and effectiveness of transportation systems, the first requirement is to spend existing resources more wisely. Investment

decisions should be based on performance-driven criteria, rather than arbitrary formulas. TDOT could prioritize efforts to modernize Tennessee's existing assets rather than continuing to expand the system. Investments of all types should take a multimodal approach, where consideration for transit users, bicyclists, and pedestrians are equal to that of the automobile.

2. Find New, Innovative Revenues. The second requirement is to generate new revenues beyond that of the federal and state government. This involves the placement of user fees, which should be better structured to reflect actual maintenance and operations needs as well as the costs of congestion. Though federal and state gas taxes fund a large share of road maintenance and construction costs, other revenues streams should be analyzed for inclusion (e.g. congestion pricing, and parking management strategies). Public-private partnerships can offer a range of approaches to privatize infrastructure assets and realize cost savings from shorter construction schedules. A range of pros and cons exists for each strategy, but they should be explored. However, the State of Tennessee currently lacks legislation to enable and promote public-private partnerships for transportation projects. "Value capture" mechanisms and impact fees also have promise in generating revenue from increases in property values caused by nearby infrastructure investments (CMAP 2018).

3. Create Cost and Investment Efficiencies. Given limited resources, the state could evaluate road and transit investments based on the degree to which they impact the economy and livability. Maintaining and modernizing the existing system should take precedence over costlier expansions.

Table 54: Sustainable Investment Strategy

Criteria	Rating	Notes
Funding	Easy	This is a free resource that can be accessed online.
Proven Technology	Moderate	Not all of the suggestions have been analyzed for success.
Cost	Moderate	The resource is free, but the cost of implementing suggestions have unknown costs.
Benefit	Moderate	It can be difficult to capture the true value of the suggestions as benefits may not be generated immediately, but over time. No complete case studies exist.
Project Control	Easy	TDOT Strategic Transportation Investments has control over whether or not to use the suggestions of CMAP.
Barriers	Moderate	There is no training for the use or integration of the suggestions.

6.1.2.14 Structures Division

The Structures Division at TDOT is responsible for designing and developing plans and specifications relating to all highway structures and for the inspection of all bridges in Tennessee. Key responsibilities include inspection, foundation design, tolerances and geometry, as well as the design of major or unusual structures. The Structures Division resolves hydrology issues and problems, including coordination of Geological Survey services, hydraulic specifications, studies involving legal action, and scour studies. The division is responsible for inspection of prefabrication plants, welding procedure review; on-site erection supervision; design and development of contract plans specifications, and development of automated structural detailing systems. Finally, Structures Division processes federal disaster assistance, and produces designs for other transportation structures such as retaining walls, box culverts and noise barrier walls.

TOOL: National Bridge Investment Analysis System - NBIAS

The National Bridge Investment Analysis System (NBIAS) was developed to assess national bridge investment needs and the tradeoff between funding and performance. Newer editions of NBIAS include environmental trade-offs as well. The tool is based on an analytical framework developed by the Federal Highway Administration (FHWA) and subsequently adopted by the American Association of State Highway and Transportation Officials (AASHTO). The system incorporates economic forecasting tools to project the multiyear funding needs required to meet user-selected performance objectives over the length of a user-specified performance period (FHWA 2018). NBIAS works with bridge condition data as reported by various entities for the National Bridge Inventory (NBI) in addition to the element/condition state inspection regime. NBIAS combines statistical models with engineering principles and heuristic rules to synthesize representative elements so they can be defined and manipulated using the state of current condition, deterioration costs, environmental preservation aspects, and future cost probabilities. Also, NBIAS includes climate zone dimensions into the stratification scheme and adding user cost components to the cost model. Outcomes can be presented by type of work, functional classification, and whether the bridges are part of the National Highway System or the Strategic Highway Network. Table 55 provides more information on NBIAS implementation.

> *The estimated cost of meeting 2015 –2040 Arkansas' State Highway System bridge needs is $4.9 billion dollars. Using National Bridge Investment Analysis System through various scenarios, the cost of meeting state bridge needs dropped about 15% to $4.16 billion dollars.*

Table 55: National Bridge Investment Analysis System

Criteria	Rating	Notes
Funding	Easy	FHWA formally endorses NBIAS as a free tool.
Proven Technology	Easy	Arkansas, Minnesota, and California have conducted a variety of case studies with the tool.
Cost	Easy	The tool is free, but there are costs associated with learning the trade-offs of the software.
Benefit	Moderate	It can be difficult to capture the true value of sustainability. Benefits of the triple bottom line can be realized in several ways including cost savings, healthier environments, time savings to users and agencies as well as improved quality of life.
Project Control	Easy	TDOT Structures Division has control over whether the tool is used.
Barriers	Moderate	FHWA does not provides training. The tool cannot account for all contingencies for all projects.

GUIDE: Iowa Department of Transportation Sustainable Bridge Design Guidelines

Iowa DOT has rewritten its Bridge Design Guideline Manual to include sustainability language. This publication could provide a template for TDOT to use when updating their manual. The manual states:

Sustainability is a concept that takes into account the long view of projects, considering costs and benefits over lifetimes rather than concentrating on a one or two year cost life cycle. Incorporating sustainability into decision-making can have positive effects for stakeholder relations, for the bottom line, and for the natural resources of the state (IDOT 2018).

IDOT Sustainable bridge design is concerned with the following:

- Does the site employ available best practices in sedimentation and erosion control?
- Does the bridge go nowhere or does it connect two existing developments?
- Does the bridge add to the economic and social value of the two bodies it connects?
- Does the bridge disturb a greenfield, wetland or farmland?
- Will the bridge be constructed in such a fashion as to minimize traffic delays?
- Does the bridge replace or improve an existing structure or is it a new structure?
- Are footings and piers required, and how does their placement impact the surrounding environment?
- Can a bridge in one location replace several smaller, possibly less functional bridges in disparate locations?

The IDOT manual provides sustainability assessment tools, sustainable processes for handling water used in construction and that which runs off the structure, and guidelines for the materials used. Sustainable Material and Resource questions include:

- Are recycled materials used in the structure?
- Can the materials used in the structure be recycled?
- If rehabilitated, are the materials from the old structure reused in the new?
- If rehabilitated, how much of the original structure is utilized in the new design (abutment stems, piers, etc.)?
- Are materials regionally available or brought in from long distances?
- Are new materials or processes utilized that reduce the overall quantity demands for the structure?
- Are otherwise landfilled materials used in the bridge construction (i.e. - fly ash or slag in concrete mixes)?
- Is the bridge designed with a complete Life Cycle Analysis in place?

The Iowa Bridge Manual provides an example of a DOT integrating sustainability concepts into Bridge design and construction. TDOT could use this as a template for updating and integrating sustainability concepts into their own manuals. Table 56 illustrates the ease in which TDOT could integrate the concepts of the Iowa Bridge Manual.

Illinois DOT used recycled materials in the upgrading and repair of the Rock River Bridge saving $1.1 million dollars using materials from nearby buildings scheduled for demolition.

Table 56: Sustainable Bridge Design Guidelines

Criteria	Rating	Notes
Funding	Easy	This is a free online guide that could act as a template for TDOT Structures Division.
Proven Technology	Moderate	The concepts in the Iowa Bridge Manual have not been independently studied or analyzed.
Cost	Moderate	The guide is free, but there are costs associated with implementing its concepts (e.g. using recycled building materials over tradition materials, etc.).
Benefit	Moderate	It is difficult to calculate true value of benefits as benefits my take time and difficult to quantify.
Project Control	Easy	TDOT Structures Division has control over whether the guide is used.
Barriers	Easy	There is no training for the use or integration of the methodology into practice.

6.1.2.15 Traffic Operations Division

The Traffic Operations Division at TDOT is responsible for traffic hardware infrastructure (e.g. traffic signals, roadway lighting, and roadway signage), as well as Intelligent Transportation Systems (ITS) deployment, architectures and management. Traffic Operations Division oversees the Traffic Management Center (TMC) and Traffic Incident Management (TIM) programs; management of TDOT wireless radio network and motorist Information Systems (e.g. Tennessee SmartWay, 511, Twitter). Finally, the division monitors transportation system performance through engineering studies, including traffic simulation and analysis.

TOOL: Adaptive Traffic Control

Adaptive Traffic Control Systems (ATCS) is an intelligent transportation system that enables traffic signals to adapt to actual traffic demand. As of 2015, ATCS is being used in 31 states and in approximately 160 municipalities in the U.S. For example, in Los Angeles County, ATCS have been installed on seven corridors on State Routes. The ATCS system was shown to reduce travel time by 12.7 percent, reduce average stops by 31 percent, and decrease average delays by 21.4 percent. Table 57 indicates the ease of implementation is easy to moderate. Adaptive signal control technologies are best suited for arterials that experience highly variable or unpredictable traffic demand for which multiple signal timing solutions are necessary during a typical time-of-day period. ATCS works by receiving and processing data from traffic sensors, this data is evaluated to optimize and update signal timing settings (i.e. determine when and how long lights should be green). The process is repeated every few minutes to keep traffic moving. Adaptive signal control technology responds to traffic patterns based on real time conditions, can change system cycle lengths, phase sequences, or phase lengths on-demand, and reverts to lower cycle lengths as soon as demand is reduced.

> *Adaptive Traffic Control Systems was shown to reduce travel time by 12.7 percent, reduce average stops by 31 percent, and decrease average delays by 21.4 percent.*

The U.S. Federal Highway Administration, through its Every Day Counts initiative, is working to accelerate the adoption of adaptive signal control technologies in the U.S. Its website states, "Real-time management traffic systems is proven to work, yet these systems have been deployed on less than 1 percent of existing traffic signals. FHWA is now working to bring these technologies to the rest of the country. Table 57 describes the ease of implementation for TDOT.

Mount Juliet, Tennessee

ATCS was initiated for 1.3 miles on SR-171 (Mt. Juliet Road) on the eight signals from Graves Crossing to Pleasant Grove Road – primarily the five-lane section of road. There was 20,000-40,000 ADT within the project limits, with queues 1 mile or longer during peak times with heavy left running movements. Mt. Juliet Road is a major commercial corridor and primary access to I-40 for western Wilson County. Mt. Juliet followed the typical TDOT Local Programs process using STP funding. The implementation process required preliminary systems engineering analysis, purchase, installation and tuning of equipment, upgrading of signal systems outside of adaptive equipment, controller upgrades, safety upgrades and detection upgrades. The system used was highly configurable, but comes with a learning curve requiring monitoring, training and field adjustments.

Table 57: Adaptive Traffic Control

Criteria	Rating	Notes
Funding	Easy	Typically funded through federal Surface Transportation Program (STP) funds. The Surface Transportation Program is designed to assist cities with a population of 5,000 or greater. Funds can be used for intelligent transportation systems. The program pays 80% of project costs unless the project is for signalization or other safety-related work which can be funded with 100% federal funds.
Proven Technology	Easy	Adaptive traffic control systems have been in utilized in Los Angeles county since the mid-1990s.
Cost	Moderate	$811,743.50 for eight signals along a 1.3-mile corridor. Hidden costs include weekly maintenance (about 10 hours per week); yearly operations costs (about $1,000 per intersection); downtime costs and training costs. Costs associated with awareness campaigns.
Benefit	Easy	Studies have shown that adaptive signal control improves average performance metrics (travel time, control delay, emissions, and fuel consumption) by 10 percent or more. Improvement might not be as dramatic in areas where traffic demand is stable and predictable during typical time-of-day periods, performance is regularly monitored, and signal timing is well maintained.
Project Control	Moderate	TDOT Traffic Operations Division does not have direct control over project though it can provide education on the application process and encourage municipalities to utilize ATCS if appropriate.
Barriers	Moderate	Barriers to program are outside of TDOT scope. These barriers include the cost of hardware, the required expertise necessary to configure and maintain the system, lack of active performance measurement.

Mt. Juliet selected the InSync system from Rhythm Engineering as the adaptive signal vendor. The costs for eight signals were $321,450.00 ($40k per signal) and include cameras, in-cabinet equipment, and 5-year support. Other systems needed included Stansell Electric internet wireless communication ($490,293.50) and Wavetronix radar detection (stop bar detection) ($262,450.00). Total initial cost equals $811,743.50. Sixteen-channel cabinet is required.

POLICY: Green Light for Midtown

New York Department of Transportation (NYDOT) has developed and launched the "Green Light for Midtown" (Table 58). It is estimated that this plan has reduced CO2 levels by approximately 150,000 metric tons. The effort is specific to the densely populated and traversed area near Times Square and Herald Square. This area is one of the most densely populated areas in the world, with a census-estimated 2016 population of 1,643,734 living in a land area of 22.83 square miles (59.13 km2), or 71,999 residents per square mile (27,799/km2), higher than the density of any individual U.S. city.

Table 58: Green Light for Midtown

Criteria	Rating	Notes
Funding	Easy	FHWA provides funding.
Proven Technology	Easy	Permanent roads closure and conversion to pedestrian only areas exist in many areas with historic downtowns (e.g. Boston, San Diego, New York City).
Cost	Moderate	Approximately $20,000 per block to close road, redirect traffic, provide pedestrian/bicycle improvements. Estimate does not include funding for preliminary engineering, engineering upgrades required for additional traffic on peripheral roads, and parking.
Benefit	Moderate	Mobility: Travel time improvement of ~13%; speed improvement of ~5%; Safety: Injuries to motorists and passengers in the New York City project area decreased by 63%; pedestrian injuries are down 35%.
Project Control	Moderate	TDOT Traffic Operations Division does not have direct control over project though it can provide education on the steps needed to initialize a permanent road closure and conversion to pedestrian only with limited product delivery admittance and public transit access.
Barriers	Moderate	Barriers to program are outside of TDOT scope. These barriers include the process for road closure and decommissioning, politics involved, businesses that may be affected, etc.

Green Light for Midtown project has reduced CO_2 levels by approximately 150,000 metric tons.

The goal of the pilot project was to open up the streets and avenues in Midtown for pedestrians by reconnecting the street grid on 6th and 7th Avenues and closing off a portion of Broadway. The project resulted in traffic signals with up to 66% more green time; ravel time improvements on 6th and 7th avenues, and safer and simpler crossings for pedestrians. Though the municipalities in Tennessee do not have areas of dense population that could support a wide area "Green Light for Midtown" project, aspects of the project (such as road closures with pedestrian enhancements with access to public transit) could possibly be applied on a limited scale to pedestrian corridors in Nashville and Memphis.

RESOURCE: Connected and Automated Vehicles

The US Department of Transportation (USDOT) is coordinating with state DOTs, academic institutions, and private sector companies to study the communication between drivers-pedestrians-cyclists and roadside equipment and control centers, aspects of Connected and Automated Vehicles (CAV) infrastructure. The goal is to improve the transportation system performance in terms of safety, congestion, mobility, energy, and emission. For example, drivers who can receive information, alerts and warnings from surrounding vehicles can make avoid running into vehicles and perform safer lane change maneuvers. At the same time, smoother lane change maneuvers and less abrupt longitudinal accelerations can, or hard braking can reduce energy consumption and resulting emissions. Various connected and automated vehicle related strategies include installing vehicle-to-infrastructure roadside equipment, providing pedestrian detection and warning, connected and platooned trucks, etc.

As CAV technology is relatively new, the implementation of CAVs can bring large-scale changes to the current transportation system, but also suffer from numerous challenges including the standardization and communication between technologies, and the role states will play regarding specific laws, infrastructure support, and privacy and data. In the context of TDOT, CAV programs can be related to various divisions, such as Long-range Planning, Multimodal, Roadway design, and Strategic Transportation Investments. TDOT can identify high impact technologies, e.g., testing of truck platooning on roadways and creation of CAV testbeds for economic development and equality. Table 59 illustrates the moderate difficulty level of implementing CAV technology. The I-24 Smart Corridor initiative is an example of a high-impact intelligent transportation systems strategy. Specifically, I-24 is one of the major routes in Nashville, TN, serving daily commuters and commercial freight. The I-24 SMART corridor project (between Murfreesboro, TN and Nashville, TN) aims to better manage existing infrastructure rather than add more capacity. The traffic volumes during peak hours exceed the corridor's capacity with frequent incidents and travel time unreliability. TDOT will manage the existing infrastructure and improve safety and travel time reliability by allocating nearly $120 million. With the emergence of CAVs and considering their potential positive influence on safety and mobility, TDOT is implementing strategies to facilitate the adoption and deployment of these technologies in the I-24 SMART corridor. Similarly, smart corridors should be established in other cities, supported by TDOT, to perform more testing of connected and automated vehicles. More on CAV in Tennessee can be found in Chapter 7.0 HIGH IMPACT STRATEGIES.

By 2050, connected automated vehicles could reduce fuel consumption by as much as 44 percent for passenger vehicles and 18 percent for trucks, according to a new study released by the US DOE Energy Information Administration.

Table 59: Connected and Automated Vehicle Program

Criteria	Rating	Notes
Funding	Moderate	Under the connected and automated vehicles (CAVs) driving environment, benefits can be had in terms of safety, congestion reduction, energy savings and emissions reductions. At the federal level, the National Highway Traffic Safety Administration (NHTSA) has studied the safety benefits of two CAV technologies – Left Turn Assist (LTA) and Intersection Movement Assist (IMA). Nationwide, they can prevent 592,000 crashes and save 1,083 lives annually. TDOT and regions/cities can potentially fund the CAV projects through CMAQ funds, IMPROVE Act by TN Legislature, or connected vehicle facility charges.
Proven Technology	Moderate	Various technologies can be used, based on the new Intelligent Transportation Systems architecture. These will include on-board wireless communication systems, vehicle tracking systems, alert and warning system, roadside wireless equipment that include Dedicated Short Range Communications units, and the development of phone apps.
Cost	Difficult	Various methods and tools can be used to calculate the costs of implementing technology. Detailed cost information can be obtained from program plans. A cost-benefit analysis can be applied to calculate the return- on-investment before the implementation of the CAV program in various cities and regions. It is expected that the cost of technology will drop over time. Alongside the initial costs (purchasing CAVs, deployment of initial equipment, there may be hidden costs such as work force training related to specific technologies, designing experiments where volunteer drivers can be monitored to learn about how well and how much they drive when using CAVs. Consideration should be given to life-cycle cost.
Benefit	Moderate	The benefits in terms of safety, congestion, energy and emissions can be calculated using various criteria. For example, reductions in near-misses, crashes, injuries, and fatalities could show substantial safety benefit, while the improvements in travel times and delays can indicate congestion benefits. The short-term and long-term benefits should be separated out.
Project Control	Moderate	TDOT can coordinate with the local public or private sector stakeholders to implement the projects as TDOT will provide an overall plan and establish new policies regarding CAVs. Different TDOT divisions will be involved in this project such as traffic operation, environmental and maintenance divisions.
Barriers	Difficult	The barriers to deployment include: 1) difficulty of installing vehicle-to-infrastructure (V2I) and I2V equipment as well as software development; 2) public retrofitting their vehicles with CAV on-board units can be costly; 3)

		the privacy of drivers will have to be protected as their driving behavior can be tracked under CAVs driving environment; 4) The connected vehicles might not coordinate well with pedestrians if a vehicle is controlled by a driving assist system; 5) In most cases, the CAV technology is designed to for normal driving conditions and it is unclear how the CAVs will perform in adverse or abnormal driving conditions, e.g., bad weather; 5) other barriers includes AV certification, insurance and liability, maintaining security of the system, e.g., against cyber-attacks, and training a work-force.

POLICY: Telematics

Telematics is the technology that helps in sending, receiving, and storing information from road vehicles (Table 60). The technology is able to monitor and transmit information such as current vehicle speed against the speed limit of the road, road conditions, the braking, cornering, and accelerating habits of the driver, etc. Vehicles equipped with telematics devices have allowed insurance provider to have more precise information to rate driver's premiums such as on-road activity (including braking and cornering speed or acceleration), the time of day when driving, and the amount of time spent behind the wheel. The California Department of Transportation began including telematics capability into its fleet of vehicles in 2015. Telematics is the technology that helps in sending, receiving, and storing information from road vehicles. The technology is able to monitor and transmit information such as current vehicle speed against the speed limit of the road, road conditions, the braking, cornering, and accelerating habits of the driver, etc. The California Department of Transportation began including telematics capability into its fleet of vehicles in 2015.

Table 60: Telematics

Criteria	Rating	Notes
Funding	Moderate	Funding to utilize telematics in DOT vehicles is provided by the DOT.
Proven Technology	Moderate	The technology used to track vehicle movement is well-established; however, protocols utilizing the data collected in an effective and meaningful manner have not been established. Additionally, issues of driver privacy need to be resolved before deployment.
Cost	Easy	A cellular data link is $250 for each device; $50 per vehicle installation cost and $25 per vehicle monthly service cost. The service life of the technology is estimated to be approximately five years. Additional costs include one employee for each year for data management ($100,000 per year including benefits and overhead). With a Wi-Fi data link, there are costs associated with the development of a database and web server software and cost of the web service to receive data from the vehicle telematics devices via the Wi-Fi station installed in each maintenance yard. In this case the vehicle would collect and store the data and then transmit the data to the server when the Wi-Fi station comes into its communications range. Support and development costs for the server and software are approximately $3,000,000 for one year.
Benefit	Easy	The advantages of this system allow DOTs data to analyze driving patterns

		and develop a more accurate understanding of how their employees act when they drive. That also means DOTs can encourage safe driving practices and perhaps seek lower insurance premiums for good driving behavior. Other benefits include the reduction in mileage (~2% - 8%) from reduced unauthorized usage and improved routing; reduction in costs associated with idle time per day (~$500 per vehicle per year); reduction in average speed by 5 MPH (Each mile per hour over 60 MPH increases cost per gallon of fuel by $0.04).
Project Control	Easy	TDOT Traffic Operations Division has director control of technology usage and implementation.
Barriers	Moderate	Barriers to program include the need to introduce new vehicle usage and telemetric data download protocols.

Telematics can save up to 25% on the cost of annual vehicle insurance premiums (depending on how the vehicle is driven).

TOOL: Intelligent Transportation Systems

An intelligent transportation systems (ITS), transportation infrastructure is complimented with information and communication technologies with the objectives of attaining improved passenger safety, reduced transportation time and fuel consumption and vehicle wear and tear. With the advent of modern communication and computational devices and inexpensive sensors it is possible to collect and process data from several sources.

ITS is classified into five systems according to their functions (FHWA 2012):

1. ATMS (Advanced Traffic Management System) detects traffic situations, transmits them to control center via communication network, and then develops traffic control strategies by combing all kinds of traffic information. Furthermore, ATMS makes use of facilities to carry out traffic control and transmits the information to drivers and concerned departments, and implements traffic management measures, such as ramp metering, signal control, speed control, incident management, electronic toll collection and high occupancy vehicle control and so on.

2. ATIS (Advanced Traveler Information System) with advanced communication technology, makes road users can access real time information in the car, at home, in the office or outdoors as the reference of choosing transportation modes, travel trips and routes. The system mainly includes changeable message signs, Highway Advisory Radio (HAR), GPS, the internet connection, telephone, fax, cable television, information Kiosk and mobile etc.

3. AVCSS (Advanced Vehicle Control and Safety System) applies advanced technologies in vehicles and roads, and helps drivers control vehicles in order to reduce accidents and improve traffic safety. The AVCSS mainly includes anti-collision warning and control, driving assistance, automatic lateral/longitudinal control, and the long-run plans of automatic driving and automatic highway system.

4. APTS (Advanced Public Transportation System) applies the technology of ATMS, ATIS and AVCSS in public transportation in order to improve the quality of service, and increase efficiency and the number of people who take public transportation. The system mainly includes automatic vehicle monitoring, Variable Position System, computer scheduling and E-tickets.

5. CVO (Commercial Vehicle Operation) applies the technology of ATMS, ATIS and AVCSS in commercial vehicle operation such as trucks, buses, taxes and ambulances in order to improve efficiency and safety. The system mainly includes automatic vehicle monitoring, fleet management, computer scheduling and electronic payment.

The USDOT's Intelligent Transportation Systems Joint Program Office (ITS JPO) is responsible for conducting research on all major modes to advance transportation safety, mobility, and environmental sustainability through electronic and ITS applications. The ITS Strategic Plan 2015-2019 outlines the direction and goals of the USDOT's ITS Program (USDOT 2018). The ITS Strategic Plan's framework is built around two key ITS Program priorities— realizing connected vehicle implementation and advancing automation. Though TDOT may encourage, but have limited control regarding commercial vehicle operation, advanced public transportation systems, and advanced vehicle control and safety systems; TDOT can directly impact the implementation of advanced traveler information systems and advanced traffic management systems through a review of best practices.

NAVIGATOR-Advanced Transportation Management System (ATMS)-Atlanta, Georgia

The Advanced Transportation Management System, or NAVIGATOR, was developed in Atlanta, Georgia to help better manage traffic flow and provide real-time traffic information to improve transportation decisions and public information (FHWA 2006). NAVIGATOR uses video detection, radar detectors, and more than 450 closed-circuit television cameras to monitor traffic flow. The system enables control center managers to detect traffic incidents and congestion rapidly, and subsequently dispatch Highway Emergency Response Operators. Five ramp meters are used to control highway traffic flow, and information technologies (such as 67 changeable message signs, the Internet, and 140 information kiosks) help provide motorists with real-time traffic information. In developing the system, more than 400 traffic intersections were upgraded to improve signal coordination throughout Atlanta and the metropolitan region (FHWA 2006). Additionally, the Metropolitan Atlanta Rapid Transit Authority (MARTA) has access to information generated by the ATMS and shares information on road conditions to its bus drivers to help manage response to congestion and incidents. The incident management components of the system resulted in substantial savings in traveler delay. Using conservative

estimates, Georgia DOT estimates that the incident management components of NAVIGATOR have reduced the average incident duration by 23 minutes, from an average of 64 minutes to 41 minutes. The result is cost savings of $45 million per year for travelers with emission savings of 614 kg/day for volatile organic compounds (VOC) and 578 kg/day of nitrogen oxides (NOx). Table 61 provides an outline of the ease of implementation regarding utilizing best practice methods for ITS.

NHTSA estimates that safety applications enabled by vehicle to vehicle and vehicle to infrastructure could eliminate or mitigate the severity of up to 80 percent of non-impaired crashes, including crashes at intersections or while changing lanes.

Table 61: Intelligent Transportation Systems

Criteria	Rating	Notes
Funding	Moderate	Some funding to utilize ITS is provided by the CMAQ Funding.
Proven Technology	Moderate	The technology used to enhance current ITS elements for ATMS and ATIS are well-established.
Cost	Moderate	Unknown. Expenses for updating or upgrading the current system has not been calculated.
Benefit	Easy	The advantages of ATMS and ATIS have been calculated; this includes time, environmental, and injury savings.
Project Control	Easy	TDOT Traffic Operations Division has director control of technology usage and implementation.
Barriers	Moderate	Barriers to program include the need to introduce new vehicle capability and additional data download protocols.

6.1.2.16 Environmental and Cost Savings of Best Practices

Table 62 provides a review of the environmental and cost savings of implementing sustainability best practices. The estimated savings from integrating sustainable strategies range from a savings of about $3,300 in fuel costs and a reduction of 6 metric tons of carbon dioxide for each green fleet vehicle to an expense savings of about $2.3 million dollars annually when implementing vegetation management best practices. Some of the sustainable resource and guide suggestions have no case studies to determine environmental and cost savings. For example, there were no known case studies found that calculated savings by utilizing the guides, resources and tools recommended for the various Environmental offices (e.g. Environmental Analysis, Ecology and Permits, Highway Beautification, Environmental Comprehensive Inspections, Environmental Facility Compliance, and Environmental Mitigation). The environmental and cost savings provided are an estimate for the amount TDOT could save on a similar project.

Table 62: Estimated Savings from Integrating Sustainable Strategies

Division	Proposed Strategy
Aeronautics	**RESOURCE: Federal Aviation Administration VALE & AIP** VALE grants have funded 105 projects at 51 airports, and have reduced ozone emissions by 1,192 tons per year . . . equivalent to removing 66,550 cars and trucks off the road
	GUIDE: SAM (Sustainable Airport Manual) SAM goals for Great Lakes airports of reducing energy consumption by 15%, diverting 50% of airport waste from landfill, and maintaining a ground fleet of at least 20% low emissions vehicles has resulted in savings of $775,000 per year.
	TOOL: Colorado Division of Aeronautics Tool Kit Denver International Airport currently recycles or reuses 21 different types of materials, including approximately 75 percent of collected aircraft deicing fluids resulting in environmental and cost savings of $ 1.1 million dollars. EcoStart motor controllers installed on escalators and moving walkways have reduced the power draw of the motors for a total savings of about 1.7 million kWh or $205,000 dollars per year.
Central Services	**POLICY: Fleet Acquisition and Management Policy** One green fleet vehicle can have a lifecycle savings on fuel cost to be about $3,300; this same vehicle can reduce emissions of around 6 metric tons of carbon dioxide each year.
	POLICY: Green Purchasing California DOT switched paper suppliers, which allowed them to purchase 30-percent recycled paper content while reducing costs by 20 percent and retrofitted 26,000 lighting fixtures with efficient light bulbs using 30 percent less electricity and lasting 6,000 more hours saving about $1.8 million dollars each year.

Construction	**TOOL: Construction Analysis for Pavement Rehabilitation Strategies (CA4PRS)** CA4PRS was used by CalTrans to select the most economical rehabilitation scenario for the I-15 Devore Project. The 4.5-km concrete reconstruction project, which would have taken 10 months using traditional nighttime closures, was completed over two 9-day periods using one-roadbed continuous closures and around-the-clock construction. Implementing continuous closures rather than repeated nighttime closures in this project resulted in significant savings: $6 million in agency costs and $2 million in road user costs.
	TOOL: Sustainable Contractor and Acquisition Procurement - INVEST TOOL Using the Sustainable Contractor and Acquisition Procurement portion of the INVEST TOOL, TXDOT was able to procure a contractor willing to integrate sustainability concepts for the Corpus Christi bridge project for $973 million dollars. This is approximately 18% less than the anticipated cost of $1.15 billion dollars.
Environmental	No case studies have been developed calculating cost or environmental savings by utilizing the guides, resources and tools recommended for the various Environmental offices (e.g. Environmental Analysis, Ecology and Permits, Highway Beautification, Environmental Comprehensive Inspections, Environmental Facility Compliance, and Environmental Mitigation).
Freight and Logistics	**GUIDE: Off-Peak Delivery Time** During a pilot project in Bristol, UK, consolidated deliveries resulted in a 73% reduction in delivery movements and a 65% reduction in vehicle mileage.
	POLICY: Left Lane Truck Restrictions Lane restrictions reduce overall crash rates by about 10 percent.
	TOOL: Expand the Smart Park Program Forty percent of commercial truck drivers spend an hour or more per trip searching for parking. Those drivers waste an estimated nine percent of driving time searching for parking...equaling $7,200 in lost wages annually due to parking shortages.
	RESOURCE: Develop Public-Private Parking Partnerships No cost-benefit or return-on-investment case studies have been available to determine benefit of public-private parking partnership development.
Long-Range Planning	**POLICY: Extension of Plan Time Horizon** As extending the timeframe for long-range plans and projects if a fairly new concept, performance measures have not been applied to projects requiring longer planning timeframes. The long-range plan incorporating extended timeframes will need to offer very clear breakdown of projections for each funding source, listing all assumptions clearly to allow for assessment.
	POLICY: Inclusion of Sustainability Language Research has not been conducted illustrating the benefits or detriments of

	including sustainability language into planning documents; however, language essential to developing a sense of sustainability as a positive force.
	GUIDE: Complete Streets A cost benefit analysis of the Cumberland Avenue Complete Streets projects indicated a cost of $42.5 million dollars, and a benefit of $89.4 million dollars. Details on how the cost and benefits were calculated can be found in Chapter 7.0 HIGH IMPACT STRATEGIES.
	GUIDE: Alternative Fuel Infrastructure The average cost of a public fast charging electric vehicle stations is approximately $70,000 dollars. Each electric vehicle can have an annual savings on fuel cost to be about $3,300 per year; this same vehicle can reduce emissions of around 6 metric tons of carbon dioxide each year. Further information about the gaps in Alternative Fuel Vehicle Service Stations and cost associated with these stations can be found in Chapter 7.0 HIGH IMPACT STRATEGIES.
	<u>Transportation Demand Management</u> **POLICY: Commute Trip Reduction Plan** The Commute Trip Reduction Plan in Washington State has reduced miles traveled by 154 million; prevented 69,000 metric tons of emissions from entering the atmosphere each year; conserved about 3 million gallons of gasoline, and saved about $30 million dollars.
Maintenance	**POLICY: Vegetation Management** North Carolina DOT has witnessed a savings of about $2.3 million dollars annually since implementing vegetation management best practices.
	GUIDE: Sustainable Pavement Management and Preservation Guidelines Texas DOT has experienced a savings of about $50 million dollars each year since implementing pavement management and preservation guidelines.
Materials and Testing	**POLICY: Replacing Hot Mix Asphalt with Warm Mix Asphalt** California replaced hot mix asphalt with cold-in-place, rubberized hot mix asphalt, and warm mix asphalt in 2010. Since that time, there has been a 10% reduction in emissions by 2015, and an anticipated reduction of 20% 2020.
	POLICY: Using Recycled and Reclaimed Materials Colorado DOT encourages sustainable pavement practices by using recycled asphalt shingles and reclaimed asphalt paving for a savings of $1.6 million dollars in binder.
Multimodal	**GUIDE: Statewide Comprehensive Public Transit Network** The annual savings is $9,370 for a person who switches their commute to public transportation, according to the American Public Transportation Association's (APTA) October Transit Savings Report. Individuals who ride public transportation instead of driving can save, on average, more than $781 per month.

	POLICY: Sustainability Language There has been no research calculating the cost and benefits of language change in policy.
Roadway Design	**TOOL: Sustainable Project Management - INVEST TOOL** Arizona DOT's use of the INVEST Tool to review manuals and policies and integrate sustainable practices have resulted in over $200 million in cost savings.
	POLICY: Sustainable Roadway Design Policy Ferdinando Corriere and Angela Rizzo have drafted a methodology for integrating sustainability into Roadway Design Manuals and Polices that have not been studied to determine cost-benefits.
Right-of-Way	**RESOURCE: North Central Texas Council of Governments Road Map to a Sustainable Public Right-of-Way** Though the report provides a list of resources, there is no study that indicates the success or failure of utilizing the methodology outlined.
	RESOURCE: Ray C. Anderson Highway Right-of-Way Solar arrays on less than 2% of the state's right-of-way could supply 30 million kilowatt hours of energy.
Strategic Planning	**TOOL: Bartella Methodology** The Bartella self-assessment methodology can be difficult to calculate its value as no complete case studies exist.
	RESOURCE: National Sustainable Transport Planning - Concepts and Practices Massachusetts DOT integration of sustainable practice into its departments has resulted in $2.9 million dollars in air pollution savings; $1.4 million dollars in sewer bill savings; $1 million dollars in water bill savings, and $5.9 million dollars in energy bill savings.
Strategic Transportation Investments	**POLICY: North Carolina Strategic Investments Law** The second 10-year plan developed under the 2013 Strategic Transportation Investments law – consists of 750 highway projects across North Carolina and is estimated to support at least 300,000 jobs. The data-driven approach to identify projects – called Strategic Prioritization – yielded a comprehensive State Transportation Improvement Program with about 1,200 projects funded across all 100 North Carolina counties and all modes of transportation. NCDOT identified ways to accelerate hundreds of projects, which allowed an additional 144 projects to be funded. This resulted in a total of 1,367 projects in the STIP at a savings of $14.5 million dollars.
	RESOURCE: Invest Strategically in Transportation Chicago Metropolitan Agency for Planning (CMAP) has developed a series of recommendations for investing strategically in transportation. The recommendations have not been studied for cost savings.
Structures	**TOOL: National Bridge Investment Analysis System - NBIAS**

	The estimated cost of meeting 2015 –2040 Arkansas' State Highway System bridge needs is $4.9 billion dollars. Using National Bridge Investment Analysis System through various scenarios, the cost of meeting state bridge needs dropped about 15% to $4.16 billion dollars.
	GUIDE: Iowa Department of Transportation Sustainable Bridge Design Guidelines Illinois DOT used recycled materials in the upgrading and repair of the Rock River Bridge saving $1.1 million dollars using materials from nearby buildings scheduled for demolition.
Traffic Operations	**TOOL: Adaptive Traffic Control** Adaptive Traffic Control Systems was shown to reduce travel time by 12.7 percent, reduce average stops by 31 percent, and decrease average delays by 21.4 percent.
	POLICY: Green Lights for Midtown Green Light for Midtown project has reduced CO2 levels by approximately 150,000 metric tons.
	RESOURCE: Connected and Automated Vehicles (CAV) By 2050, connected automated vehicles could reduce fuel consumption by as much as 44 percent for passenger vehicles and 18 percent for trucks, according to a new study released by the Energy Information Administration.
	POLICY: Telematics Telematics can save up to 25% on the cost of annual vehicle insurance premiums (depending on how the vehicle is driven).
	TOOL: Intelligent Transportation Systems NHTSA estimates that safety applications enabled by vehicle to vehicle and vehicle to infrastructure could eliminate or mitigate the severity of up to 80 percent of non-impaired crashes, including crashes at intersections or while changing lanes.

6.1.3 Sustainability Practice Lead

The importance of sustainability is being realized widely in the 21st century. The concept embodies the promise of a societal consciousness and responsibility towards a more equitable and ecologically friendly transportation network. Sustainability can accordingly be defined as meeting the needs of Tennessee's residents without compromising its ability to meet the needs of future residents. Putting sustainability at the forefront of TDOT's policies and practices can create positive association and increased consumer confidence in TDOT's deliverables and actions.

In transportation departments statewide the two disciplines, energy and sustainability, are gradually becoming combined in order to enable a DOT to maintain and grow their economic, social and environmental base while actively contributing to sustainability in their state. Though TDOT may have several employees engaged with aspects of sustainability across their own division; this is often not their main focus, and sustainability monitoring can become an "add-on" to a much broader role. Thus, their focus is diluted. With the appointment of a Sustainability Lead, a coordinated, strategic approach can be provided, led by a single individual who draws together all aspects of sustainability - energy management, social and ethical due diligence – a complex, technically challenging and constantly changing market due to legislation and technology – and creates a green strategy for the whole of TDOT. Additionally, if one individual who delegates out responsibilities manages sustainability in a strategic manner, then TDOT will be more easily able to present a clear and transparent sustainable strategy.

Division directors indicated a need for a Sustainability Practice Lead who would be responsible for overseeing the compliance of sustainability initiatives. No director identified specific individual/s whose main purpose was to make careful examination of or initiate sustainability practices into projects. The proposed sustainability practice lead could research initiatives, and coordinate with other division directors. An examination of other DOTs with a sustainability practice lead and the responsibilities of this lead is provided.

What is a Sustainability Practice Lead?

The Sustainability Practice Lead will be a person responsible for the process of integrating sustainability processes into TDOT management decision making and other projects. This will involve interfacing with and directing technical personnel and staff on projects, attending client meetings, and facilitating workshops and other in-house training. It may also involve community outreach. Generally, the lead will have a broad, impact-based approach to sustainability that includes social, environmental and economic aspects of projects. This person will be able to demonstrate strong collaboration skills that allow TDOT to define projects and deliverables that provide value to their clients.

Other responsibilities of the Sustainability Practice Lead could include:

- Develop plans and strategy for TDOT, working closely with various divisions;
- Assist in proposal preparation and procure grants to fund sustainability initiative.
- Connect with TDOT staff and perhaps municipalities, keep them informed, seek feedback, listen to complaints and praise, manage expectations and responds appropriately.
- Be in charge of the appraisal, performance, development, morale, and motivation of staff in the sustainability discipline.
- Mentor and develop people, promote learning from successes and problems within the group and across TDOT.

A few departments of transportation have sustainability practice leads, also known as sustainability directors or managers. Most notably is California Department of Transportation. In 2015, Governor Jerry Brown appointed Ellen Greenberg as the California Department of Transportation's (Caltrans) Deputy Director for Sustainability, a position created to lead the department's efforts in developing and implementing initiatives to align with California's goals on sustainability.

Washington State DOT (WSDOT) has a sustainability program lead and a "Sustainability Team" that meets every six to eight weeks to coordinate agency-wide efforts that are associated with sustainability. A planning group consisting of representatives from maintenance, operations, environmental, adaptation, materials, and planning meets bi-weekly to identify and oversee sustainability initiatives. The group has established goals with specific action items and "process owners" in charge of implementation. The WSDOT sustainability program lead coordinates the activities of the Sustainability
Team and monitors legislative activities and sustainability activities at other agencies.

Interestingly, some larger metropolitan areas have included Sustainability Directors. For example, San Antonio, a metropolitan area in southwest Texas hired its first sustainability director in March 2014. In this case, the director is responsible for the overall leadership of the Office of Sustainability, as well as the city's sustainability efforts and environmental policy.

No matter what level or title is used to define the sustainability lead, there are certain core competencies sustainability leaders share. These include the ability to understand the intricacies of the sustainability framework – its' context in the bigger picture. Knowledge and willingness to collaborate with others outside of TDOT, this would include private groups and other state agencies. The lead would have the ability to redesign established policies, processes and procedures, and be sustainably literate about current and future trends. Finally, TDOT Sustainability Lead should be sensitive to the motivations and emotions of others.

6.1.4 Formalization of Collaboration Strategies

During the surveys conducted in this study, eight of the division directors remarked on the need to have in place some type of formalized method for integrating sustainability aspects of other divisions into their own projects, procedures, documentation and other efforts – a comprehensive multidisciplinary approach to integrating sustainability concepts into final deliverables. Though most divisions were required to work with other departments in the project process, there was no impetus to do so outside of federal requirements or to develop protocols to include input from the best examples of various divisions outside of the federal requirements.

Communications is a part of sustainability efforts. This includes carefully crafted dialogues around one specific idea. A high degree of coordination is required for initiative implementation. In order to assist in communicating effectively, a generalized framework for communication mechanisms and specific steps are provided.

Various departments of transportation have used a variety of mechanisms to implement collaborative efforts between divisions. These efforts have included the appointment of a coordinator, divisions co-locating within one floor of a facility, or establishing goal specific task forces. These mechanisms can be used to address a range of purposes, such as project development, program implementation, oversight and monitoring, as well as information sharing or cross training. Most often DOTs use more than one mechanism to address an issue. Although collaborative mechanisms differ in complexity and scope, they all benefit from certain key features, which raise issues to consider when implementing these mechanisms (GAO 2012). A generalized framework for communication among divisions for all types of communication strategies includes:

- Identifying and defining specific outcomes (both long-term and short-term), and the individual or group who is accountable, as well as a method to monitor progress;
- Bridging different division cultures by identifying the missions of the participating divisions, and agreeing on a common terminology and definition among divisions;
- Using data to communicate effectively, including who is responsible for data collection, analysis, and application of data to guide communications work;
- Framing the goals effectively and convincingly using the data provided;
- Deciding on leadership and how leadership will be sustained over the long-term, and clearly identifying the roles and responsibilities of leader(s);
- Clearly identifying the roles and responsibilities of each team member, as well as any relevant division resources;
- Deciding upon specific funding amount and source, as well as each staff member to be assigned a role, and tools needed, and
- Documenting aspects of the generalized communication framework.

The efforts to promote cross-division communication and alter internal culture are only supporting measures. Nothing can replace strong political leadership, a talented and empowered staff with adequate resources, and effective partners. Building on all of that, a well-coordinated internal outreach plan is still a must-do to sustain momentum. The following is a set of steps to take to formalize communication strategies:

One Problem at a Time - Have one individual identify one problem that needs cross-division consultation and input. This may be a problem that has required input from multiple divisions before. For example, highway construction requires input from Right-of-Way Division, Environmental Division, Materials and Testing, etc. Chose a single comparatively simple task involved in the entire project that requires input and collaboration from two or three divisions at most.

Seek to Understand the Problem – Ask probing questions to try to flesh out all aspects of the problem while trying to understand the problem and the assumptions each of the other divisions have. This will give all members a clean and clear picture of what the real issue is.

Keep Comments Objective - Take an objective, neutral point of view – do not become engaged in the battle. Take the role of negotiator or fact finder. The more people get wrapped up in the battle and in trying to win, the more likely they are to start feeling that the issue is a personal. Don't Seek to Blame –

Understand Assumptions and Legacy procedures - Seek solutions and understanding by identifying any underlying assumptions. Find the logic behind the actions and procedures taken by each division. Outline and document these underlying assumptions and the legacy processes. This will provide a baseline for identifying areas where collaboration can be forceful.

Agree on the Problem – Work to gain agreement on what the problem is before attempting to find solutions through collaboration. This means on agreeing about the various nuances of the problem.

Agree on a Solution – Not every problem will have one solution. Some issues will require multi-faceted answers. Additionally, research may need to be conducted before a solution can be decided upon. When all divisions agree on how to solve a problem, it provides a roadmap for personnel and leadership.

Document Everything – Document all possible solutions, team members input, as well as roles, responsibilities and a timeline of activities.

Define Communication Expectations – In order to effectively communicate project scope, issues, schedule, and quality and foster trust between divisions the following communication expectations can be included in the process. Hold regularly scheduled meetings to achieve strategic objectives of cross division collaboration. This includes developing and distributing a

meeting agenda at least one week prior to a meeting; reviewing progress on projects using status and task group reports, and drafting meeting minutes.

The **Project Communication Handbook** by the California Department of Transportation Office of Project Management explains the various processes in detail involved in Department project communication. This could be used as a template for TDOT to formalize multi-division collaboration strategy.

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6.1.5 Formalization of Existing Practices

Unwritten sustainability practices at TDOT, uncovered during the course of this study, include paper recycling and reduction, general context sensitive solutions concepts, the encouragement of flexible work hours, and encouragement for employees to utilize public transit. During the survey, four of the directors mentioned that there is a need to "formalize" the unwritten policies to provide consistency throughout the separate TDOT divisions. Also, there is a desire to formalize administrative practices that are sustainable across all divisions (e.g. online documentation, digital signatures, public outreach through internet, emailed invoice and payment, and electronic plan submittal).

These responses included the adoption of policies because they "increased production and efficiencies"; the belief that "aspects of internal TDOT process delivery should include sustainability initiatives", and the concept of "Do it Right the First Time, every time" that includes cost and time savings from having to retrofit or re-work a project. Five division directors specifically stated that initiating sustainability policies and procedures into TDOT projects are the "Right Thing to Do" because sustainability practices are a part of good resource stewardship. Of those who responded affirmatively, the types of solutions included the following. Please note that the solutions described below are not necessarily utilized by all TDOT divisions.

- Online documentation (e.g. printable not fill-able forms, manuals);
- Digital signature contract books that eliminate the need for printed books;
- Public outreach through the internet;
- Software used to communicate with Tennessee counties;
- Electronic plan submittal;
- Use of various online solutions (e.g. email, and video conferencing);
- Integration of telecommuting practices;
- Scanned and emailed invoice process and scanned reports, studies, etc.
- Consultants/contractors receive copies of TDOT sustainability standards and guidelines;

Some of the benefits associated with these practices include significant time savings with regards to issuing project work orders; reduction in waste and corrective actions and improvement of process efficiencies. More flexibility in employee work location and the resulting decrease in traffic may be difficult to quantify as a benefit but are considered sustainable.

While unwritten rules can work, the formalization of the practices mentioned above can provide continuity throughout the various TDOT divisions. Formalization will assist existing personnel and new employee learns exactly what and how they can achieve some objective. A formalized process will assist TDOT in procedure control, information, education and direction. Research of current practices – who, what, where, how and why- should be conducted before

formalization of procedures. This includes documenting procedure length, and project requirements and intricacy. Basic Tips for Policy or Procedure Writing include the following:

- Use everyday words and phrases
- Rewrite wordy phrases
- Watch for redundancy
- Make good use of transitions
- Delete unnecessary adjectives and modifiers
- Keep clauses and phrases short or break them into separate sentences
- Generally, keep sentences to 15 to 20 words at most
- Keep paragraphs short
- Use one-sentence paragraphs when appropriate
- Use bulleted lists
- Start with an action verb
- Use present tense
- Write in the active voice (Subject-verb-object)
- Avoid jargon and clichés

Below is a list of other DOTs that have integrated solutions mentioned by TDOT directors into their policy.

Online Fillable, Printable Forms – Texas Department of Transportation (TxDOT) website contains fillable forms and a Frequently Asked Question (FAQ) page. The FAQ page provides information on the types of browsers that are compatible with TxDOT electronic forms; the mobile devices that can be used to open online forms; actions to take if the online form cannot be opened; software requirements, as well as download and fill-out procedures. Though not a written policy per se, the information can be used to enhance paperless documentation.

E-Construction How-to Guide – The Florida Department of Transportation has developed this guide to collect, review, approve and distribute highway construction contract documents in a paperless environment. The guide describes how to get "buy in" from decision makers, using e-construction techniques in sampling, testing, inspection, reporting, etc. TDOT could use the guide as a template for their own e-Construction processes.

Telework Policy – The US Department of Transportation created a Telework Policy in 2013. This policy outlines the management of telework in all situations, including regular telework, ad hoc telework, unscheduled telework and telework in emergencies. The goal is to promote telework by DOT employees with appropriate controls for performance accountability, safety, and information security.

Online Community Outreach – The North Carolina Department of Transportation (NCDOT) combined online and targeted face-to-face community engagement to involve more community members than ever before to help inform the 10-year plan. NCDOT has since developed an online public engagement hub used for outreach and listening efforts.

6.2 Core Strategic Actions

Core Strategic Actions for TDOT identified in the March 2018 meeting included the development of in-house sustainability training, the establishment of various work groups (i.e. public transit, connected and automated vehicles, fleet management and smart communities), and raise sustainability awareness internally, the integration of outcome measurements, and the creation of planning to practice protocols.

1. Develop In-House Training/Education – (Ranked #3) During the survey, three directors discussed the need for in-house training that would include a series of educational opportunities that would build upon each other specific to certain themes.

2. Establish Work Groups – (Ranked #8) A number of working groups to research specific topics and achieve specified goals were requested by the directors. These working groups include:
    A. Public Transit Work Group – (Ranked #5)
    B. Connected and Automated Vehicles Work Group – (Ranked #12 B)
    C. Fleet Management Work Group – (Ranked #9)
    D. Smart Communities Work Group – (Ranked #10)

3. Raise Sustainability Awareness Internally – (Ranked #6) Engaging employees in sustainability is a growing trend with significant benefits.

4. Integrate Outcome Measurement – (Ranked #7) Six division directors mentioned the need and reliance on public feedback to determine if a project is successful or not, but that there was no formalized method to receive, document and measure this feedback.

5. Provide Planning to Practice Methods – (Ranked 12 A) Planning to integration is part of best practices found in the Best Practices Applied to TDOT section of the report.

6.2.1 In-House Sustainability Training

The final question of the background data section of the survey asked if the division provided some type of training program to encourage employee engagement in addressing sustainability issues. Of the 15 responses received, eight responded "Yes" (53%) and seven responded "No" (47%). Further discussion indicated that TDOT did not have any specific training program or training strategy regarding sustainability education. Those division leaders who wanted to educate their employees did so by other means and organizations through webinars and workshops. These include the International Right-of-Way Association, National Highway Institute, Federal Highway Administration, and various smart growth education activities.

Three directors specifically discussed the need for in-house training that would include a series of educational opportunities that would build upon each other specific to certain themes. In addition, one director discussed the need for new hires to have exposure to sustainability concepts early in the employment process. Sustainability education should begin with new employee orientation. This would include the desire to make current and future employees aware of the sustainability policies and programs already in place.

A review of state DOTs do not indicate permanent department-wide in-house education or curriculum, but some states do provide in-house education for a particular division depending on their needs. Third parties generally provide this education. For example, Colorado DOT provided education for employees on how to use new materials and design principals for a specific storm-water project. The National Center for Sustainable Transportation (NCST), part of a USDOT initiative has conducted research on sustainability education at DOTs. To this end, NCST has developed a series of eight, modular, sustainable transportation courses, spread across undergraduate, graduate, and professional education levels (NCST 2015). The NCST may provide a starting point for TDOT's sustainability education effort.

TDOT may want to develop in-house sustainability education curriculum in order to raise TDOT personnel awareness of sustainability actions; develop consistent educational materials and in-house educational methods; empower their employees to integrate sustainability designs into TDOT projects and provide a model for MPOs and other organizations to follow with related training.

One quote offers a clear understanding of barriers to sustainability: "*At times educational disciplines and work environments do not encourage the inclusion of sustainability aspects into a final product or deliverable. Difficulty may arise because these aspects are often not quantifiable and require abstract thinking to understand their long-term benefits.*"

6.2.2 Establish Work Groups

During the March 2018 meeting, a number of division directors mentioned the need to establish a series of work groups to study:

1. Public Transit;
2. Connected and Automated Vehicles;
3. Fleet Management, and
4. Smart Communities

In this context, the TDOT work group would include not only interested parties, but also individuals with a working knowledge or some expertise in the subject area. These groups would achieve a series of specific goals based on objectives to be achieved. These groups would be domain-specific and focus on discussion or activity around a specific subject area.

6.2.2.1 Public Transit Work Group

The Public Transit Work Group studies statewide challenges facing aspects of public transit. Most importantly, the group will purposefully integrate solutions to the issues of mobility, sidewalks, street maintenance and planning, public safety at intersections and traffic management into the statewide transportation plan.

The Massachusetts Department of Transportation has created a transit work group with the following responsibilities. The final work group document Transit Work Group: A documentation of existing issues, barriers and recommendations can provide a starting point for the TDOT Public Transit Work Group. The work group performed the following tasks:

- Cataloged existing barriers, either organizational, legislative or past practice, that detracted from the MassDOT common goal and mission;
- Recognized cultural difference and how these differences affect use of public transit;
- Identified issues and barriers are that were actionable, either by changing business process, policy or legislation;
- Reviewed the barriers and recommend specific and detailed remedies;
- Developed and implemented a detailed, realistic action plan, and
- Provided regular joint updates to stakeholders during development.

Though the MassDOT report provides a good starting point for TDOT's own work group, it does not add elements of sustainability within the recommendations. TDOT may want to do this. The Office of Sustainability at Indiana University (http://sustain.iu.edu/) has developed an online Work Group who are integrating sustainability into campus transit. Though this represents a small geographic region when compared to the TDOT working group, some of the goals can be modified and used. The goals for the campus work group are to "promote a sustainable transportation system that will provide safe access and mobility for students, faculty, staff and visitors, and to ensure that individuals have a broad range of safe and convenient transportation options to walk, bicycle, carpool, or ride public transit to and around campus." The objectives are to:

- Reduce single occupancy vehicles on campus by 20 percent.
- Integrate sustainability into the Campus Master Plan.
- Collaborate with the City and County to develop better routes for pedestrians and bicyclists to get into campus.
- Encourage more car- or van-pooling for those that live outside the city, by using a combination of effective transit alternatives and pricing incentives (e.g. higher cost for parking).
- Examine the expansion of the bus system to cover some of the major population areas outside of the city.

Various members of their working group include campus Capital Planning and Facilities Vice President, Parking Services, Bicycle and Pedestrian Coordinator, Motor Pool, and various faculty members. The efforts by the Indiana University could assist TDOT in outlining the persons involved in and goals of their own working group.

6.2.2.2 Connected and Automated Vehicles Work Group

The Working Group on Connected and Automated Vehicles (CAV) can include deployment support, signal phasing and timing, education and outreach, coordination with other committees and national organizations, monitoring emerging technologies and coordinate evaluation, management of CAV-related assets, and performance measures. The group works to cooperatively pursue projects and other activities that are best accomplished through partnerships between multiple agencies, companies, universities, and other organizations and that ultimately advance Tennessee's leadership position in connected and automated vehicle research, deployment, and operations to benefit the state. CAV deployment is a complicated issue and may require sub-groups within the work group and working with external partners such as TennSMART (see more on TennSMART below).

Infrastructure changes will be needed for facilitate the use of CAVs: Some elements, such as traffic signal interfaces or roadside equipment to send infrastructure information or to receive messages broadcast from vehicles, are unique to state and local DOT interests. Communications will take place vehicle to vehicle (V2V) and vehicle to communication infrastructure (V2I), i.e., integrated data exchange.

The specific milestones anticipated by National Highway Transportation Safety Association include the Issue regulation mandating V2V technology by 2018; the beginning of a phase-in period for new car production in 2019, and by 2021, the integration of V2V technology included on 100% of new car production. Throughout it all, there will be a mixture of old and new technology during transition.

Consider communications infrastructure as transportation infrastructure. Transportation agencies will also need to grapple with the communications infrastructure required by the connected portion of CAV technology. This includes identifying how agencies will ensure CAVs have timely, accurate information about construction, detours, and other road hazards. It also includes monitoring the evolution of intersection design and signalization infrastructure.

Michigan Department of Transportation (MDOT) provides one example of a well-organized CAV working group. The Michigan Connected and Automated Vehicle Working Group is a part of the Center for Automotive Research (CAR) (www.cargroup.org). CAR coordinates a quarterly Connected and Automated Vehicle (CAV) working group on behalf of the Michigan Department of Transportation (MDOT). The group works to cooperatively pursue projects and other activities that are best accomplished through partnerships between multiple agencies, companies, universities, and other organizations and that ultimately advance Michigan’s

leadership position in connected and automated vehicle research, deployment, and operations to benefit the state and our industry (automotive and more) and enhance safety and mobility in Michigan and beyond. This CAV working group is one of the first in the United States and can offer valuable guidance for TDOT's CAV working group.

6.2.2.3 Fleet Management Work Group

Fleet management is the management of commercial motor vehicles such as cars, vans, trucks, specialist vehicles (such as mobile construction machinery), and trailers, as well as private vehicles used for work purposes (the 'grey fleet'), aviation machinery such as aircraft (planes and helicopters), ships and rail cars. Management includes a range of functions, such as vehicle financing, vehicle maintenance, vehicle telematics (tracking and diagnostics), driver management, speed management, fuel management and health and safety management. The goal is to minimize the risks associated with vehicle investment, improving efficiency, productivity and reducing their overall transportation and staff costs while increasing fleet sustainability.

The US Department of Energy (www.energy.gov) provides an example of a Federal Fleet Management working group. The Federal Energy Management Program (FEMP) helps the federal fleet community access the latest information, applications, and resources related to fleet efficiency. FEMP provides guidance and assistance to help agencies implement federal legislative and regulatory requirements mandating reduced petroleum consumption and increased alternative fuel use.

The INTERFUEL Working Group helps federal fleets meet alternative fuel, efficient vehicle, and petroleum reduction goals. The Interagency Committee on Alternative Fuels and Low Emission Vehicles (INTERFUEL) working group was established in 1991 to help federal agencies share fleet management best practices. INTERFUEL focuses on the addition of alternative fuel vehicles into federal fleets as well as other vehicle technologies, online fleet tools, and management case studies.

INTERFUEL serves as a forum where federal agencies analyze and resolve issues, coordinate implementation, review reporting requirements, and discuss policies and programs affecting federal fleets. The INTERFUEL committee plays a central role in implementing legislation, executive orders, and new policies designed to improve federal fleet management. INTERFUEL can provide resources for TDOT's Fleet Management working group.

6.2.2.4 Smart Communities Work Group

Smart Communities Guidebook, developed by the State University of San Diego describes a Smart community as "a geographical area ranging in size from neighborhood to a multi-county region whose residents, organizations, and governing institutions are using information technology to transform their region in significant ways. Co-operation among government, industry, educators, and the citizenry, instead of individual groups acting in isolation, is preferred. The technological enhancements undertaken as part of this effort should result in fundamental, rather than incremental, changes" (Lindskog 2004). Figure 19 shows schematically a model for the holistic view on Smart Communities (Lindskog 2004):

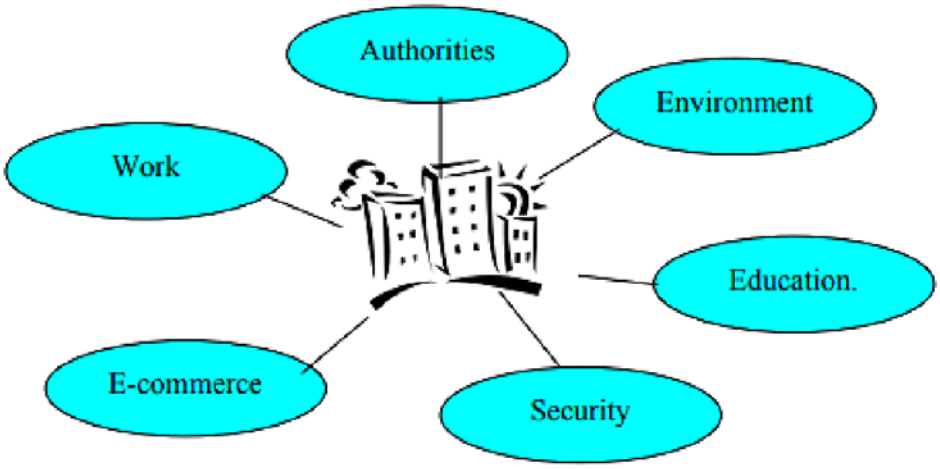


Figure 19: Holistic View of Smart Communities

The **Smart Cities Council** (https://smartcitiescouncil.com) could prove to be a significant resource for TDOT's Smart Cities Working Group. Smart Cities is an international consortium of leading companies advised by top universities, laboratories and standards bodies. The goal of Smart Cities is to make the vision of a world where digital technology and intelligent design have been harnessed to create smart, sustainable cities with high-quality living and high-quality jobs into a reality. The Smart Cities Council provides a combination of advocacy and action, including:

Readiness Guides: High-level models and metrics against which cities can measure their progress. Our Readiness Guides answer the questions "Where does our city rank now?" and "What should we work on first?"

Financing templates and case studies: Guidance for emerging financing models, some of which combine public, private, philanthropic and development sources.

Policy frameworks and case studies: Examples of policies that promote economic development while also safeguarding citizens.

Visibility campaigns: Coordinated, joined-voices initiatives to help citizens understand that smart cities represent a path to a better future. These campaigns include awards, events, publishing and research.

Regional networking events: High-level, invitation-only events where cities and their citizens can learn directly from some of the world's top experts in the many disciplines that combine to create a smart city.

Membership is free. Members have access to news (i.e. Online publication, email newsletter, social media feeds), information (i.e. Web portal, online library, presentations from past conferences, reduced fee for research studies), and networking (i.e. Invitations to private networking receptions regionally, reduced fee to events, access to invite-only LinkedIn Group). The group also offers Smart Cities Readiness Challenge Grants – one of which has been won by the State of Virginia's Smart Cities Working Group. Each year, the Smart Cities Council donates coaching, workshops, products, services and more free benefits to five communities in North America.

Another resource is the **National Institute of Standards and Technology** (NIST - www.nist.gov). NIST has created the International Technical Working Group on IoT-Enabled Smart City Framework. This working group has completed a preliminary report address the two barriers that currently exist to effective and powerful smart city solutions. First, many current smart cities ICT deployments are based on custom systems that are not interoperable, portable across cities, extensible, or cost-effective. Second, a number of architectural design efforts are currently underway (e.g. ISO/IEC JTC1, IEC, IEEE, ITU and consortia) but have not yet converged. TDOT's working group on Smart Cities could benefit by becoming a member of the Smart Cities Council and contacting the National Institute of Standards and Technology.

6.2.3 Raise Sustainability Awareness Internally

At TDOT, the most frequently cited barriers to sustainability mentioned by division directors included low awareness of potential and/or existing programs, policies and procedures; the cost of implementation and legislative or regulatory prohibitions. The directors who selected "Other" were asked to clarify their responses. The results indicate some reasons that could be managed directly by TDOT.

These include an individual or generalized resistance to change if there is not a clear understanding of the reason for the protocol change. Another barrier concerns the unfavorable concept of what constitutes "Sustainability" as the term is not well-understood and not well-defined, as well as a lack of knowledge regarding the applicability of sustainable practices to the specifics of projects. There is a need for TDOT to integrate into a new way of looking at the business of the DOT – to focus on the management and operations of the facilities as well as traditional road building. Engaging employees in sustainability is a growing trend with significant benefits. Many departments of transportation are pursuing a variety of different initiatives but have to reach a tipping point where sustainability embeds itself into transportation culture – Not considered something "else" that needs attention.

The New York State Department of Transportation (NYSDOT) provides a good example of its effort to raise sustainability awareness internally. NYSDOT has shown its commitment to improving the quality of the transportation infrastructure in ways that minimize impacts to the environment, including the depletion of irreplaceable resources. To recognize transportation project designs, operations and maintenance practices that incorporate a high level of environmental sustainability, NYSDOT is implementing “GreenLITES” (Green Leadership in Transportation Environmental Sustainability),” a transportation environmental sustainability rating and awareness program. GreenLITES is tasked with recognizing and increasing the awareness of the sustainable methods and practices that are already incorporated into project designs and daily operations, as well as any new practices.

To assist in awareness, GreenLITES has established a project self-certification program that distinguishes transportation projects and operations based on the extent to which they incorporate sustainable choices. It is primarily an internal management program for NYSDOT to measure performance, recognize good practices, and identify where improvements are needed. TDOT could replicate this program internally as well. Additionally, GreenLITES provides the department with a way to demonstrate to the public how it is advancing sustainable practices. This raises awareness outside of the department of transportation. NYSDOT project designs and operations are evaluated for sustainable practices and based on the total credits received; an appropriate certification level is assigned. The rating system recognizes varying certification levels, with the highest level going to designs and operational groups that clearly advance the state of sustainable transportation solutions. The NYDOT provides a strong example of how TDOT could raise sustainability awareness both internally and externally.

6.2.4 Integrate Outcome Measurements

In March 2018, six division directors mentioned the need and reliance on public feedback to determine if a project is successful or not, but that there was no formalized method to receive, document and measure this feedback. The requirement for a well-defined and consistent methodology to measure or monitor the eventual outcomes of the sustainability programs and policies can provide a basis for program modification.

When analyzing the ability to include outcome measurements for public feedback, two elements need to be in place: 1) a well-defined method of capturing public feedback, and 2) a method for categorizing or if possible, quantifying the feedback so that program or policy changes can take place.

Typical public hearing requirements are required for federally funded and non-federally funded projects. Public hearings are required for federally funded major transportation improvements, generally prior to a decision point. All Environmental Impact Statements (EISs) require public hearings. A public hearing or an opportunity for a public hearing is required for Environmental Assessments as well. The primary difference between a public meeting and a public hearing is the flexibility that public meetings can employ versus the scripted nature and set standards of a public hearing. Documentation of public involvement activities is critical to measure successes and demonstrate federal and state compliance for public involvement. However, integration of public feedback into a project is not federally or state mandated.

TDOT has the flexibility in its use of public feedback. Conducting meaningful public involvement involves seeking public input at specific and key points in the transportation decision-making process (ADOT 2017). Public feedback should involve not only mandated meeting requirements, but also online and other efforts (e.g. mail, telephone, email, project website, TDOT social media sites, In-person interviews, and online surveys and forms) at specific points or times in the process.

Arizona Department of Transportation tags feedback in the following way:

1. Date – This is important for documenting the evolution of the project. It also establishes a benchmark for a timely response.
2. Comment – It is important to document the comment so a sufficient response can be developed and to understand potential trends that could emerge. All comments provided by members of the public should be documented as such (e.g., provided by a member of the public).
3. Name, address, telephone number and email address – This information is optional and is often redacted within reports or summaries but is valuable information to obtain for the life of the project.
4. Nature of comment – This data will allow for easy categorization of comments

Categorizing the feedback can take many forms that depend on project stage and the types of questions asked (Townsend 2018). Feedback can be categorized based on:

General Feedback Type – Is the feedback actionable or is the feedback an angry rant with no logic? TDOT personnel may want to concentrate efforts on feedback that is actionable.

Prompted or Unprompted Feedback - Unprompted feedback deserves special attention. The public feedback that is not prompted means that an issue is apparent – one of which TDOT may be completely unaware. TDOT may be more likely to hear the out-of-nowhere issues via unsolicited feedback or from open-ended survey questions rather than, say, a survey with multiple choice answers. However, people are generally motivated to provide unsolicited feedback if they have an extreme experience or problem.

Feedback Volume – If the majority of feedback is input at a certain date in the project process, this may provide TDOT with input on whether or not that part of the project should be changed. The overall volume of feedback about a single issue relative to other issues matters. It will also protect TDOT from "recency" bias, where the public assumes things, they hear recently have the greatest importance.

Repetitious Feedback – Public feedback that refers to a specific issue over time may indicate that TDOT may need to re-evaluate a core task or a basic process. The repetitious feedback may be something TDOT has become immune to ("Oh we've heard that for years") and has become trite or a dull background whine. Either way, this kind of feedback is really worth listening to, especially when it relates to project quality, environmental issues or difficulty.

Feedback Characteristic – Characteristics of the person giving the feedback can help in categorizing feedback type. Feedback can be categorized based on geographic region (i.e. address), type of feedback (e.g. verbal, and email) or date of feedback, which may provide a link to the project stage at which the comment was made.

Public feedback can provide both quantitative and qualitative results. The major quantitative public input methods include well-defined surveys and forms, whereas the common qualitative public input methods could include interviews, public hearings and comment review. Text mining may prove beneficial when there are multiple qualitative comments. Regardless of methods used to solicit public feedback, the purpose of obtaining feedback is to improve the project or situation in a way makes for sound and logical policy, procedure or process.

6.2.5 Provide Planning to Practice Methods

Planning to integration is part of best practices found in the "Best Practices Applied to TDOT" section of this report. A framework was used to identify specific projects that are easy to implement for each division. A generalized implementation strategy for a TDOT project is found below (IPMI 2013).

In the public sector, one of the main reasons projects fail is that implementation strategies are not thought through completely. Until implementation occurs a project remains an investment of resources. Any type project realizes its full value only when deployed successfully and consistently. As all projects have a different set of goals and challenge that they need to overcome when deciding upon an appropriate implementation strategy. General guidelines for an implementation process are provided (IPMI 2013).

General Project Implementation Rules:

- Be clear on the outcomes for the project;
- Build on the experience of implementing previous projects, but do not necessarily replicate the approach;
- Recognize that different approaches may be required if the project or change in project is mandatory or optional;
- Complement rather than replicate local resources;
- Promote early wins so TDOT personnel and the public see evidence of improvement or benefit quickly;
- Learn from both sceptics and enthusiasts to provide a balanced approach;
- Collect and respond to feedback including time for making changes in plan; respond viably.
- Adopt an implementation strategy that is sustainable;
- Anticipate and be prepared for end user expectation, pitfalls and real-life challenges.

Process to Assist TDOT in Project Implementation:

Step 1: Profile the Project – describe publicly the type of change the project will deliver across the state. Include the factors of sustainability – environmental, societal, and economic. TDOT will need to answer in some detail the following questions (IPMI 2013):

- What project or change is being implemented?
- What will the project or change look like?
- What will the impact of the project or change be?
- How different will the project or change be from the current situation?
- How many people are directly impacted by the project or change?
- When does the project or change need to happen by and is there a deadline?

- What is the level of risk and the potential for things to go wrong if the project or change is implemented?
- What additional community support systems are required for project or change delivery?
- How well defined is the solution or the problem requiring the project or change?
- Is further change to the solution likely?
- How important is quality of the solution?
- How complicated is the change from status quo to new solution for the user?

Step 2: Decide and justify the approach. Using the project profile from Step 1, TDOT should consider how the project or change fit in with existing policy, procedure and programs or fit in to any future changes. TDOT could justify a project or change by:

Rational Justification - By using a rational scenario, TDOT can present a by-the-numbers case for change. TDOT can demonstrate its analysis, detailed cost-benefit projections, and examinations of all the alternative options. By asking the public to look at the numbers, TDOT is asking to public to support a project or change based on sound data and logical projection; however, some will always argue with the calculation and challenge any assumptions (Bacharach 2013).

Best Practices Justification - By making the case that "Everyone is doing it" may seem simplistic, but it is often a very sensible justification there is a lack of time or resources to experiment with an array of alternatives (Bacharach 2013). This approach shows that a project or change has already been used by someone else (a.k.a. Best Practices), and that results are predictable. Critics of the best practices approach may identify parameters that are different from those being mimicked.

Regulation Justification - Laws or regulatory changes occasionally require TDOT to implement a new project or change a project, its processes or the way it operates. TDOT can use these regulations to justify changes. With regulation, there is a strong third-party mandate for change, and TDOT can easily obtain the information about rules and regulations. Unfortunately, mandated regulations do not always translate into effectiveness (Bacharach 2013).

Standards Justification - While regulations provide an explicit measure to justify change, standards expectations provide implicit reasons for change. When TDOT uses the standards justification, it is stating that the project or change is "expected" of it by the public, government, etc. This justification suggests that if TDOT does not do something, it will be at a disadvantage, and that by doing something, beneficial results are more likely to happen. However, this approach may not be beneficial to the bottom line. Critics can claim the costs are too high and the change is basically unnecessary.

Step 3: Describe what will be required. TDOT will need to consider a number of practical elements to ensure a complete understanding of the implementation approach. Critically this step will also help TDOT ensure it is able to have access to appropriate resources (IPMI 2013). The following checklist can be used to make sure the project or change is ready implementation. The list will include the following items:

- Resources required for the implementation and when the implemented project or change will represent "business as usual";
- Roles and responsibilities of all personnel;
- Level of flexibility in the implementation approach at a local, regional, state and federal level;
- A list of actions or items that can change;
- A list of actions or items that cannot change:
- Names of all stakeholders, municipal leaders, TDOT personnel, etc. who need to be involved;
- The relationship of this project or change with other projects;
- Measures of progress and reporting requirements;
- Communication requirements;
- Training requirements;
- Key milestones;
- Timeframe;

The above represents one general planning to practice or implementation method. The implementation strategy can help TDOT to develop a realistic project plan that will address the needs of the key stakeholders who will be affected by the proposed project or change. The goal is to cause minimal disruption throughout the implementation.

6.3 Summary

The Next Steps outlined in Chapter 6.0 provide a roadmap for the actions TDOT could take to integrate sustainability practices consistently across all divisions. These actions are categorized as developing policies that provide greater clarity on sustainability issues and core strategic actions that can be taken. This means developing a definition of sustainability; identifying specific best practices to be integrated into TDOT programs; designating a sustainability practice lead, who could develop in-house and new hire training and raise awareness of sustainability, thus creating a solid link between planning and practice. The formalization of collaboration and current sustainability practices, as well as the creation of working groups and integration of outcome measurements was also discussed. Other next steps include partnering with non-governmental organizations and securing outside support.

7.0 HIGH IMPACT STRATEGIES

In 2017, the U.S. Department of Energy Vehicle Technologies Office created the Energy Efficient Mobility Systems Program in order to understand the impact technologies are having and will have on the range of mobility options available. The Energy Efficient Mobility Systems Program seeks to understand the future that could result from these technologies and services, and to create solutions that focus on analytical research in order to understand the impacts that new mobility technologies and services will have at the vehicle, traveler, and overall transportation system-level (USDOE 2017). This report reviews a number of high impact technologies and strategies, including connected and automated vehicles (CAV) such as truck platooning and passenger vehicle CAV technologies, alternative fueled vehicle infrastructure, complete streets and transportation demand management techniques.

7.1 Connected and Automated Vehicles (CAV)

Connected and automated vehicles fall under the umbrella of intelligent transportation systems, which is the application of advanced information and communications technology to surface transportation to achieve enhanced safety and mobility. Connected vehicles essentially "talk" to infrastructure and other vehicles electronically, and automated vehicles take connected technology a step further by eliminating the need for full-time human driver (USDOT 2018).

Communication takes place between vehicles (vehicle to vehicle (V2V)) or between the vehicle and infrastructure (V2I). V2V would allow vehicles to use dedicated short-range communication (DSRS) and an on-board or in-vehicle unit to communicate data with each other automatically about position and speed, so that every vehicle on the road is aware of where other nearby vehicles are. V2I is similar in that it uses a wireless system, but V2I communicates with equipment located roadside, such as mounted at interchanges, intersections, and other locations (e.g. petrol stations) providing the interface to vehicles within their range. Additionally, is newer vehicle to cloud (V2C) technology, which combines connected navigation, social media, music streaming, etc. as well as, vehicle to pedestrian (V2P) communication modeling, and vehicle to everything (V2X) communication which is the passing of information from a vehicle to any entity that may affect the vehicle, and vice versa.

U.S. highway users wasted 6.9 billion hours stuck in traffic in 2014, according to the Texas Transportation Institute. Connected vehicle mobility applications will help drivers navigate the roads more efficiently, as well as help system operators improve the operation of the nation's transportation system, reducing congesting, travel delay, and overall mobility.

Automated vehicle technology references automated driving levels 0 to 5, which each level representing the tasks the driver must undertake. For example, in Level Zero, there is no automation; the driver performs all operating tasks like steering, braking, accelerating or slowing down, etc. At Level One, there is some driver assistance. At this level, the vehicle can assist with some functions, but the driver still handles all accelerating, braking, and monitoring of the surrounding environment. At Level Two, there is partial automation, where the vehicle can assist with steering or acceleration functions and allow the driver to disengage from some of their tasks. This includes crash avoidance technologies, like blind spot monitoring, lane departure warning, and forward collision warning. However, the driver must always be ready to take control of the vehicle and it still responsible for most safety-critical functions and all monitoring of the environment. At Level Three, there is conditional automation, where the vehicle controls all monitoring of the environment (using sensors like LiDAR). The driver's attention is still critical at this level but can disengage from "safety critical" functions like braking and leave it to the technology when conditions are safe (USDOT 2018). At Level Four, there is high automation. The vehicle is capable of steering, braking, accelerating, monitoring the vehicle and roadway as well as responding to events, determining when to change lanes, turn, and use signals. At Level Four, the automated driving system would first notify the driver when conditions are safe, and only then does the driver switch the vehicle into this mode. It cannot determine between more dynamic driving situations like traffic jams or a merge onto the highway (USDOT 2018). Finally, at Level Five, there is complete automation, which requires no human attention.

There were 5.6 million crashes in 2013, according to NHTSA. The number of fatalities from vehicle crashes is falling but still accounted for 32,719 deaths. Automated vehicle safety applications will give drivers the tools they need to avoid potential crashes and significantly reduce the number of lives lost each year.

7.1.1 CAVs in Tennessee

In Tennessee, there are at least five barriers facing the connected cars of the future (Bansal 2017). These barriers include: (1) Trust of CAV technology with regards to safety, which is a major concern for future adopters of CAV enabled vehicles, as these vehicles are still being tested; (2) Data ownership and privacy standards and controls, which includes the digital security of connected vehicles an individual rents or uses in car-sharing services and the monetizing of data collected through connected vehicles with abilities like targeted ads and services; (3) Constructing the digital-physical infrastructure and communications systems, which will include developing and deploying standards that facilitate communications between cars, roadways, intersections, construction zones, travel apps, and more elements of the day-to-day driving experience. Currently, the National Highway Traffic Safety Administration and

the U.S. Department of Transportation are working on vehicle-to-vehicle and vehicle-to-infrastructure standardization. (4) Connected Car Security, which means making sure the mechanisms within the vehicle that control steering, gas, brakes, and more cannot be remotely hacked. General Motors and others have formed the Auto Information Sharing and Analysis Center, which is a vulnerability-sharing consortium that organizes information to educate automakers (Bansal 2017), and (5) Standardization of communication and connectivity, which means the standardization of everything from the operating systems for the cameras and sensors that enable vehicle-to-infrastructure connectivity to the infotainment systems that double as navigation and communication hubs. The State of Tennessee is currently involved in various CAV projects to address these barriers, including the development of Signal Phase and Timing Corridors, CAV Legislation, TennSmart Consortium (see below) and other partnerships.

7.1.1.1 Signal Phase and Timing Corridors

To foster CAV technology, the American Association of State Highway and Transportation Officials (AASHTO) Connected Vehicle (Signal Phase and Timing) SPaT Deployment Challenge was initiated. The SPaT challenge encouraged state and local public-sector transportation infrastructure owners and operators to cooperate together to achieve deployment of Dedicated Short Range Communications (DSRC) infrastructure with SPaT broadcasts in at least one corridor or network (approximately 20 signalized intersections) in each of the 50 states by January 2020. As of June 2018, 32 states have committed to the challenge. In Tennessee, as seen in Figure 20 the City of Knoxville is leading the way in preparation for full deployment of CAV technology (Table 63). Perhaps a TDOT working group would be able to encourage participation of other metropolitan areas in the SPaT Challenge, as Knoxville is the only Tennessee community actively engaged in the challenge.

Figure 20: Knoxville SPaT Challenge

Table 63: Tennessee Metropolitan Areas Participating in AASHTO SPaT Challenge

Location	Description
(A) Knoxville: SR 1 from Hayfield Road to Neyland Drive	147 ATC Signal Controllers capable of SPaT data output to cloud connect services broadcasting SPaT data to various 2017 brand CAV.
(B) Knoxville: SR 169 from Joe Hinton Road to 21st Street	147 ATC Signal Controllers capable of SPaT data output to cloud connect services broadcasting SPaT data to various 2017 brand CAV.
(C) Knoxville: SR 71 from Blount Avenue to Majestic Grove Road	147 ATC Signal Controllers capable of SPaT data output to cloud connect services broadcasting SPaT data to various 2017 brand CAV.
(D) Knoxville: SR 33 from Colonial Circle to Depot Street	147 ATC Signal Controllers capable of SPaT data output to cloud connect services broadcasting SPaT data to various 2017 brand CAV.
(E) Location: Cumberland Ave / UT Campus Area	DSRC at 1 signalized intersections currently broadcasting and expanding to 17 signalized intersections for broadcasting SPaT data messaging to vehicles

7.1.1.2 CAV Legislation

As the technology for automated vehicles continues to develop, and infrastructure is being prepared, it is necessary for state and municipal governments to address the potential impacts of these vehicles on the road. The number of states considering legislation related to automated vehicles has increased. Since 2012, at least 41 states and Washington D.C. have considered legislation related to automated vehicles, including Tennessee.

Tennessee Senate Bill 151 was passed in June 2017. It authorizes the operation of automated vehicles on the public roads of Tennessee, provides for related requirements, including insurance requirements. With the passing of the bill, the terms driver and operator now include the "automated driving system (ADS)-operated vehicle and when the context requires, the ADS when the ADS is engaged". Automated driving system or ADS is defined as:

> *. . .technology installed on a motor vehicle that has the capability to drive the vehicle on which the technology is installed in high or full automation mode, without any supervision by a human operator, with specific driving mode performance by the automated driving system of all aspects of the dynamic driving task that can be managed by a human driver, including the ability to automatically bring the motor vehicle into a minimal risk condition in the event of a critical vehicle or system failure or other emergency event . . .*

An ADS-operated vehicle may drive or operate on streets and highways in this state with the ADS engaged without a human driver physically present in the vehicle if the vehicle meets the following conditions:

- If the vehicle has been, at the time it was manufactured, certified by the manufacturer as being in compliance with applicable federal motor vehicle safety standards;
- The vehicle is capable, in the event of a failure of the automated driving system that renders that system unable to perform the entire dynamic driving task relevant to its intended operational design domain, of achieving a minimal risk condition;
- ls registered in the state, the vehicle is identified on the registration as an ADS-operated vehicle; and
- The vehicle is covered by primary automobile liability insurance in at least five million dollars ($5,000,000) per incident for death, bodily injury, and property damage. . .

The complete bill can be found in Appendix C.

7.1.1.3 TennSMART Consortium and other Partnerships

The TennSmart Consortium is a group of 20 public and private partners across the state to accelerate the development and deployment of intelligent mobility innovations in Tennessee and to advance the state's role in the adoption of CAV technologies. These technologies include smart infrastructure, wireless on-the-go charging, cybersecurity and more (Deese 2018). The founding members are:

- Bridgestone Americas
- Cummins Filtration
- DENSO Manufacturing Tennessee
- FedEx Corporation
- GRIDSMART Technologies
- Local Motors
- Lyft
- Miovision
- Nissan North America
- Oak Ridge National Laboratory
- Stantec Consulting Services
- Tennessee Department of Environment and Conservation
- Tennessee Department of Labor and Workforce Development
- Tennessee Department of Transportation (TDOT)
- Tennessee Technological University
- Tennessee Valley Authority
- Top Five Inc.
- University of Memphis
- University of Tennessee
- Vanderbilt University

Providing opportunities for collaboration between agencies, private sector and academia, TennSMART (http://tennsmart.org/) research and development is focused on the following:

- Connected and automated vehicles – Leveraging high performance computing, data science, and advanced sensors and communications protocols to develop technologies and algorithms for vehicle-to-vehicle and vehicle-to-grid interactions that enable smart

routing, alleviate congestion, improve safety, and increase the efficiency of the entire transportation system

- Electric vehicles – Advancing wireless charging technologies that allow vehicles to charge on the go, to automate the charging process, and to share energy back and forth between vehicles, buildings, and the grid for maximum energy savings and convenience

- Cybersecurity – Developing systems and technologies that validate the trustworthiness of messages from vehicles and the infrastructure, address identity and privacy needs, and explore best paths to provide the computing power necessary in a connected world

- Freight efficiency – Exploring new paradigms in freight transport including the development of hybrid electric heavy-duty powertrains, truck platooning technologies, automated multimodal freight delivery, and unmanned aerial systems

- Multimodal commuting – Facilitating mode shifting to optimize energy efficiency and convenience in passenger commutes through the development of smart technologies that increase connectivity between various forms of transportation

Nashville – Bloomberg Partnership

Nashville is one of 10 cities worldwide chosen for an automated vehicle initiative launched by Bloomberg Philanthropies in New York and the Washington, D.C.-based Aspen Institute. The others are Austin, Buenos Aires, Argentina, Helsinki, London, Los Angeles, Paris, São Paulo, Tel Aviv and Washington D.C. The program, called the Bloomberg Aspen Initiative on Cities and Automated Vehicles, gives Nashville an edge in self-driving advances by supplying access to data and coaching from urban planners and other experts in order to help prepare the city for self-driving cars and how to use those cars to address transit issues.

According to their website (https://www.bloomberg.org/program/government-innovation/bloomberg-aspen-initiative-cities-autonomous-vehicles/), in October 2017, Bloomberg Philanthropies released its Global Atlas of Autonomous Vehicles in Cities. The atlas is a comprehensive, first-of-its kind map that shows how city governments around the globe are preparing for the transition to autonomous vehicles. The project highlights cities working towards the transformation to a driverless future by hosting industry tests, organizing their own pilots and developing proactive policies and plans. Tracking 120 cities as of December 2018, this Atlas is the world's first inventory of how cities around the globe are preparing for the transition to a world with AVs. Results indicated that about 50% of cities have been working on AV technology infrastructure and integration for 12-36 months, nearly every city indicated interest in using AVs for last-mile solutions (i.e. gaps in public transit), cities suffer from roadblocks in the form of other levels of government, and both North America and Europe have an equal number of pilot projects underway, with concentrations of activity in the Netherlands, Scandinavia, the United Kingdom, and the United States.

7.1.2 Large Truck Platooning in Tennessee

As of April 2017, vehicle platooning became legal in the State of Tennessee (TDOT 2018). Platooning is linking two or more vehicles in a convoy using wireless communications and sensor technology. However, in order to operate a platoon, notification must be given to TDOT and the Tennessee Department of Safety. This must include a plan for the general operation of the platoon (TDOT 2018). By law, all commercial motor vehicles must contain a driver-operator with an appropriately endorsed valid commercial driver license and must be present behind the wheel of each vehicle. Each truck in the platoon has a driver, but the trucks following the leader are in automated mode with the exception of steering. Studies show that platooning significantly reduces the drag that each vehicle experiences resulting in less fuel consumption, greater fuel efficiency and less pollution. From a safety standpoint, the constant monitoring and updates among the vehicles in the platoon, estimated at 50 times per second, reduces the impact among vehicles in case of a crash and provides reaction times much faster than humans (TDOT 2018). Tennessee is now one of four states that have passed legislation providing an exemption for platooning from its Federal Trade Commission laws (Deese 2018).

Maintaining the communication between the vehicles is critical, but the loss of signal can and will occur. Thus, platooning trucks are equipped with a secondary system for such instances with systems to handle degradation or loss of communications. If a satellite loses contact, the primary system has a sensing subsystem to maintain spacing until a connection can be re-established. There are other operational systems in place in the event of other failures.

The Tesla Company has unveiled its own all-electric semi, scheduled for rollout in 2019. With enhanced Autopilot, the Tesla Semi features automatic emergency braking, automatic lane keeping, lane departure warning and event recording. Tesla semis can travel in a convoy, autonomously following a lead truck. And they have already been reserved by Wal-Mart, PepsiCo and Anheuser-Busch. Without a trailer, the Tesla Semi achieves 0-60 mph in five seconds, compared to 15 seconds in a comparable diesel truck. It does 0-60 mph in 20 seconds with a full 80,000-pound load, a task that takes a diesel truck nearly 60 seconds. Most notably, it climbs 5 percent grades at a steady 65 mph, whereas a diesel truck maxes out at 45 mph (Deese 2018). In Europe, rigorous tests are taking place with fully automated public road testing expected to happen in 2021.

According to US Office of Energy Efficiency & Renewable Energy, 65 percent of current long-haul truck miles could potentially be platooned, reducing total truck fuel consumption by 4 to 10 percent. In 2014, 3,852 people died in large truck crashes in 2015 –about 70% were occupants of cars and other passenger vehicles. Truck platooning with vehicles in automated modes could reduce the number of accidents.

7.2 Alternative Fuel Vehicle Infrastructure in Tennessee

In 2017 the U.S. Department of Energy (DOE) Vehicle Technologies Office (VTO) created the Energy Efficient Mobility Systems (EEMS) Program to understand the impact technologies are having and will have on the range of mobility options available. EEMS was created to understand the future that could result from these technologies and services, and to create solutions that focused on analytical research to understand the impacts that new mobility technologies and services will have at the vehicle, traveler, and overall transportation system-level (USDOT 2017). Several high impact technologies and strategies were reviewed within this report, among them were alternative fueled vehicle (AFV) infrastructure.

Alternative Fuel Vehicles Infrastructure in Tennessee

Currently, as seen in Table 64, the State of Tennessee has 653 stations with access to alternative fuels (AFDC 2018). Alternative fueling stations are used by a variety of AFV vehicles, including plug-in electric vehicles (PEVs), and vehicles using biodiesel, ethanol, natural gas, propane, etc. The trend of U.S. alternative fueling stations by fuel type from 1992 to 2018 illustrates that propane stations were the most numerous until 2011, when they were surpassed by electric vehicle supply equipment (EVSE) or charging units (AFCD 2018). The growth in EVSE units accelerated starting in 2011, following the 2010 increase of plug-in electric vehicles offered by major automakers. The number of EVSE is expected to increase as the population of electric vehicles continues to grow (AFDC 2018).

Information from the Alternative Fuels Data Center indicates Tennessee is in the top twenty states that have both publicly and privately-owned alternative fueling stations. Tennessee has 560 publicly owned stations and 93 privately owned alternative fueling stations (Table 64). Of these, 21 are biodiesel; 23 are Compressed Natural Gas (CNG); 78 are Ethanol (E85); 455 are electric charging stations; there are no publicly or privately-owned Hydrogen (HY) stations; 5 Liquefied Natural Gas (LNG) stations, and 71 Liquefied Petroleum Gas (LPG) stations. In contrast, California has more than 21,500 publicly and privately-owned alternative fueling stations, and Alaska has 20 (not seen in Table) (AFDC 2018).

Given the current and future growth in plug-in electric and other alternative fueled vehicles, TDOT can encourage the provision of electric charging and alternative fueled infrastructure. As seen in Figure 21, the majority of Tennessee's 560 publicly-accessible AFV stations are located in highly populated areas – near Knoxville, Nashville, Chattanooga and Memphis. In Figure 1, Biodiesel stations are seen as red diamonds; E85 stations are seen as black stars; electric stations are seen as blue triangles; LPG stations are seen as yellow squares; CNG stations are seen as green circles, and LNG stations are seen as orange octagons. Reliable access to public fueling stations is a key component to ensuring that AFVs are a convenient option for consumers and fleets. Limited range, or range anxiety, is a primary concern of those driving AFVs. The following research concentrates on access to public, not privately-owned alternative fuel stations.

Table 64: Public and Private Alternative Fuel Stations

Fuel	Public	Private	Total
Bio-diesel (B20 and above)	7	14	21
Compressed Natural Gas (CNG)	13	10	23
Electric	401	54	455
Ethanol (E85)	69	9	78
Hydrogen	0	0	0
Liquefied Natural Gas (LNG)	1	4	5
Propane (LPG)	69	2	71
TOTAL	560	93	653

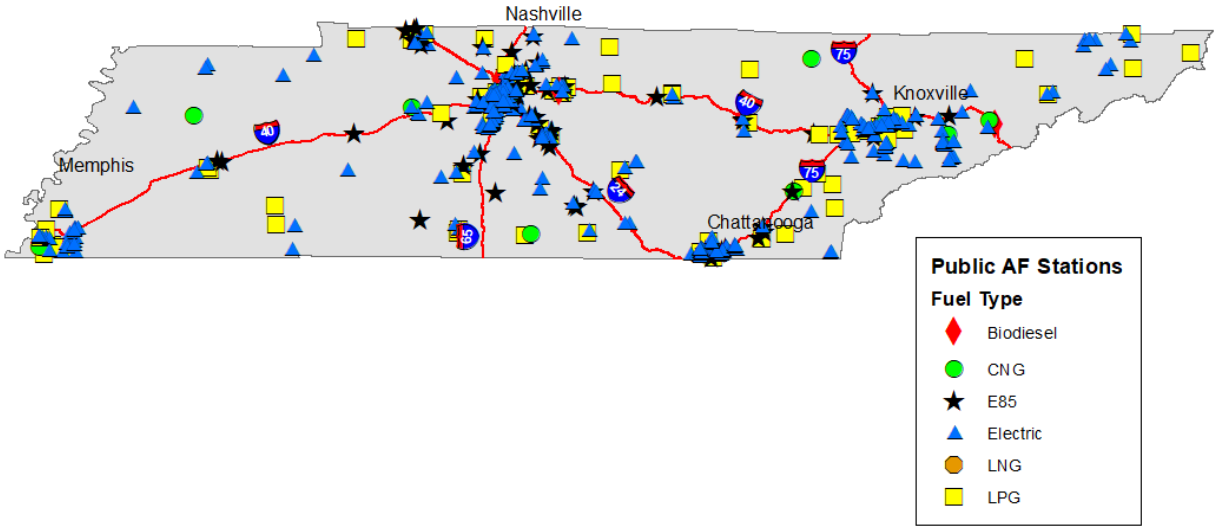


Figure 21: Tennessee Publicly-Accessible Alternative Fueling Stations

7.2.1 Fueling Corridors in Tennessee

There have been several approaches to easing range anxiety and one showing particular promise involves the development of "fueling corridors." Fueling corridors are stretches of highways and roads that are publicly marked as having fueling stations for one or more types of alternative fuels within established distances. Fueling corridors also allow consumers in range-limited vehicles to use their vehicles for long distance trips, rather than just for commuting. In addition to increased access to fueling stations, AFV corridor signage on highways increases public awareness. A few states are already creating intra-state corridors. For example, as part of the 2011 Oklahoma First Energy Plan, Oklahoma set a goal of installing at least one public compressed natural gas (CNG) station every 100 miles along the state's interstate highways. The state met this goal in 2016 (AFDC 2018). In 2015, Nevada completed the Electric Highway in 2016. This highway has plug-in electric vehicle charging stations (each with one DC fast chargers and two Level 2 chargers) on U.S. Route 95 from Las Vegas to Reno (AFDC 2018).

As part of the Fixing America's Surface Transportation (FAST) Act, the USDOT designated 55 national hydrogen, propane, and natural gas fueling, and PEV charging, corridors in strategic locations along major highways in November 2016 (AFCD 2018). The initial group of 55 designated corridors covered 35 states. The corridors were designated as "signage ready," which meant the corridor contained one station approximately every 50 miles for PEV charging stations, 100 miles for hydrogen, 150 miles for propane and CNG, and 200 miles for liquefied natural gas. "Signage pending" corridors mean there is a need for more fueling infrastructure. Accessible stations are those located within five miles of the interstate or highway corridor (AFCD 2018). Tennessee's I-40 corridor plan was submitted in 2016, and in 2017, the Tennessee Department of Transportation submitted documentation to request that I-75, I-24 and I-65 be added to the list of interstates in Tennessee that should be designated "alternative fuel corridors" (TCF 2018).

7.2.2 Current Gaps in Fueling Corridors in Tennessee

Using geographic information system (GIS) software and Manhattan distances, gaps in publicly-accessible stations located on Tennessee's alternative fuel corridors (I-40, I-75, I-24 and I-65) were calculated. All fueling stations within 5-miles of each corridor were extracted and divided based on fuel type. Gaps were identified based on the recommended distance between stations of a specific fuel type (e.g. 50-miles distance between electric charging stations). No distinction was made based on the station operating hours (open 24/7; open during business hours, call ahead for appointment, etc.). Because no recommended distances were recommended for biodiesel or ethanol (E85) stations, gaps could not be calculated.

Interstate 40 Corridor

Interstate 40 spans 455 miles throughout the entire state, from the Arkansas state line to the North Carolina state line. It passes through Memphis, Jackson, Nashville, Cookeville, and Knoxville. Currently there are 238 public alternative fuel stations within five miles of the I-40 corridor. Table 65 identifies the number of fuel stations based on fuel type on the I-40 corridor and the recommended distance between stations.

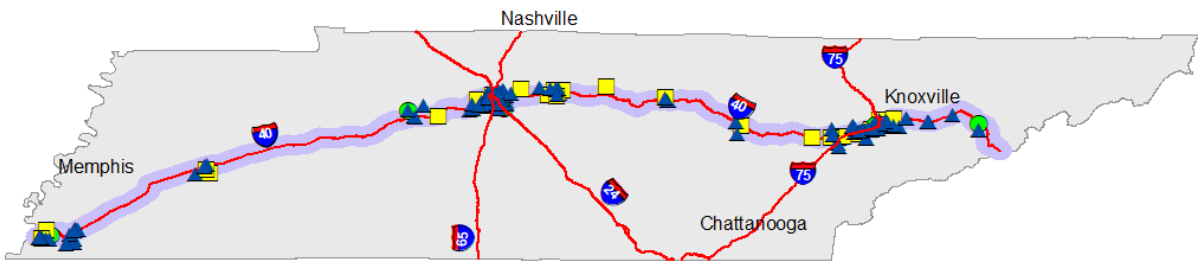


Figure 22: Public Alternative Fuel Stations on the I-40 Corridor

Table 65: Public Alternative Fuel Stations for I-40 Corridor

Fuel Type	# of Stations	Distance (Miles)
Bio-diesel	5	Undetermined
E85	26	Undetermined
Electric	171	50
Hydrogen	0	100
CNG	7	150
LPG	28	150
LNG	1	200
TOTAL	238	

The current location of publicly-accessible electric stations (seen as blue triangles) can be located within five miles of the I-40 Corridor. There are two gaps in the electric stations on the I-40 corridor (Figure 22). There is **62 miles distance** between the stations located at Mckellar-Sipes Regional Airport in Jackson, TN (308 Grady Montgomery Drive) and the station at LaQuinta Inn and Suites in Memphis, TN (2839 New Brunswick Road). Both facilities are public, but the station at LaQuinta Inn are for Tesla customers only. There is **97 miles distance** between Victory Nissan West in Dickson, TN (2219 Highway 46 S), which is a public facility open during business hours only, and Carlock Nissan in Jackson, TN (495 Vann Drive), which is a public facility open during business hours. Users must call ahead. The nearest Arkansas eclectic station to Memphis, TN is at the Walmart Super Center in Forest City (205 Deaderick Road), which is 45 miles distance. The nearest North Carolina eclectic station to the one in Newport, TN is one at the Haywood Community College in Clyde, NC (185 Freedlander Drive), which is 50 miles distance.

The current location of publicly-accessible compressed natural gas (CNG) stations (seen as neon green circles) located within five miles of the I-40 Corridor indicates there are is one pair of CNG stations that are located more than 150 miles distance. There is **180-mile distance** between the CNG stations located at Piedmont Natural Gas in Nashville (541 Spence Lane) and Knoxville Utilities Board (1820 Third Creek Road). Both are open 24/7. The nearest North Carolina CGN station to the AmpCGN station in Newport, TN (1130 W Highway 2570) is one at PSN Energy Asheville, NC (15 Overland Industrial Blvd), which is 72 miles apart. The nearest Arkansas CGN station from Memphis is one in Forest City, 45 miles distance.

The current location of liquid petroleum gas (LPG) stations (seen as neon yellow squares) indicate there are no pair of LPG stations that are located more than 150 miles apart on the I-40 corridor. However, the nearest out-of-state LPG station to the U-Haul in Millington, TN (7910 Highway 51 N) is Red Baker Propane in Oklahoma City, OK (9005 S Sunnylane Road), which is **480 miles distance**. The nearest North Carolina LPG station to the one in Knoxville, TN is 120 miles distance in Asheville, NC.

The current location of publicly-accessible liquefied natural gas (LNG) stations (seen as orange octagons) within five miles of the I-40 Corridor indicates there is only one LNG station located at Clean Energy - Knoxville Flying J #722 (800 Watt Road). This station is located more than 200 miles from any other public LNG station on the I-40 corridor, though there is a private LNG station in Nashville. The Knoxville station is located **400 miles** east of the nearest public LNG station in West Memphis, Arkansas, and **235 miles** west of the Clean Energy in Charlotte, NC (2612 Distribution Drive). Another public LNG stations should be placed less than 200 miles west of Knoxville within five miles of I-40.

Interstate 75 Corridor

Interstate 75 spans 162 miles from the Georgia state line to the Kentucky state line. It passes near Chattanooga and through Cleveland, Charleston, Athens, Sweetwater, Knoxville, and Caryville. Currently there are 94 publicly-accessible alternative fuel stations within five miles of the I-75 corridor. Table 66 identifies the number of fuel stations based on fuel type on the I-75 corridor and the recommended distance between stations. Figure 23 maps these locations.

Table 66: Public Alternative Fuel Stations for I-75 Corridor

Fuel Type	# of Stations	Distance (Miles)
Bio-diesel	0	Undetermined
E85	14	Undetermined
Electric	67	50
Hydrogen	0	100
CNG	2	150
LPG	10	150
LNG	1	200
TOTAL	94	

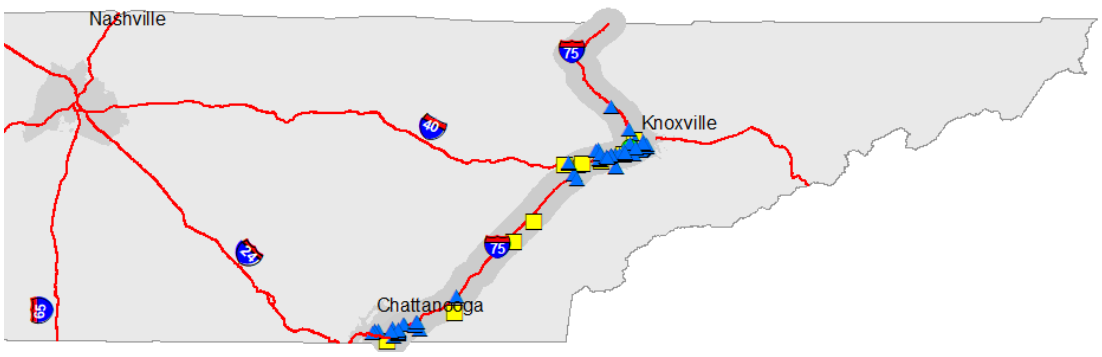


Figure 23: Public Alternative Fuel Stations on the I-75 Corridor

The location of public electric stations (seen as blue triangles) can be identified within five miles of the I-75 Corridor. The distance between the closest stations indicates there is one gap in the electric stations on the I-75 corridor (Figure 3). There is **57-mile distance** between the Shell Station in Cleveland, TN (947 Paul Huff Pkwy NW) and the Ingles Market in Lenoir City, TN (404 US-321). Both are public facilities open 24 hours per day.

The location of compressed natural gas (CNG) stations (seen as neon green circles) within five miles of the I-75 Corridor indicate there is no gap more than 150 miles between stations in the State of Tennessee. That is the Knoxville Utilities Board station (1820 3rd Creek Road) and the Athens Utility Board station (1818 Holiday Drive). The closest CNG station north of Knoxville, TN on the I-75 Corridor is the one sponsored by the City of Somerset, KY (244 Chappells Dairy Rd), which is 130 miles north of Knoxville. The nearest CNG station south of the Athens, TN station is a Fuel-A-New facility in Ringgold, GA (469 Rollins Industrial Ct), which is 75 miles south of Athens, TN.

The location of liquid petroleum gas (LPG) stations (seen as neon yellow squares) within five miles of the I-75 Corridor indicates there are no public LPG stations located more than 150 miles apart in the state of Tennessee; however, the nearest LPG station on the I-75 corridor in the State of Kentucky is in Louisville (4612 Preston Hwy) nearly **250 miles** north of the Knoxville facility.

The location of liquefied natural gas (LNG) stations (seen as orange octagons) within five miles of the I-75 Corridor indicate there is only one LNG station located on this corridor at Clean Energy - Knoxville Flying J #722 (800 Watt Road). This facility is located less than 200 miles from the Kentucky-Tennessee and the Georgia-Tennessee state lines. However, the closest public facility in Kentucky to the Knoxville Flying J is the Clean Energy in Walton, Kentucky (249 Shorland Drive) nearly **300 miles** distance. The nearest facility in Georgia is the public Clean Energy - Atlanta Fulton Industrial Park in Atlanta, Ga (5955 Bakers Ferry Rd SW), which is 198 miles south of the Knoxville Flying J.

Interstate 24 Corridor

Interstate 24 spans 180 miles through the state from the Kentucky state line to Chattanooga. It passes through Clarksville, Nashville, Murfreesboro, and Monteagle. Currently there are 186 publicly-accessible alternative fuel stations within five miles of the I-24 corridor. Table 67 identifies the number of fuel stations based on fuel type on the I-24 corridor and the recommended distance between stations.

Table 67: Public Alternative Fuel Stations for I-24 Corridor

Fuel Type	# of Stations	Distance (Miles)
Bio-diesel	3	Undetermined
E85	24	Undetermined
Electric	146	50
Hydrogen	0	100
CNG	3	150
LPG	10	150
LNG	0	200
TOTAL	186	

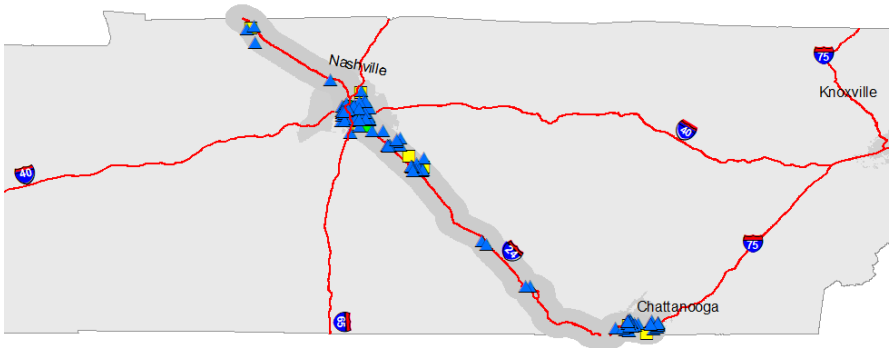


Figure 24: Public Alternative Fuel Stations on the I-24 Corridor

The locations of electric stations (seen as blue triangles) within five miles of the I-24 Corridor indicate no gaps of more than 50 miles in the electric stations on the I-24 corridor (Figure 24). This includes the nearest stations in Kentucky and Georgia. The three compressed natural gas (CNG) stations (seen as neon green circles) are all located in Nashville, TN, within five miles of the I-24 Corridor. Thus, there are no gaps in facility locations of more than 150 miles distance on the I-24 Corridor within the state of Tennessee as the Tennessee-Georgia state line is 130 miles south of Nashville and the Tennessee-Kentucky state line is 70 miles north. However, the nearest CNG station south of Nashville is a Fuel-A-New facility in Ringgold, GA (469 Rollins Industrial Ct), which is 148 miles distance. The nearest CNG station on the I-24 corridor north of the public Trillium station in Nashville, TN (402 N 1st Street) is the Freedom Waste Service facility in Princeton, KY (10129 US Highway 62 W), which is about 100 miles north of the Nashville facility. The locations of liquid petroleum gas (LPG) stations (seen as neon yellow squares) indicate there are no pair of LPG stations that are located more than 150 miles apart on the I-24 corridor in the state of Tennessee; however, the nearest LPG station on the I-24 corridor north of the U-Haul facility in Clarksville, TN (2830 Wilma Rudolph Blvd) is **160 miles** north at the U-Haul in Carbondale, IL (415 N Illinois Ave). The closest facility south of the East Ridge, TN LPG station is a U-Haul in Snellville, GA (2040 Scenic Hwy N), 130 miles south.

Interstate 65 Corridor

Interstate 65 spans 122 miles from the Alabama state line to the Kentucky state line, passing through Columbia, Brentwood, Nashville, and White House. Currently there are 125 alternative fuel stations within five miles of the I-65 corridor. Table 68 identifies the number of publicly-accessible fuel stations based on fuel type on the I-65 corridor and the recommended distance between stations.

Table 68: Public Alternative Fuel Stations for I-65 Corridor

Fuel Type	# of Stations	Distance (Miles)
Bio-diesel	4	Undetermined
E85	10	Undetermined
Electric	100	50
Hydrogen	0	100
CNG	3	150
LPG	8	150
LNG	0	200
TOTAL	125	

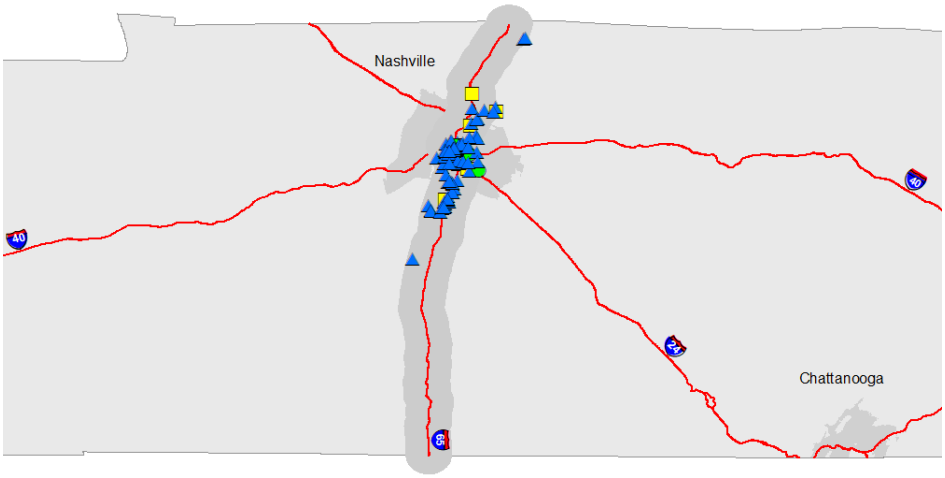


Figure 25: Public Alternative Fuel Stations on the I-65 Corridor

The locations of electric stations (seen as blue triangles) within five miles of the I-65 Corridor indicate no gaps within the State of Tennessee, but one gap of more than 50 miles in the electric stations on the I-65 corridor (Figure 25). There is a gap of **75 miles** from the public station at KOHL's in Spring Hill, TN (1001 Crossings Blvd) and the Tesla Supercharger at Fairfield Inn in Athens, AL (21282 Athens-Limestone Blvd). The distance between the electric stations in Portland, TN (one at 100 South Russel Street and one at the Baseball Field at 321 Portland Avenue) are approximately 30-35 miles from the nearest electric station in Bowling Green, KY (Meijer - Tesla Supercharger at 1676 W Park Drive).

The location of the three compressed natural gas (CNG) stations (seen as neon green circles) on the I-65 Corridor are the same as those on the I-24 Corridor. All are located in Nashville, TN (Trillium at 402 N 1st Street; Clean 'N' Green at 1428 Antioch Pike, and Piedmont Natural Gas at 541 Spence Lane). There are no gaps in service of more than 150 miles on the I-65 Corridor within the state of Tennessee (Figure 5); however, the nearest CNG station north of the public Trillium station in Nashville, TN is the Clean N' Green in Louisville, KY (7501 Grade Lane), which is **180 miles** distance. The nearest CNG station south of the Clean 'N' Green in Nashville, TN is one at the City of Athens, AL (1755 Trigreen Drive), which is 100 miles distance. The location of liquid petroleum gas (LPG) stations (seen as neon yellow squares) indicate there are no LPG stations that are located more than 150 miles apart on the I-65 corridor in the state of Tennessee. The nearest LPG station on the I-65 corridor north of the Nashville Country RV Park in Goodlettsville, TN (1200 Louisville Hwy) is the U-Haul in Bowling Green, KY (1817 Campbell Lane) approximately 50 miles distance. Also, the nearest LPG station on the I-65 corridor south of the Brentwood, TN U-Haul station (1691 Mallory Lane) is the Heritage Propane in Huntsville, AL (7230 Governors Dr. W), which is 125 miles apart.

Summary

Table 69 provides a concise summary of both the intra-state gaps in alternative fuel station locations and gaps in service in adjacent states. The recommended distance between electric stations is 50 miles; between the CNG stations and the LPG stations is 150 miles for both types, and the distance between LNG stations is 200 miles. The I-40 corridor has six service gaps based on recommended station distance; the I-75 corridor has three gaps; the I-24 corridor has one gap (not within the state), and the I-65 corridor has two gaps (none within the state). Of the five service gaps in the State of Tennessee, three pertain to the distance of electric charging stations. Two stations are located 61 and 57 miles apart, not the recommended 50 miles apart; however, one electric charging station is located 93 miles distance from the next closest station (Jackson to Dickson). One CNG station pair in the state is further away than the recommended 150 miles - the stations of Nashville and Knoxville, which are 180 miles distance, and the need for LNG service station less than 200 miles west of Knoxville, TN. There are eight service gaps between the Tennessee Interstate Corridors (I-40, I-75, I-24 and I-65) and the facilities in adjacent states. These include three on the I-40 corridor; two on the I-75 corridor; one on the I-24 corridor, and two on the I-65 corridor. Regarding electric stations, there is a gap of more than 50 miles between the facility in Spring Hill, TN and the nearest facility in Athens, AL. There is a gap in service of more than 150 miles between the CNG stations in Nashville, TN and Louisville, KY. There are three service gaps for LPG stations; one of 480 miles gap on the I-40 Corridor between Millington, TN and Oklahoma City, OK; one of 250 miles on the I-75 Corridor between Knoxville, TN and Louisville, KY, and one of 160 miles on the I-24 Corridor between Clarksville, TN and Carbondale, IL. Finally, only two of the Tennessee corridors have LNG facilities (I-40 and I-75). There are three services gaps; two on I-40, one of 400 miles from Knoxville, TN to West Memphis, AK and one of 235 miles from Knoxville, TN to Charlotte, NC. There is one gap in LNG service on the I-75 Corridor – 300 miles between Knoxville, TN to Walton, KY.

Table 69: Intra-state and Interstate Gaps in Alternative Fuel Station Locations

Corridor	Fuel Type	Tennessee Gaps	Gaps in Adjacent States
I-40	Electric	61 miles - Memphis to Jackson 93 miles - Jackson to Dickson	None
	CNG	180 miles – Nashville to Knoxville	None
	LPG	None	480 miles - Millington to Oklahoma City, OK
	LNG	One needed <200 miles west of Knoxville, TN.	400 miles – Knoxville to West Memphis, AK 235 miles - Knoxville to Charlotte, NC
I-75	Electric	57 miles - Cleveland to Lenoir City	None
	CNG	None	None
	LPG	None	250 miles – Knoxville to Louisville, KY
	LNG	None	300 miles – Knoxville to Walton, KY
I-24	Electric	None	None
	CNG	None	None
	LPG	None	160 miles – Clarksville to Carbondale, IL
I-65	Electric	None	75 miles – Spring Hill to Athens, AL
	CNG	None	180 miles - Nashville to Louisville, KY
	LPG	None	None

7.2.3 Cost of Alternative Vehicle Service Station Infrastructure

The costs associated with building new alternative fuel service station infrastructure or modifying existing infrastructure is varied as each AF type may require different technical components, and other capital costs. As such a generalized review of capital costs is provided, not including the expense of land (e.g. parcel size, and location) or specific requirements for retail infrastructure components, such as type or number of refueling or recharging outlets. General capital costs are provided for electric, hydrogen, compressed natural gas, liquid petroleum gas, and liquefied natural gas.

Electric Service Stations

Charging equipment for plug-in electric vehicles (EVs) is classified by the rate at which the batteries are charged. For example, AC Level I equipment provides charging through a 120-volt AC outlet; it takes about one hour of charge for the vehicle to travel 2 to 5 miles (AFDC 2018). Table 70 provides a review of charging station levels, vehicle range, charging time and plug type.

Table 70: Electric Charging Types

Level	Range (miles)	Time (minutes)	Plug
AC Level I	2 - 5	60	120-volt AC plug
AC Level 2	10 – 20	60	240-volt AC plug for residential; 208-volt AC plug for commercial;
DC Fast Level 3	60 - 80	20	208/480V AC three-phase input;

Public charging stations concentrate on AC Level 2 or DC fast charging infrastructure. Public stations are more expensive than home chargers and costs vary over a larger range depending on the type of installation, number of stations and site specifics. As seen in Table 71, for AC Level 2 public station types (garage and curbside), a single-port charging station hardware usually costs about $1,500 but can be as high as $3,000 as public stations are heftier, often pedestal mounted, include LCD screens, advanced payment and data tracking communication, and dual-port power routing capabilities (Agenbroad 2014). Labor is one of the major contributors to public station cost (40 percent to 70 percent of total). Parking garage installations are the easiest and most economical public charging stations and typically cost $3,500 - $6,4000 (Agenbroad 2014). Curbside and surface lot stations tend to be more expensive than parking garage installations because they frequently require costly ($25 to $100/ft.) trenching or directional boring to run conduit and wire to the station (Agenbroad 2014). Installing a multi-port station, or multiple stations at once, reduces the cost per charger, but demand must exist to justify the extra capacity. Cost is reduced mainly because a single trench/bore, conduit and wire can be used to service the adjacent stations. However, multiple stations are more likely to require a breaker box upgrade, and the feeder wire that is run from the box to the stations will be slightly more expensive, but the added cost can be divided across the extra stations. There are other costs in installing multi-port stations including permitting (Agenbroad 2014).

Table 71: Electric Station Cost

	Level 2 Parking Garage	Level 2 Curbside	DC Fasting Charging
Charge Station Hardware	$1,500 – $2,500	$1,500 – $3,000	$12,000 – $35,000
Electrician Materials	$210 – $510	$150 - $300	$300 – $600
Electrician Labor	$1,240 – $2,940	$800 – $1,500	$1,600 – $3,000
Other Materials	$50 – $100	$50 – $150	$100 – $400
Other Labor	$250 – $750	$2,500 – $7,500	$5,000 – $15,000
Transformer	N/A	N/A	$10,000 – $25,000
Motorization	$250 – $500	$250 –$ 500	$600 – $1200
Permitting	$0 - $100	$50 - $200	$50 - $200
TOTAL ($2014)	$3,500 - $6,400	$5,300 - $13,150	$29,650 - $80,400

Public DC fast charging (Level 3) stations allow much faster charging; however, their current cost ranges from about $30,000 to $85,000 per station (Agenbroad 2014). The two main contributors to their high cost are expensive equipment; and the need to install a 480V transformer. Project overhead also can be much higher for a level 3 station — 40 hours of time or an additional $10,000 would not be unusual (Agenbroad 2014). Not included in the review are data and payment communications and capabilities that may be subscription based, and maintenance costs.

TOOL: Electric Vehicle Infrastructure Projection Tool (EVI-Pro) Lite found at https://afdc.energy.gov/evi-pro-lite provides a simple way to estimate how much electric vehicle charging stations a state or municipality might need. For example, there were 5,848,300 light-duty vehicles on the road in Tennessee as of the end of 2016 and 4,200 of those were plug-in electric vehicles. If the state would like to support 250,000 electric vehicles by 2025, the results indicate, the state would need:

- 6,081 - Workplace Level 2 Charging Plugs
- 4,229 - Public Level 2 Charging Plugs (There are currently 945 plugs with an average of 2.3 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator)
- 750 - Public DC Fast Charging Plugs (There are currently 153 plugs with an average of 2.9 plugs per charging station per the Department of Energy's Alternative Fuels Data Center Station Locator)

Hydrogen Service Stations

The state of Tennessee has no hydrogen service stations (either publicly-accessible or private). Currently, there are two kinds of hydrogen cars. One car uses hydrogen fuel cells and the other car uses an internal combustion engine (ICE) to burn hydrogen. A hybrid car also exists that switches back and forth between gasoline and hydrogen. Some hydrogen cars currently use compressed H2 while others use liquid hydrogen. Issues of storage, containment, delivery and safety all need to be addressed before hydrogen fuel stations become commonplace in the consumer market (Melania 2013). Currently USDOE is coordinating the efforts of codes and standards organizations to develop more robust codes and standards that ensure the safe use of hydrogen for transportation and stationary applications. One of the outputs of this effort will be a national standard for hydrogen vehicle infrastructure (AFDC 2018).

Compressed Natural Gas (CNG)

There are essentially three types of CNG stations: fast-fill, time-fill, and a combination of these two. Typically, publicly-accessible retail stations use fast-fill and fleets that have private central refueling and the ability to fill overnight use time-fill. Costs of installing any type of natural gas infrastructure varies based on size, capacity, and the type of natural gas (Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) or both). Cost vary based on the way the natural gas is

dispensed (fast-fill, time-fill) as well as, calculating pressure and storage needed for the types of vehicles being fueled (AFDC 2018). For this cost analysis, fast publicly-accessible fast fill stations will be reviewed. Fast-fill stations are best suited for retail situations where vehicles arrive randomly and need to fill up quickly. For a station serving light-duty vehicles, the space needed to store the equipment measures about the size of a parking space. Fast-fill stations receive fuel from a local utility line at a low pressure and then use a compressor on site to compress the gas to a high pressure. Once compressed, the CNG moves to a series of storage vessels so the fuel is available for a quick fill-up. CNG can also be delivered via dispensers alongside gasoline or other fuel dispensers (AFDC 2018). As seen in Figure 26, CNG at fast-fill stations is often stored in the vessels at a high service pressure (4,300 pounds per square inch (psi)) so the dispenser can deliver it to a vehicle quickly. The dispenser uses sensors to calculate pressure and measure the number of GGEs delivered to the tank, taking temperature into account.

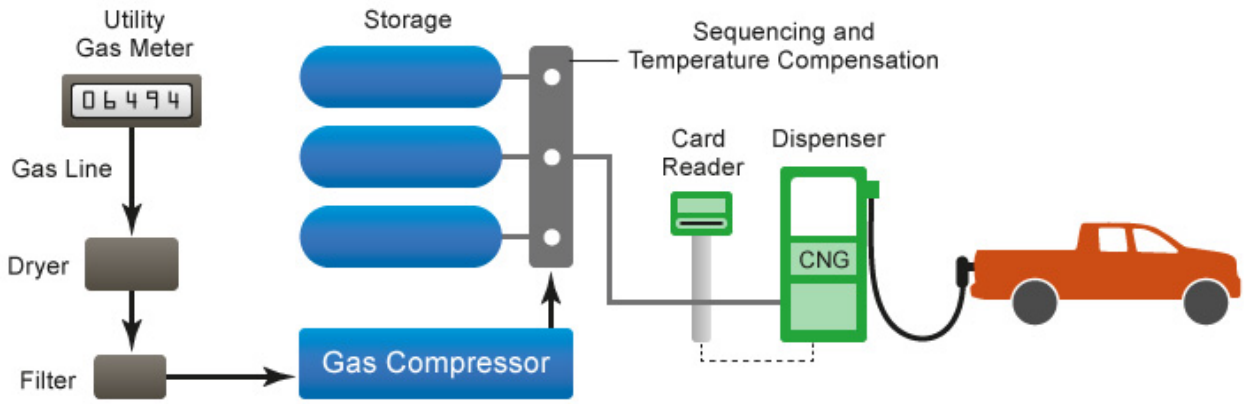


Figure 26: CNG Fast Fill Station (Source: AFDC)

According to a report published by the National Renewable Energy Laboratory, costs for installing a public fast-fill CNG fueling station can range up to $1.8 million depending on the size and application (USDOE 2014). Smaller starter fueling units that may not be practical for repeated public use can cost between $45,000 and $75,000 (Table 9). Stations are described in Table 72 based on their gasoline gallon equivalent (gge) and are divided into Starter, Small, Medium and Large station types (USDOE 2014). Starter stations are designed to serve up to four sedans/pickups fueling 10 gge per day, while the large station is designed to service light- to heavy-duty vehicles such as delivery vans, work trucks, refuse trucks, class 8 tractors, and local fleets, or serve an airport with light- and medium-duty vehicles such as taxis, shuttle buses, and local fleets.

Table 72: CNG Station Types and Cost

Station Type	GGE	Cost	Application	Assumptions
Starter	20 - 40	$45,000–$75,000	Station serving up to four sedans/pickups fueling 10 gge/day	One compressor; 2–5 psi inlet gas pressure; 3,780 standard cubic feet storage; one single-hose dispenser.
Small	100 - 200	$400,000–$600,000	Station serving 15–25 pickups/delivery vans fueling 7 gge/day or 9–16 taxis/work trucks fueling 12 gge/day	One compressor; 5–15 psi inlet gas pressure; 16,250 standard cubic feet storage; one single-hose metered dispenser
Medium	500 - 800	$700,000–$900,000	Station serving 50–80 light/medium-duty vehicles fueling 10 gge/day or 45–65 taxis fueling 12 gge/day	One compressor; 30 psi inlet gas pressure; 34,000 standard cubic feet storage; one dual-hose metered dispenser
Large	1500 - 2000	$1.2–$1.8 million	Large retail station serving light- to heavy-duty vehicles such as delivery vans, work trucks, refuse trucks, class 8 tractors, and local fleets, or Airport station serving light- and medium-duty vehicles such as taxis, shuttle buses, and local fleets	Two compressors; 30 psi inlet gas pressure; 55,000 standard cubic feet storage; two dual-hose metered dispensers

Liquid Petroleum Gas (LPG)

Liquefied petroleum gas (LPG) (a.k.a. propane) is an alternative fuel that has been used for decades to power light-, medium- and heavy-duty propane vehicles; as such propane infrastructure is well-established across the United States. Propane is stored under pressure inside a tank as a colorless, odorless liquid. As pressure is released, the liquid propane vaporizes and turns into gas that is used in combustion. An odorant, ethyl mercaptan, is added for leak detection. (AFDC 2018). Propane has a high-octane rating, making it an excellent choice for spark-ignited internal combustion engines. Fuel providers and fleets can place propane dispensers alongside gasoline, diesel, or other alternative fuels. The infrastructure needed for propane is very similar to that for gasoline and diesel. Propane is transported to the site via a delivery truck and put into onsite storage tanks, traditionally above ground. The fueling dispenser is also similar to a gasoline dispenser. The difference is that propane is delivered to the vehicle under a low pressure, so it remains a liquid (AFDC 2018).

Table 73: LPG Station Types and Cost

Size	Design	Fuel Use (Gallon)	Cost	Application
Small	1,000-gallon storage tank; 1 single hose dispenser	100 – 400	$45,000–$60,000	3 school buses (16 gal/day); 10 shuttle vans (20 gal/day); 30 taxis (7 gal/day)
	2,000-gallon storage with twin 1,000-gallon tanks; 1 dual-hose dispenser	200 - 800	$60,000 - $70, 000	20 school buses (15 gal/day); 30 shuttle vans (18 gal/day); 60 taxis (7 gal/day); 65 delivery vans (6 gal/day);
Medium	12,000- gallon storage tank; 2 dual-hose dispensers	450 - 1800	$120,000 - $145,000	35 school buses (14 gal/day); 65 police cruisers (7 gal/day); 100 shuttle vans (20 gal/day)
	18,000-gallon storage tank; 3 dual-hose dispensers	900 - 2400	$150,000 - $220,000	60 school buses (16 gal/day); 70 shuttle vans (20 gal/day); 100 school buses (10 gal/day); 150 taxis (10 gal/day)
Large	30,000-gallon storage tank; 4 dual-hose dispensers	900 - 3000	$225,000 - $300,000	70 shuttle vans (20 gal/day); 100 delivery vans (9 gal/day); 250 school buses (10 gal/day)

As seen in Table 73, and according to a report published by the National Renewable Energy Laboratory entitled *Costs Associated with Propane Vehicle Fueling Infrastructure,* costs for installing a publicly accessible LPG fueling station can range from $60,000 for a small station to $300,000 for a large station depending on the size and application (USDOE 2014). Propane production, storage, and bulk distribution capabilities already exist across most of the U.S., which means establishing propane fueling infrastructure for vehicle refueling requires the build-out of dispensing equipment—including the storage tank, pump, dispenser, and card reader at a station (AFDC 2018).

Liquefied Natural Gas (LNG)

LNG stations are structurally similar to gasoline and diesel stations because they all deliver a liquid fuel. LNG dispensers deliver fuel to vehicles at pressures of 30 to 120 psi. Because LNG is stored and dispensed as a super-cooled, liquefied gas, protective clothing, face shield, and gloves are required when fueling a vehicle, and personnel must also be trained on fueling procedures (AFDC 2018). There are three options for LNG fueling: mobile, containerized, and permanent large stations. In mobile fueling, LNG is delivered by a tanker truck that has on-board metering and dispensing equipment. A starter station, or containerized station, includes a storage tank, dispensing equipment, metering and required containment (AFDC 2018). Liquefied natural gas fueling stations are available mostly in areas that service the long-haul trucking industry, not generally used in family vehicles. According to the Energy Information Administration, an LNG fueling site can range from $1 to $4 million (USDOE 2014).

Summary

There is a trend for alternative fuel vehicles. This trend has been driven by consumers who are environmentally conscious and legislative mandates that require can manufactures to meet stricter emissions standards and higher gas-mileage rules. While there is a range of alternative fuel car options, most vehicles being manufactured are gas-electric hybrids, plug-in vehicles, or electric vehicles. Natural gas, fuel-cell and flex-fuel vehicles are slowly increasing in use. The most common alternative-fuel vehicles are gas-electric hybrids that combine gas and electric propulsion systems. These hybrids have been available in the U.S. for more than 15 years with about 50 models currently available for sale (AFDC 2018). The battery in gas-electric hybrids is charged from the engine and through braking, which then allows the battery to power the car at low speeds and during stops and starts. Similar to the gas-electric hybrid, plug-in hybrids have larger batteries that can run the car on electricity alone for limited distances with zero emissions. Owners can fill up their car with regular gas at the pump and then plug into an electric power source to recharge the battery. Electric vehicles run solely on battery power, dispensing with the gas engine altogether. These vehicles have a specific range of miles they can travel before they need to be “refueled” by plugging them into an electrical power source. Finally, the growth in natural gas as an energy source has also helped increase the demand for natural-gas-fueled vehicles. Similar to gas-powered cars, natural gas vehicles use compressed or liquefied natural gas and have cleaner emissions. Fuel-cell vehicles use hydrogen-powered, fuel-cells, which come with the advantage of zero emissions and the potential for up to three times the efficiency of gas-powered cars. The vehicles have on-board fuel cells that run on compressed hydrogen, and in turn power an electric motor. Factors currently inhibiting wider adoption of fuel cell vehicles include the cost of the cars, as well as a limited network of hydrogen fueling stations (AFDC 2018). Finally, flexible-fuel vehicles run on a mixture of gas and ethanol. Produced primarily from corn, ethanol has benefited from government mandates requiring more fuels be made from renewable sources. Flex-fuel vehicles currently have the best network of fueling stations (AFDC 2018). These trends will provide a guide map for TDOT to follow when building alternative fuel corridors.

7.3 Complete Streets – Cumberland Avenue Corridor Cost-Benefit

Smart Growth American has defined the concept of "Complete Streets" in the following way:

> *Complete Streets are streets for everyone. They are designed and operated to enable safe access for all users, including pedestrians, bicyclists, motorists and transit riders of all ages and abilities. Complete Streets make it easy to cross the street, walk to shops, and bicycle to work. They allow buses to run on time and make it safe for people to walk to and from train stations (SGA 2018).*

The specific design elements of Complete Streets vary, based on context and project goals, but they may include the following (Wikipedia 2018):

- Pedestrian infrastructure such as sidewalks; traditional and raised crosswalks; median crossing islands; audible cues for people with low vision, pushbuttons reachable by people in wheelchairs, and curb cuts; and curb extensions;

- Traffic calming measures to lower speeds of automobiles and define the edges of automobile travel lanes, including a road diet, center medians, shorter curb corner radii, elimination of free-flow right-turn lanes, angled, face-out parking, street trees, planter strips and ground cover.

- Bicycle accommodations, such as protected or dedicated bicycle lanes, neighborhood greenways, wide paved shoulders, and bicycle parking.

- Public transit accommodations, such as Bus Rapid Transit, bus pullouts, transit signal priority, bus shelters, and dedicated bus lanes.

A cost-benefit analysis of a specific complete streets project includes the process of defining the project and potential benefits. Typical questions include:

- ✓ Where are the geographic boundaries? How long, and wide?
- ✓ How many elements (i.e. businesses, utilities, and traffic signals) are involved?
- ✓ What is the schedule? Start and completion dates?
- ✓ Who is the project trying to serve?
- ✓ What type of baseline data is available (e.g. number of residents and their demographics, travel methods and patterns, types of employment opportunities, businesses, and housing)?
- ✓ Are there safety issues, concerns about stagnant local economies, or other issues that the project would help reduce or improve?

- ✓ What are the predicted outcomes, the benefits (e.g. reduction in collision and injury costs, increase in net new businesses, employment levels, and property values and private sector investments)?

Quantitative project aspects are less difficult to calculate than qualitative benefits. Qualitative costs can include lifecycle and capital costs (e.g. construction, wages, right-of-way, engineering design), as well as maintenance and operations costs. Quantifying benefits is more difficult as it requires applying monetary value to quality of life and equity issues. The role of GaBi software should be explored further for lifecycle analysis.

7.3.1 Complete Streets in Tennessee

In the United States, complete streets policies have been gaining traction as more places realize the benefits of having safe, accessible, and healthy streets in their communities. In total, over 900 complete streets policies have been passed, including those adopted by 33 state governments, the Commonwealth of Puerto Rico, and the District of Columbia. Table 74 lists the cities in Tennessee that have enacted some type of policy (e.g. legislative, and resolution, plan) regarding complete streets. Tennessee has a total of ten Complete Streets policies at all levels of government. Its policies cover approximately 1,500,000 people, or about 24% of the state population (2010 US Census). According to the US Census, almost 84% of Tennessee commuters drive to work alone, with around 3% of trips to work are made by walking, riding a bicycle, or using public transit. Around one household in four (23%) has either one or no private vehicle available. Around 3,000 Tennessee residents consider themselves frequent bike commuters.

Table 74: Complete Street Policies in Tennessee

Tennessee City	Policy	Type	Level	Year
Chattanooga	City Code II Ch. 32, Art. XIV	Legislative	City	2014
East Ridge	Resolution No. 2456	Resolution	City	2015
Hendersonville	Land Use and Transportation Plan	Plan	City	2009
Kingsport	Resolution	Resolution	City	2011
Knoxville	Resolution No. 287-09	Resolution	City	2009
Knoxville	Ordinance No. O-204-2014	Legislative	City	2014
Knoxville TPO	Complete Streets Guidelines	Guidelines	Region	2009
Memphis	An Order Establishing a Complete Streets Policy for the City of Memphis	Executive Order	City	2013
Nashville	Executive Order No. 40	Executive Order	City	2010

Nashville	Amended Executive Order No. 031	Executive Order	City	2016

7.3.2 Knoxville Example (Cumberland Avenue Corridor Project)

The Knoxville example of Complete Streets project includes work performed on an approximately 0.75 mile (3,880 feet) stretch of Cumberland Avenue from Alcoa Highway to 22nd Street (Phase 1) and (22nd Street to 16th Street (Phase II). The project started in April 2015 and ended in January 2018 (Knoxville 2018). The goal of the project is to connect University of Tennessee students and residents to area employers and retail outlets. The plan recommended a "road diet" for Cumberland Avenue. There are two components to the Project as outlined in the Corridor Study: 1) an Urban Design Plan, and 2) a Streetscape Plan.

Demographics

Data from the US Census for 2010 was used to describe the area residents. Additionally, the US Census Bureau American Community Survey (ACS) was used to calculate some demographic and travel data for Census Tract 69 residents for the most recent year data is available (2016). Because the ACS survey is completed by only one in six households (about 3.5 million housing unit addresses), there is a margin of error associated with the 2016 data (+-) in order to achieve a 90% confidence rate.

In 2010, the population of the area (Census Tract 69) was approximately 6,650 with those born between 1982-2000 comprising 91% of the population (Median age of 21.8). There were about 3,000 housing units; of these, about 400 were vacant. Of the homes that were occupied, about 2,450 (82%) were rental properties. The most frequently cited structure was one built between 1970 and1979 (30.6 %), and one with 20 or more units (38%).

According to the US Census Bureau, about 2,500 residents were employed either full or part-time in 2010. The unemployment rate was 5.5%. Regarding occupations, approximately 34% worked in the service occupation; 31% worked in sales and office occupations and about 30% worked in management, business, science and arts. With regards to industry, 36% worked in arts, entertainment and recreation, and accommodation and food services; about 28% worked in educational services, and health care and social assistance; and 13% worked in retail trade. In 2010, the mean household income was approximately $17,400 and the median was approximately $8,900.

ACS estimated a population of about 7100 in 2016. Of these residents, about 75% are between the ages of 20-24 (Median age of 21.6). There are about 3,125 housing units; of these, 460 were vacant. About 2,520 or about 92% were rental properties. The most frequently estimated residential structure was one built between 2000-2009 at 20.6%, and one with 20 or more units at 37%.

According to the ACS, about 3500 residents were employed either full or part-time. The unemployment rate was 5.5%. Regarding occupations, approximately 41% worked in a service occupation; 24% worked in sales and office occupations and about 23% worked in management, business, science and arts. With regards to industry, 37% worked in arts, entertainment and recreation, and accommodation and food services; about 25% worked in educational services, and health care and social assistance; and 9% worked in retail trade. In 2016, the mean household income was approximately $19,300 with a median income of about $15,600.

A comparison of demographic characteristics of residents in Census Tract 69 in 2010 and 2016 indicate a few differences of note. These include:

- An increase in population by ~ 7%;
- An increase in housing units by ~ 4%;
- An increase in vacant housing by 15%;
- An increase in rental properties by ~ 10%;
- A shift in housing structure from those constructed in the 1970's to those built between 2000-2009;
- An increase in mean household income by ~ 11%;
- An increase in residents working in service occupations by 7%;
- A decrease in residents working in sales and office occupations by -7%;
- A decrease in residents working in in management, business, science and arts by -7%;
- A decrease in residents working in retail trades by – 4%.

The Cumberland Avenue Corridor Project Summary (Knoxville 2018) highlights four economic metrics. These include:

- An increase in the price per square foot land sales from $ 56 to $ 82 or ~ 47%;
- An increase of appraised value (115%) to $201 M (2017);
- A decrease in retail sales & use tax from 50% share of retail sale before project, to 41% during construction, and 48% in 2017;

Transportation

According to the ACS, in 2010, 10.6% of residents had no vehicle and 60.5% had one; 28.9% had more than one vehicle. During this year, about 71% of residents drove alone to work, ~19 % walked, 1% bicycled, and about 2% used public transportation. By 2016, 8.7% of residents had no vehicle; 41.5% had one, and nearly half (49.8%) had more than one vehicle. In 2016, about 70% of residents drove alone to work; ~ 17% walked; about 1% bicycled to work and 1.7% used public transportation.

In 2010, there were 150 vehicle crashes from 17th Street to Volunteer Blvd (Knoxville 2018). In 2017, this number had dropped to 37 crashes. There were nine pedestrian-bicycle crashes in 2008 with pedestrian traffic of 2,500 (measured at 16th and Cumberland Avenue), and one crash in 2017 with pedestrian traffic for 4,500 (measured at 16th and Cumberland Avenue).

Economic Activity

A Cumberland Avenue Merchant Survey was conducted before construction of the corridor. A summary of the November 2007 survey indicates the presence of approximately 55 businesses. A response rate of 69% (38 respondents) indicates the average tenure of business to be 20 years. The types of businesses that responded were restaurant/bars (37%); service (29%); retail (24%); financial (8%) and other (8%).

Customers typically arrive at businesses in the Cumberland Avenue district using personal vehicles (58%); on foot (38%) or bus/trolley (4%). The typical customer being served included UT students (37%); area residents other than UT students (27%); employees from area businesses (22%); tourists (8%) and other (6%). The destinations most frequently mentioned as driving customers to Cumberland Avenue include area restaurants, UT campus and UT athletic games, Ft. Sanders Regional Medical Center, and East Tennessee Children's hospital. Survey respondents indicated they have limited off-street parking for customers and their employees. It is estimated that there are approximately 780 off-street parking spaces available for the 38 businesses responding.

7.3.3 Cumberland Avenue Corridor Cost-Benefit Analysis

As seen in Table 75, a cost-benefit analysis of the Cumberland Avenue Complete Streets projects indicates a cost of $42.5 million dollars, and a benefit of $89.4 million dollars. Costs include two project cost types (i.e. streetscape and urban design plan), and annual maintenance costs. The project maintenance cost is ongoing and will change depending on replacement cost for street furniture, etc. Only the first year of maintenance cost is included in the analysis. Benefits include an increase in public transit usage, and a subsequent reduction in energy consumption and greenhouse gas emissions, and savings on the costs of congestion, parking, etc. Benefits also include the amount of time spent productively on a bus, an increase in bicycle and walking commuting. Accident reduction in vehicle crash rates. Including property damage and societal harm from missed work is included. Additionally, property value, property tax, and wage and employment increases are included. Finally, health benefits are calculated as assuming a certain percentage of walking/cycling pedestrians will benefit from life-long exercise and result in additional life accrued at a certain value. The cost-benefit analysis indicates that for every $1.00 spent in cost, there is a $2.10 benefit.

Table 75: Cost-Benefit of Cumberland Avenue Corridor Complete Streets

HEADING & DESCRIPTION	COST	NOTES
Project Costs		
Project Cost (Streetscape) - 80% FHWA STBG Funds through TDOT	$ 16,000,000	These estimates include NEPA, Design, ROW and Construction. Source: Cumberland Avenue Corridor Project Summary. City of Knoxville. 2018.
Project Cost (Streetscape) - 20% local match	$ 4,000,000	
Project Cost (Streetscape)– KUB Underground utility infrastructure (gas, water, sewer)	$ 5,000,000	
Project Cost (Urban Design Plan)	$17,395,265	This is the contract price for project designer: Vaughn & Melton Consulting Engineers, Inc. The contractor is Southern Constructors, Inc. Source: Cumberland Connect (cumberlandconnect.com)
Annual Maintenance Cost - Includes added maintenance for all project components (e.g. repairs, replacement, mowing, cleaning, and tree trimming) for LED lighting, 90 trees, pavers, street furniture, Silva cell technology, and garbage/recycle containers.	$18,269	Estimate based on maintenance costs for complete streets project (Main Street) in Concord, New Hampshire, and Smart Growth America documentation.
Project Benefits		
Transit - Bus Trips – include benefits of energy consumption and greenhouse gas reduction, costs of congestion, and parking.	$665,270	On average KAT ridership increases by 4% between 2014 and 2015. (Source: Mass Transit Magazine). Assumes a savings of $9370 per year (Source: APTA); assumes part-time use of transit.
Transit - Amount of time spent productively on a bus by passengers (e.g. reading, working, and studying)	$ 154,425	Assumes minimum wage per hour is $7.25; assumes 2 trips of 30 minutes times 150 days.
Transit – Bicycle Commuters	$ 74,657	Assumes an increase of bicycle commuters of 3% per year (Source: LAB). Savings are approximately $2103 per year (Source: Roth);

		assumes part-time usage.
Transit – Walking Commuters	$ 1949	Assumes a benefit of $2.89 per hour (Source: Hamm); assumes a one-hour part-time commute.
Crash – Reduction in vehicle crash rates. Includes property damage and societal harm from missed work and slight injury.	$ 1,017,000	Assumes $9,000 cost per accident Source: Copeland.
Property – Property Value Increase. Housing stock only.	$ 19,862,280	Assumes a property value increase of 5.2% (Source: SGA). Property value data (Source: US Census)
Property – Property Tax Increase	$ 459,315	Tax rate of 9.25% assumed for property assessed at 25% of market value price.
Income – Increase in Wage and Number of Employees	$1,900,000	Based on US Census and ACS data. An increase in 1000 employees with a salary increase of $1900 dollars per year.
Health - Trips Reliant on Walking within 1/2-mile of Study Area - Additional Life Accrued to More Physical Activity	$ 65,436,750	Assumes 4500 pedestrian trips (Source: City of Knoxville pedestrian counts at 16th and Cumberland Avenue); Assumes 22.9% of pedestrian count will benefit from life-long exercise (Source: CDC); assumes additional life accrued is 1.27 years (Source: SGA); assumes value of one year of life equal to $50,000 (Source: Kingsbury).

7.4 Transportation Demand Management (TDM)

Transportation demand management (TDM) is a set of strategies intended to reduce the demand for roadway travel, and especially for single-occupancy vehicles. Some of these strategies are aimed at reducing total travel demand, such as telework and flex and compressed work, while others are designed to reduce peak period demand, like high-occupancy vehicle (HOV) lanes, public transit, ride sharing (e.g. carpooling/vanpooling), car and bike sharing or walking/biking incentives.

7.4.1 TDM in Tennessee

Based on the **Statewide Transportation Demand Management Plan for Tennessee Nonattainment and Maintenance Areas**, the TDM plan guides TDOT's effort to create more efficient TDM management practices by establishing a statewide vision and developing goals and objectives that provide the framework for long-term program implementation and sustainability. The Tennessee plan has six key recommendations (TDOT 2018):

1. Introduce a standard Commuter Program structure;
2. Establish a statewide TDM brand;
3. Identify a statewide TDM coordinator (team);
4. Maintain core TDM services for regional implementation;
5. Increase accountability, and
6. Develop standard operating procedures for administration of TDM projects.

Currently, the recommendations have not been initiated. There is a need to coordinate efforts and establish a vision for TDM in Tennessee. While TDM efforts have been funded for many years, there has been little attempt to coordinate programs, operations and outcomes. There is a common belief in the value of employer engagement, but the level of employer outreach and private sector engagement is very low. The current TDM programming is fragmented, leaving gaps in service and missed opportunities. This greatly limits the state's ability to demonstrate collective impacts (TDOT 2018).

7.4.2 TDM Tools and Toolkits

A number of other state departments of transportation have developed toolkits and publications to foster transportation demand management practices (i.e. Arizona, Colorado, Massachusetts, North Carolina, Pennsylvania, Virginia and Washington). There publications can act as templates for TDOT. Additionally, there are a few online tools that can be used to make TDM decisions.

- **Arizona Department of Transportation** has developed a comprehensive toolkit with case examples, performance measures, land use worksheets and implementation descriptions. Source: https://apps.azdot.gov/ADOTLibrary/publications/project_reports/PDF/AZ654.pdf

- **Bay Area Air Quality Management Tool** is an excel-based tool that quantifies vehicle miles traveled and reductions from transportation demand measures that are translated into reductions in air pollution and greenhouse gas emissions. Source: www.ca-ilg.org/post/transportation-demand-management-tdm-tool

- **Colorado Department of Transportation** has developed a toolkit that highlights the six different application where TDM can be applied, including "core" and "support" strategies that are often the key ingredients of any TDM plan, and implementing alternatives. Source: www.codot.gov/programs/commuterchoices/documents/cdot_tdm_toolkit_oct-1.pdf

- **Commute Calculator** calculates how much a monthly commute really costs based on the number of round-trip miles per commute day, number of commute days per month, cost of parking per month, cost of gasoline per gallon, and car's miles per gallon. Source: http://metro.kingcounty.gov/ridertools/commute-calculator.html

- **Group Carpool** allows individuals and business owners create an online resource for people interested in carpooling. Source: www.groupcarpool.com/

- **Massachusetts Department of Transportation** has developed an evidence-based method for making transportation demand management decisions. Source: www.indecon.com/projects/massdot-evidence-based-policy-making-for-transportation-demand-management-tdm/

- **Modeify** is a route-planning program that picks the best commute for each commuter. A free version is found at Arlington's CarFreeAtoZ website and app. Source: www.carfreeatoz.com/planner

- **North Carolina Department of Transportation** has a Statewide Transportation Demand Management Strategic Plan that contains a series of regional plans and methods for scoring success or failure. Source: https://connect.ncdot.gov/business/Transit/Documents/North%20Carolina%20Statewide%20Transportation%20Demand%20Management%20(TDM)%20Strategic%20plan%20Update%20-%20January%202018.pdf

- **Pennsylvania Department of Transportation** highlights a series of Best Practices, identifies barriers to TDM implementation and provides pricing and incentive guidelines to influence modal choice. Source:

www.dot7.state.pa.us/BPR_PDF_FILES/Documents/Research/Complete%20Projects/Operations/Task%205.1%20Final%20Project%20Documentation.pdf

- **Virginia Department of Transportation** has developed a TDM plan that includes various program structures, staffing needs and potential partnerships, as well as program funding sources. Source: www.drpt.virginia.gov/media/1846/fairfax-county-tdm-plan.pdf

- **Washington State Department of Transportation** provides a TDM Primer for Transportation Planners and Engineers. Source: www.wsdot.wa.gov/Choices/Demand.htm

Summary

Tennessee Department of Transportation is in the position to develop a long-range transportation demand management plan specific to the needs of the state. This plan can be developed with an overall scope of providing statewide public transit, as well as regional TDM strategies. TDOT can encourage individual employers to provide TDM strategies for their employers, such as the programs implemented by Washington state employers. There exist a number of free or low-cost options that can be considered (e.g. group ride websites, flex and telecommuting hours). Though the objective may be to concentrate efforts near nonattainment areas, the change in mindset can impact the entire state. Providing a TDOT Statewide **Transportation Demand Management Plan for Tennessee Nonattainment and Maintenance Areas,** written to include all areas (urban and rural) and written with long-term planning in mind can enhance sustainable strategies in the future.

8.0 POTENTIAL FUNDING SOURCES

Funding opportunities for sustainability actions vary depending on the type of entity searching for funding. Participants in the March 2018 TDOT Division Directors meeting mentioned partnering with non-governmental organizations and securing outside support as part of their next steps agenda. The entities eligible for funding opportunities include:

- Municipalities, including cities or townships, counties or special district entities;
- State governments;
- For profit institutions, including small businesses;
- Non-profit institutions;
- Tribal governments or organizations;
- Institutions of higher education, both private and public;

8.1 Examples of Funding Sources

Municipalities, including cities or townships, counties or special district entities can choose from a number of grants relating to sustainability objectives. For example, the US Department of Agriculture provides grants to protect and encourage community forest and open spaces, agricultural development programs, and wetland preservation among others. Other US Departments provide grants for municipalities. These include grants for Regional Innovation Strategies and Economic Development Assistance Programs (Commerce); grants to strengthen public health systems and services through national partnerships (Health and Human Services); freight and transit security grants (Homeland Security); Ecosystem Vegetation Monitoring and Data Analysis as well as Agricultural Water Conservation and Efficiency Grants (Interior); Clean Fuels Grant Program and the Bus and Bus Facilities Livability Initiative (USDOT), and the EPA provides sustainable skylines initiatives and advancing public health protection through water infrastructure sustainability grants.

State governments can receive grants from most of the US Departments from which municipalities can; however, the scope and type of the grant may be different. Additionally, other institutions and US Departments are willing to provide grants. These include the Corporation for National and Community Service, which provides AmeriCorps and Training and Technical Assistance grants; HUD's Lead-Based Paint Hazard Control Grant Program, and Department of Labor's mine safety program.

For profit institutions, including small businesses, grants are available to them for very specialized services. These include rhinoceros and tiger conservation, combating wildlife trafficking and deployment of fish ladder funds sponsored by the U.S. Fish and Wildlife Service. Other specialized grants include those for food security research (USDOA), Bluefin tuna and coral reef research and preservation programs (USDOC), and technical assistance to the

survivors of torture and oral health programs (USHHS). Few grants from the USDOT are available to for-profits agencies, as many of these grants are issued to state DOTs and institutions of higher education.

Non-profit institutions are eligible for a number of grants pertaining to partnerships and community development, as well as other objectives. These include sustainable water partnership and Middle East water security partnership (USAID); the non-profit capacity building grants (Corporation for National and Community Service); grants for rural cooperative development (USDA) and Capacity Building for Community Development and Affordable Housing Grants (HUD).

A number of grants for tribal governments or organizations (both federally recognized or not) are specific to American Indian tribes and their territories. These include community development block grants program for Indian Tribes and Alaska Native Villages (USHUD), U.S. Department of Justice Coordinated Tribal Assistance Solicitation, and the tribal riparian planting and tribal resilience and ocean and coastal management and planning grants (USDOI). Additionally, some grants are eligible to but not specific to Indian tribes. These include Farmers- Market Supplemental Nutrition Assistance Program Support Grants (USDA); Minority Serving Institutions Partnership Program (USDOE); Racial and Ethnic Approaches to Community Health grants (USHHS), and Program to Prepare Communities for Complex Coordinated Terrorist Attacks (USDHS).

Finally, grants for institutions of higher education, both private and public, seem to be concentrated in the area of research. These include Feed the Future Innovation lab for Peanut Research (USAID); conservation innovation grants (USDA); Ecological Effects of Sea Level Rise Program - Advancing Predictive Capabilities to Evaluate Natural and Nature-based Features (USDOC); University Center of Excellence for Integrated Computational Material Science and Engineering of Structural Materials (USDOD), and Integrated Enhanced Geothermal Systems Research and Development grants and the creation of Industrial Assessment Centers (DOE).

8.2 Funding Sources for TDOT

Political considerations often influence where resources are allocated either statewide or nationally, as well as the difficulty in obtaining funds. Existing available funding through an application process is considered the easiest to obtain. Funding requiring a match or multi-tiered evaluation process is considered moderate to obtain, and funding requiring special legislative action, such as an earmark or state authorization; tax increase or bond issue would be considered difficult. A list of potential funding sources for some of TDOT's divisions are found in Table 76.

Table 76: Funding Sources for TDOT Divisions

Division	Potential Funding Source
Aeronautics	• The Federal Aviation Administration provides funding through VALE (Voluntary Airport Low Emissions Program) to use Airport Improvement Program (AIP) funds and Passenger Facility Charges (PFCs) to finance specific airport air-quality improvements. Eligible airports include Nashville International, Memphis International, McGhee Tyson, Lovell Field and Tri-Cities Regional TN/VA. Currently, only the Memphis International airport has taken advantage of this program. • FAA also funds Sustainable Airport Master Plans. • An Aircraft Owners and Pilots Association (AOPA)-backed bill introduced in the Indiana House of Representatives (House Bill 1267) would require that state revenue from aviation fuel and sales-and-use taxes be deposited in the state airport development grant fund, creating a sustainable funding stream for Indiana's aviation system. • Eco-skies is a partnership program of United Airlines—the model can be modified for airports. The Eco-skies program has partnered with Clean the World, which recycles used soap; Conservation International, which uses its resources to protect nature, and others. • Another example is the Los Angeles International Airport Sponsorship Program, which is designed for brands that want to raise their profile in untapped markets. Sponsors are showcased throughout the airport. • An airport landside program is when the side of an airport terminal to which the general public has unrestricted access has property which is developed. In addition to providing a steady revenue stream, landside development also holds potential benefits for the local community. • Hangar rental can be another revenue generator. Airports profit from access to accommodate a range of needs—from housing small recreational aircraft and corporate jets to commercial fixed-base operators. In standard agreements, hangar sites can be leased by a tenant for a fixed period of time, the tenant will finance the structure's construction and upkeep, and ownership of the hangar will revert to the airport upon expiration of the lease period.
Central Services	• The U.S. Department of Energy's (DOE) Alternative Fuel Transportation Program (the Program), also known as the State and Alternative Fuel Provider Fleet Program, implements provisions of

	Titles III–V of the Energy Policy Act (EPAct) of 1992, as amended. These provisions are designed to reduce U.S. dependence on imported petroleum by accelerating the introduction of alternative fuel vehicles (AFVs) in state government and alternative fuel provider fleets. • Municipal Leasing is another option. This is a hybrid tax-exempt structure with features similar to both a loan and a lease. It is not classified as a debt. • The California Department of Resources Recycling and Recovery offers grants to purchase items made from old tires. The Tire-Derived Product Grant Program promotes markets for recycled-content products derived from waste tires generated.
Construction	• The Surface Transportation Block Grant program provides flexible funding that may be used by States and localities for projects to preserve and improve the conditions and performance on any Federal-aid highway, bridge and tunnel projects on any public road, pedestrian and bicycle infrastructure, and transit capital projects, including intercity bus terminals. • The Office of Energy Efficiency and Renewable Energy's (EERE's) State Energy Program (SEP) seeks applications to advance policies, programs, and market strategies that accelerate job creation, reduce energy consumption, and help achieve energy and climate security for the nation. • Department of Homeland Security - The National Dam Safety Program (NDSP) supports state dam safety programs in the development and maintenance of the dam safety programs. The program enables statutory dam safety programs to take precautions that ensure the safety of the dams.
Environmental	• National Institute of Environmental Health Sciences (part of the National Institute of Health) provides federal research funding in the form of grants for research projects, research center funding, training and career development, etc. • The Fish and Wildlife Service supports efforts to increase scientific knowledge and apply it effectively on the ground by identifying information from natural, physical and social sciences needed to further landscape-scale conservation efforts. • The Environmental Enhancement and Mitigation (EEM) grant program offers grant funding for eligible projects that mitigate the environmental effects from the construction or modification of state transportation facilities.

	• National Park Service - Save America's Treasures grants from the Historic Preservation Fund provide preservation and/or conservation assistance to nationally significant historic properties and collections
Freight and Logistics	• Environmental Protection Agency announces the availability of funds to promote and stimulate information exchange among State hazardous and solid waste officials, other State officials actively involved in the management of these wastes, and EPA officials to jointly resolve Resource Conservation and Recovery Act (RCRA) implementation issues, and identify emerging issues that are at both State and Federal levels. • Eco monic Development Administration projects must be located within and targeted to communities or regions that have been impacted, or can reasonably demonstrate that they will be impacted, by coal mining or coal power plant employment loss, or employment loss in the supply chain industries of either.
Maintenance	• Environmental Protection Agency has grants that address the national Resource Conservation Challenge (RCC) priorities of increasing recycling of solid waste, construction and demolition debris, and industrial materials. • Environmental Protection Agency has grants to promote the transition to reduced-risk pest management practices in agriculture to protect human health and the environment. • Environmental Protection Agency announces the availability of funds to promote and stimulate information exchange among State hazardous and solid waste officials, other State officials actively involved in the management of these wastes, and EPA officials to jointly resolve Resource Conservation and Recovery Act (RCRA) implementation issues, and identify emerging issues that are at both State and Federal levels.
Materials and Testing	• Centers for Disease Control and Prevention is encouraging submission of an application from qualified organizations for a National Center for Construction Safety and Health Research and Translation. An applicant is encouraged to propose trans-disciplinary approaches and coordination for impactful applied and intervention research, hazards identification and controls, develop partnerships for implementing prevention and intervention activities, and to serve as a leader in research translation and research-to-practice for the protection of construction workers in the U.S. • DOT Federal Highway Administration Accelerated Innovation

	Deployment - The AID Demonstration provides incentive funding for eligible entities to accelerate the implementation and adoption of innovation in highway transportation.
Multimodal	• The Federal Transit Administration (FTA) has the availability of Section 5309 funds for exempt discretionary grants for Urban Circulator Systems which support the Department of Transportation Livability Initiative. • DOT Federal Highway Administration - Multistate Corridor Operations and Management program. • DOT Federal Transit Administration - FTA makes available for the Innovative Coordinated Access and Mobility Pilot Program to finance innovative capital projects for the transportation disadvantaged that will improve the coordination of transportation services and non-emergency medical transportation services.
Roadway Design	• DOT National Highway Traffic Safety Administration - Announcement of a Request for Application (RFA) is to provide assistance to State Highway Safety Offices with older driver populations to incorporate the Highway Safety Guidelines No. 13 with a comprehensive older driver safety program. • DOT Federal Motor Carrier Safety Administration - The FMCSA provides SaDIP funds to allow eligible recipients that collect, analyze, and report large truck and bus crash and inspection data to improve the quality of the commercial motor vehicle (CMV) data reported by States to FMCSA. Specifically, applications are sought that will improve the timeliness, efficiency, accuracy, and completeness of State processes and systems. • DOT Federal Motor Carrier Safety Administration - The MCSAP Basic and Incentive grant program is a Federal formula grant program that provides financial assistance to reduce the number and severity of crashes, injuries, and fatalities involving commercial motor vehicles.
Strategic Transportation Investments	• DOT Federal Highway Administration - As directed in The Fixing America's Surface Transportation Act (FAST Act), funds are available for projects enhancing compliance of motor fuel and highway use taxes.
Structures	• DOT Federal Highway Administration funds are used for highway bridge replacement and rehabilitation projects on public roads that demonstrate cost savings by bundling multiple highway bridge projects. • DOT Federal Highway Administration Accelerated Innovation

	Deployment - The AID Demonstration provides incentive funding for eligible entities to accelerate the implementation and adoption of innovation in highway transportation. • DOE Weatherization and Intergovernmental Program provides grants, technical assistance, and information tools to states for their energy programs. The funding can be used to encourage installation of green infrastructure—such as green roofs—as part of the weatherization process.
Traffic Operations	• USDOT provides BUILD grans which are discretionary. These grants can be used to enhance traffic operations. • US Department of Energy - Through its Vehicle Technologies Office (VTO), the DOE has allocated millions of dollars in 2017 to its Transportation as a System (TAS) Initiative. TAS seeks to explore opportunities for energy efficiency at the system-level, above its traditional vehicle-level focus. Earlier this year, VTO created the Energy Efficient Mobility Systems (EEMS) subprogram and then released its Fiscal Year 2017 Vehicle Technologies Program Wide Funding Opportunity Announcement (FOA), which included the agencies first formal foray into the CAV technology area. • Department of Transportation - While the DOE's CAV efforts are principally focused energy efficiency, the DOT's CAV efforts are more focused on road safety albeit with an eye towards sustainability. Furthermore, the DOT has subprograms supporting CAV innovations from early to advanced stages in technology development, reflecting the DOT's having started initiatives in this space earlier than the DOE. • There is every indication that momentum for CAV funding opportunities with the federal government through these programs and others such as the Advanced Research Projects Agency Energy (ARPA-E) are only going to increase, despite uncertainty on Capitol Hill.

8.3 Summary

Funding opportunities for sustainability projects can vary depending on the type of entity (e.g. municipality, state, university) searching for funding. State DOTs can receive grants from most of the same US Departments as municipalities; however, the scope and type of the grant may be different. Additionally, while State DOTs may concentrate their funding search within that of USDOT or FTA, other US Departments are willing to provide grants that could assist TDOT in achieving its sustainability goals. Political considerations often influence where resources are allocated either statewide or nationally, as well as the difficulty in obtaining funds. Existing available funding through an application process is considered the easiest to obtain. We have provided a table of possible available funding sources through the application process for some of TDOT's divisions, though other funding sources could be available. These include FAA funds for the Aeronautics Division; DOE funds for the Central Services Division; Homeland Security and Office of Energy Efficiency and Renewable Energy monies for Construction; National Institute of Environmental Health Science and Fish and Wildlife Service grants for the Environmental Division; Economic Development Administration and EPA grants for the Freight and Logistics Division; Centers for Disease Control and Prevention grants for Materials and Testing Division; Federal Motor Carrier grants for Roadway Design Division, DOE Weatherization grants for Structures, and BUILD grant and DOE for CAV grans the Traffic Operations Division. Whereas funding through an application process is one source, TDOT public and private partnerships, e.g., with universities and industry, have yet to be explored fully.

9.0 CONCLUSIONS AND RECOMMENDATIONS

In October 2015, the Tennessee Department of Transportation (TDOT) tasked a project team at the University of Tennessee's Center for Transportation Research to assist with the development and implementation of sustainable strategies. The research team investigated issues of strategic importance to TDOT, aiming to weave sustainability into the fabric of TDOT as a way of thinking. In this project, the team identified, selected and suggested specific sustainable strategies for implementation. This document presents the results of the study.

During the first half of research, we conducted a review of sustainable practices in departments of transportation throughout the United States in order to locate relevant documents and publications directly relating to sustainability issues and practices. Then, we used text mining techniques to identify sustainable practices that could be applied to TDOT.

The team performed three different text mining operations (i.e. word cloud analysis, keyword topic review, and similarity plot of phrases) on the sustainable transportation documentation of five entities or groups of entities: 1) TDOT reports, 2) documents of DOTs adjacent to Tennessee, 3) other DOT papers, 4) Smart City finalist vision narratives, and 5) vision narratives from three Tennessee cities who submitted applications to the Smart City Challenge. In a comparison of word clouds from the five entities, energy was one of the most frequently identified words. Other shared words included environment and water. Furthermore, "data" and "smart" were the most frequently found words in applications for both the Smart City finalists and Tennessee Smart City participants. Other word shared by the Smart City finalists and Tennessee participants included transit, system, public, infrastructure and traffic. The project team performed a rigorous topic analysis in order to identify keywords associated with the thematic concepts more frequently cited in the various retrieved documents. TDOT and the Adjacent DOTs reference biofuels and fuel types as one of the top five topic areas, while TDOT and Tennessee Smart City participants share key concepts relating to safety. Finally, similarity plots analyzed which phrases were most often used in the documentation. The sustainability documentation from the five entities (TDOT, Adjacent DOTs, Other DOTs, Smart City finalists and Tennessee Smart City participants) contained phrases relating to energy conservation and emissions reduction. The Smart City finalists used phrases directly related to Connected and Autonomous/Automated Vehicles (CAV) while the Tennessee Smart City participants used words related to emerging (shared) transportation management companies, i.e. Lyft and Uber. TDOT and Adjacent DOTs also used waste management related phrases contained words such as waste, water, pollution, and greenhouse gas (GHG). Three entities (i.e. Other DOTs, Smart City finalists and Tennessee participants) used phrasing directly related to data centers, data sharing or real-time information.

The team conducted transferability analysis (the difficulty level of transferring a policy or technology from one DOT to TDOT) using socio-demographic distribution and hierarchical clustering. In addition, we developed an example of a transferability matrix. In order to

analyze the transferability of strategies at other DOTs to TDOT, team members used socio-demographic comparison using quantifiable attributes such as population, area, median household income, population density, etc. The most similar quantifiable attributes between other DOTs and TDOT include population, GDP, air pollution, mean travel time to work, average road length, and fatality per 100 million VMT. Hierarchical clustering provided a comparison of Tennessee to all other states, highlighting the states most like Tennessee based on the clustering and combination of a series of attributes. Tennessee is most like North Carolina and Wisconsin. Finally, this report provides an example of transferability. Chapters of this Green Generates Green Final Report provide specific examples of sustainability actions that can be applied to each TDOT division.

We reviewed performance measures used to analyze the implementation and subsequent operation of a changed or new sustainability practice, policy or program. In this regard, we identified different types of performance measures across a variety of entities, both public and private. Performance measures such as cost-benefit analysis and return-on-investment, both quantitative (e.g., crash rates, traffic speeds) and qualitative (e.g., environmental justice), were used to monitor the success or failure of a specific process or project component. Cost benefit ratio integrates qualitative data into a measurement that may not be fully "accurate", while ROI utilizes hard data and can provide a well-defined result but may lack important subtleties.

In order to establish a benchmark for existing sustainability-related actions at TDOT, we conducted a survey of fifteen TDOT Division Directors in July and August 2017. The TDOT divisions surveyed were Aeronautics, Central Services, Construction, Environmental, Freight Logistics, Long-range Planning, Maintenance, Materials and Testing, Multimodal, Roadway Design, Right-of-way, Strategic Planning, Strategic Transportation Investments, Structures and Traffic Operations. This 22-question survey included five sections: Division Background Data, Policy Information, Cost-Benefit Information, Barriers to Sustainability and Sustainability Practices of Other Departments of Transportation (DOT). The survey provided information about current sustainability actions taken by TDOT personnel as well as desired actions for the future.

As a continuation of the survey, a meeting of the Division Directors in March 2018 provided input as to the next steps TDOT should take in order to integrate sustainability policies, protocols and procedures into TDOT operations. Analysts from the Lipscomb University Institute for Sustainable Practice created a priority list of actions using a weighted metric. This list provided a series of guidelines for TDOT personnel. Chapters in this report provide the next steps to enhancing sustainability (creating the capacity to endure). They provide examples of easy or moderate-to-implement sustainability activities in Tennessee. In many cases, TDOT personnel have already partially implemented some of the suggestions made. In other cases, the information provided will start TDOT on its way to integrating sustainability policies, procedures and programs into the fabric of the department.

Finally, the potential funding sources for sustainable actions are identified and examples of strategies that can be used by TDOT are identified. Some of the funds available to states come

from federal Departments outside USDOT or some non-conventional sources within USDOT. While some state DOTs concentrate their funding search within that of USDOT, other federal Departments and some less frequently tapped USDOT sources may be willing to provide grants that could assist TDOT in achieving sustainability goals. These include a) FAA funds for the Aeronautics Division, 2) DOE funds for the Central Services Division, 3) Homeland Security and Office of Energy Efficiency and Renewable Energy monies for Construction, 4) National Institute of Environmental Health Science and Fish and Wildlife Service grants for the Environmental Division, 5) Economic Development Administration and EPA grants for the Freight and Logistics Division, 6) Centers for Disease Control and Prevention grants for the Materials and Testing Division, 7) Federal Motor Carrier grants for Roadway Design Division, 8) DOE Weatherization grants for Structures, 9) US DOT BUILD grants, and DOE grants for CAVs appropriate for the Traffic Operations Division. Whereas funding through an application process is one way to access funds, TDOT public and private partnerships is another possibility that has yet to be explored fully.

Most importantly, the final report provides a series of recommendations agreed upon by TDOT Division Directors during the March 2018 meeting. These recommendations highlight important insights that point to establishing a program that enhances TDOT's "capacity to endure." The recommendations form the framework for the creation of a comprehensive program that can weave sustainability concepts into TDOT's fabric while building upon new initiatives and supporting initiatives currently underway. Generally, the directors mentioned the desire for dialog among different division directors, so they can collaborate on comprehensive sustainable strategies. Awareness and training for tools that can help TDOT staff evaluate the benefits and costs of sustainable actions and strategies that can hasten the diffusion of sustainable practices. Specific recommendations are found below.

Recommendation #1: Define Sustainability

Many state departments of transportation are moving to incorporate sustainability into their planning and day-to-day operations. A definition of what sustainability means to TDOT provides clarity and a baseline of understanding for all TDOT employees. Specific steps can be used to define sustainability as it relates to TDOT. This report provides a framework that is based on defining sustainability as the capacity to endure and for sustainable strategies to be cost-effective, in line with the concept of "green generates green."

Recommendation #2: Integrate Best Practices

This report provides 50 specific best practices that can be incorporated into 15 TDOT Divisions (e.g. included Aeronautics, Central Services, Construction, Environmental, Freight Logistics, Long-range Planning, Maintenance, Materials and Testing, Multimodal, Roadway Design, Right-of-way, Strategic Planning, Strategic Transportation Investments, Structures and Traffic Operations). Best sustainability practices categorized as a resource, guide, tool or policy have been identified as either being moderate or easy to integrate and utilize. This will allow the

TDOT division directors to begin the process of sustainability integration. The practices include new technologies, electric vehicle infrastructure, alternative modes, and land use.

Recommendation #3: Hire a Sustainability Practice Lead

TDOT Division directors indicated a need for a Sustainability Practice Lead who would be responsible for creating, coordinating, and overseeing the compliance of sustainability initiatives. With the appointment of a Sustainability Lead, a coordinated, strategic approach can be provided, led by a single individual who draws together all aspects of sustainability - energy management, social and ethical due diligence, etc., to create a green strategy for the whole of TDOT.

Recommendation #4: Formalize Collaboration

Eight of the division directors remarked on the need to have in place some type of formalized method for integrating sustainability aspects of other divisions into their own projects, procedures, documentation and other efforts. This final report provides guidance on how to achieve a comprehensive multidisciplinary approach to integrating sustainability concepts into final deliverables. Though most divisions were required to work with other departments in the project process, formalized collaboration would enhance project impact and allow input from the best examples of various divisions at TDOT.

Recommendation #5: Formalize Existing Sustainability Policies and Actions

A number of TDOT division directors indicated the following of unwritten sustainability practices, such as paper recycling and reduction, etc. and the need to "formalize" the unwritten policies to provide consistency throughout the separate TDOT divisions. This would include the formalization of key administrative practices that are sustainable across all divisions. Guidelines for formalization have been provided in this report, including online documentation, digital signatures, public outreach through internet, emailed invoice and payment, and electronic plan submittal.

Recommendation #6: Develop In-House Training/Education

TDOT division directors discussed the need for in-house training that would include a series of educational opportunities that would build upon each other specific to certain themes. The training program would be used to encourage employee engagement in addressing sustainability issues. Currently, TDOT does not have in-house training related to sustainability. To show leadership, a sustainability program could include new hires given exposure to sustainability concepts early in the employment process. Sustainability education could begin with new employee orientation. This would include the desire to make current and future employees aware of the sustainability policies and programs already in place.

Recommendation #7: Establish Work Groups

TDOT division directors indicated a need to create a number of working groups to research specific topics and achieve specified goals. These working groups can include public transit, connected and automated vehicles, fleet management, and smart communities. In this context, the TDOT working groups would include not only interested parties, but also individuals with a working knowledge or some expertise in the subject area. These groups would achieve a series of specific sustainability objectives and goals. These groups would be domain-specific and focus on discussion or activity around a specific subject area. Specifics for the creation of each of the work groups is found in this Green Generates Green Final Report.

Recommendation #8: Raise Sustainability Awareness Internally

Engaging employees in sustainability is a growing trend with significant benefits. At TDOT, the most frequently cited barriers to sustainability mentioned by division directors included low awareness of potential and/or existing programs, policies and procedures; the cost of implementation and legislative or regulatory prohibitions. The directors also mentioned a resistance to change, and a negative association with the term "sustainability." Many of these obstacles can be addressed by specific TDOT initiatives outlined in this report.

Recommendation #9: Integrate Outcome Measurements

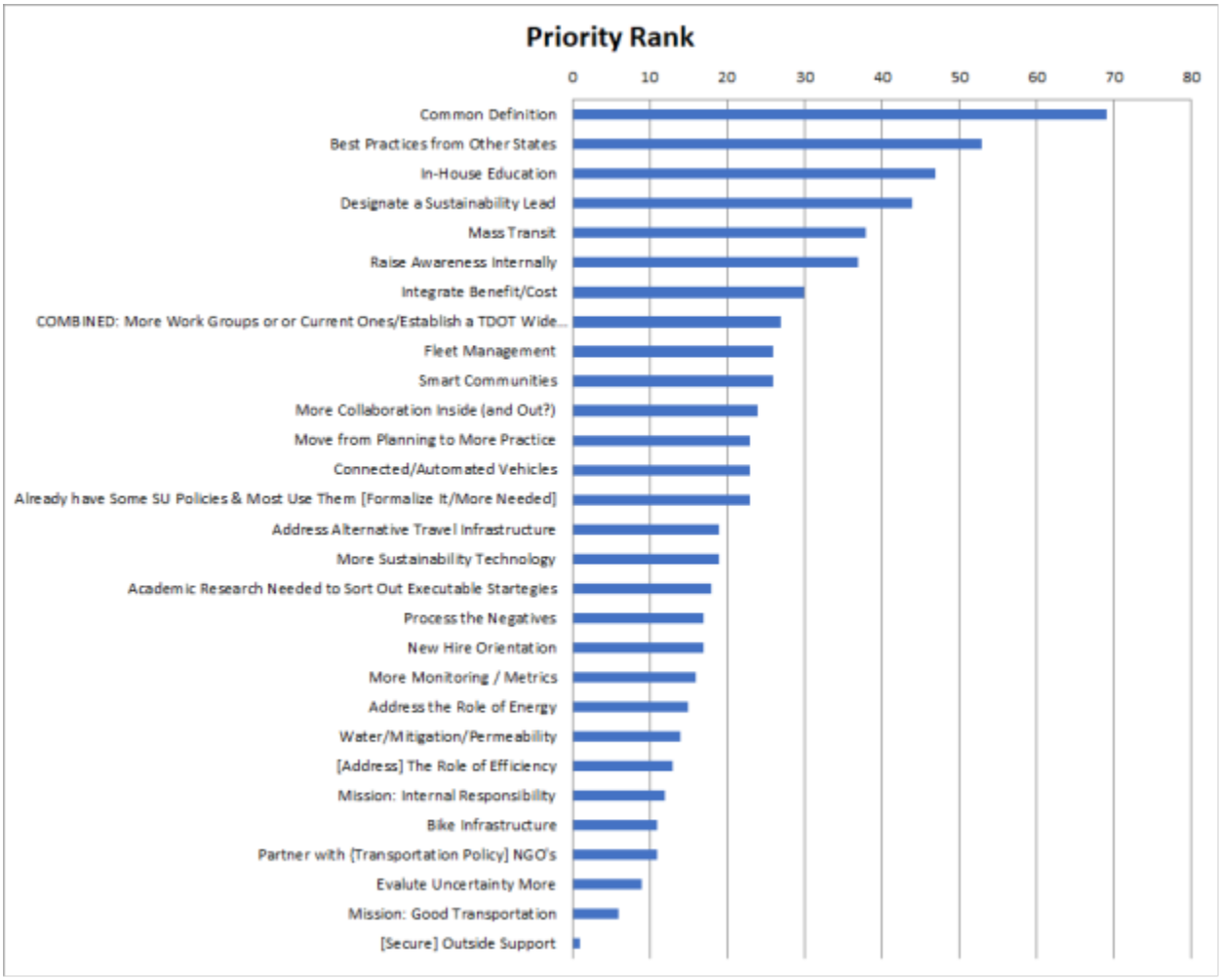
TDOT division directors mentioned the need and reliance on public feedback to determine if a project is successful or not, but that there was no formalized method to receive, document and measure this feedback. Other means of outcome measurement have been identified and discussed in this final report. A meticulous application of outcome measurement and project monitoring is needed to determine if a project is a success of failure, as well as to determine any changes that need to be made to practices, policies, and protocols.

Recommendation #10: Provide Planning to Practice Methods

Planning to integrate sustainability is part of best practices found in the Best Practices Applied to TDOT section of this report. Each of the 50 resources, guides, tools or policies have been identified as either being moderate or easy to integrate into practice. This will promote the process of sustainability integration across disciplines and different divisions at TDOT.

This Green Generates Green Final Report provides information to effectively integrate sustainability practices, protocols and policies into the fabric of TDOT's day-to-day operations.

Appendix A: Ranked Next Steps



Email Correspondence
Sent: Wednesday, March 21, 2018 4:56 PM
To: Alan Jones (Alan.Jones@tn.gov);
Asad Khattak (asadjkhattak@gmail.com);
Noltenius, Melany Strike (mnolteni@utk.edu)
From: G. Dodd Galbreath (dodd.galbreath@lipscomb.edu)
Assistant Professor of Sustainability
Founding Director of Institute for Sustainability Practice

Overall, I see two primary strategic focuses potentially coming out of the discussion and needs addressed yesterday. These are:

(A) Greater Clarity and Focus for Sustainability in TDOT, and

(B) Core Strategic Actions for Sustainability.

There appears to be a strong desire by the Directors to do the following, if one extrapolates or infers these next steps from the prioritized action items.

A. Greater Clarity and Focus: These address priority #'s: 1, 2, 4, 11, and 12C

1. **Define sustainability for TDOT: Since there is less interest in forming new broader work groups, perhaps Allen and the associated executive leadership team could prepare a very brief policy summary about sustainability as a mission at TDOT.**
    - Develop a draft. Keep it simple and focused.
    - Ask for edits and input from the Directors. Don't convene more meetings.
    - Derive definitions and areas of focus from the perspectives offered yesterday for both internal and external responsibilities.
    - Integrate or address these items below in the draft:
        - A Common Sustainability Definition for TDOT
        - Best Practice Areas in TDOT (these are the categories Toks discussed and can be derived in part from other states' best practices and TN trends such as the Reinvestment Act)
        - Propose/designate a Sustainability Lead (to assess and guide progress)
        - Formalize collaboration/communication networks internally and externally
        - Formalize existing policies and "safe" new ones (list them, don't discuss them - let each stand on their own per prior administrative practice)

2. **As a separate report, inventory and categorize best practices from other states and countries as bench marks for new or expanded TDOT initiatives:**
    - This seems like an excellent role for Dr. Assad's Team.

B. Core Strategic Actions (also in preparation for a new administration): These address priority #'s: 3, 5, 6, 7, 8, 9, 10, & 12A/12B

1. **Organize the following priorities as "actions items" with Toks' leadership.**
    - **3, 6, & 9 & 12B:** The Sustainability Lead will plan and organize:
        - Informational and marketing efforts to create greater sustainability awareness department wide after Part A is begun. At a minimum, this should take the form of a draft plan that could be updated for the new administration.
        - "Leading by example" practices such as TDOT fleet trend models of electric, CAV and Public Transit uses by employees and in commuting, new paving technologies, a zero-energy management plan and goal for the entire agency.
    -
    - **5, 7, 8, 10, 12A & 12B:** Immediately, re-task existing groups or develop a focused " Transit AND CAV Policy Vision Group" for the expressed goal of defining and visioning TDOT's core mission of infrastructure support for responding to market and public driven Public Transit and CAV expansions in the future.
        - Have this two part "policy vision" ready and waiting for the new administration in January as a draft product. Do not create a finished product to give it a chance for fresh adoption.
        - Design draft models of calculating benefit cost issues of each.
        - Integrate smart community concepts into this effort since one or both impact land use and community infrastructure allocation therein.
        - Fund/conduct applied labs/experiments in association with the University of Tennessee to test the practice of trending transportation tools and future TDOT management thereof. Integrate findings in above policies and practices.

Below is the information sent previously:

From Professor Galbreath

The methodology: Greens dots (short term) are weighted 3 points; orange dots (midterm) are weighted 2 points; and pink (longer term) are 1 point and cumulatively added up for the ranking.

The data fields are in descending order and the bar graph is in ascending order since it was a "canned" graph option.

The top 12 are an interesting summary of Director level priorities.

1. Common Definition	69
2. Best Practices from Other States	53
3. In-House Education	47
4. Designate a Sustainability Lead	44
5. Public Transit	38
6. Raise Awareness Internally	37
7. Integrate Benefit/Cost	30
8. [I COMBINED TWO VOTES - Similar Topics] A. More Work Groups or Current Ones // B. Establish a TDOT Wide CAV/Plan Working Group	27
9. Fleet Management	26
10. Smart Communities	26
11. More Collaboration Inside (and Out?)	24
12. [THREE TIED for #12] A. Move from Planning to More Practice// B. Connected/Automated Vehicles// C. Already have Some SU Policies & Most Use Them [Formalize It/More Needed]	23

Appendix B: TDOT Rules on Truck Lane Restriction Along Interstates

RULES
OF
TENNESSEE DEPARTMENT OF TRANSPORTATION
CHAPTER 1680-2-5
TRUCK LANE RESTRICTIONS ALONG INTERSTATES AND
MULTI-LANE ACCESS CONTROLLED HIGHWAYS
TABLE OF CONTENTS

1680-2-5-.01 PURPOSE AND SCOPE.

(1) The purpose of these rules is to implement Tennessee Code Annotated § 55-8-195 by establishing criteria for the designation and enforcement of lane restrictions for truck tractors and semi-trailers as defined in Tennessee Code Annotated § 55-8-101 and in these rules.

(2) The truck lane restrictions established under these rules shall apply only in designated areas where appropriate signage has been posted on eligible highways as defined in these rules.

Authority: *T.C.A. § 55-8-195.* ***Administrative History:*** *Original rule filed June 23, 2005; effective October 28, 2005.*

1680-2-5-.02 DEFINITIONS.

(1) "Access controlled highway" means a highway or street especially designed for through traffic, with grade-separated interchanges rather than at-grade intersections, and to which owners or occupants of abutting land or other persons have no legal right or easement of access from abutting land.

(2) "Bus" means every motor vehicle designed for carrying more than ten (10) passengers and used for the transportation of persons, and every motor vehicle, other than a taxicab, designed and used for the transportation of persons for compensation.

(3) "Eligible highways" means highways on the Interstate Highway System and access controlled, multilane divided highways on the state highway system that have three (3) or more lanes in each direction of travel.

(4) "Semi-trailer" means every vehicle with or without motive power, other than a pole trailer, designed for carrying persons or property and for being drawn by a motor vehicle and so constructed that some part of its weight and that of its load rests upon or is carried by another vehicle.

(5) "Truck tractor" means every motor vehicle designed and used primarily for drawing other vehicles and not so constructed as to carry a load other than a part of the weight of the vehicle and load so drawn.

Authority: *T.C.A. § 55-8-195.* ***Administrative History:*** *Original rule filed June 23, 2005; effective October 28, 2005.*
1680-2-5-.03 TRUCK LANE RESTRICTIONS.

(1) Except as otherwise provided in these rules, truck tractors and semi-trailers shall be restricted to the right two (2) lanes of travel in designated areas of eligible highways where appropriate signage has been posted.

(2) Truck lane restrictions shall not apply when truck tractors and semi-trailers are passing other motor vehicles. The passing maneuver shall be safely completed in as short a time period as feasible. The passing maneuver shall consist of passing one motor vehicle at a time.

(3) Buses are not subject to the restrictions established in these rules.

Authority: *T.C.A. § 55-8-195.* ***Administrative History:*** *Original rule filed June 23, 2005; effective October 28, 2005.*

1680-2-5-.04 GUIDELINES FOR ESTABLISHING TRUCK LANE RESTRICTIONS ON ELIGIBLE HIGHWAYS.

(1) Interstate highways and other access controlled, multilane divided highways that have three (3) or more through lanes in each direction of travel are eligible for truck lane restrictions.

(2) Only those portions of eligible highways approved by the Department of Transportation and where appropriate signage has been installed shall be considered as having truck lane restrictions.

(3) Truck lane restrictions shall terminate within two (2) miles of a left lane exit to allow ample time for lane transitions.

(4) Existing truck lane restrictions may be temporarily terminated or modified during highway construction and other special events at the discretion of the Department of Transportation.

(5) Truck lane restrictions should be avoided in areas where the average truck spacing is less than 500 feet per lane.

(6) Signs shall be placed in accordance with the Manual on Uniform Traffic Control Devices (MUTCD) to provide motorists with notification of the restricted zone. Examples of the signs may be found in the current edition of the Tennessee Supplement to Standard Highway Signs and the MUTCD.

(7) These rules do not apply to those portions of highways where “truck climbing lanes” have been established due to excessive grades or where special truck lane restrictions have been established in construction zones.

(8) The Commissioner of the Department of Transportation reserves the authority to remove or modify truck lane restriction zones established under these rules.

Authority: *T.C.A. § 55-8-195.* ***Administrative History:*** *Original rule filed June 23, 2005; effective October 28, 2005.*

Appendix C: Tennessee State Senate Bill No. 151

PUBLIC CHAPTER NO. 474
SENATE BILL NO. 151
By Lundberg, Green, Bowling, Hensley, Jackson, Kelsey
Substituted for: House Bill No. 381
By Lambeth, Timothy Hill, Marsh, Swann, Kevin Brooks, Ragan, Daniel, Gant, Reedy, Shaw, Mark White, Powell, Mitchell, Staples, Hardaway, Kane, Zachary, Jernigan

AN ACT to amend Tennessee Code Annotated, Title 5; Title 6; Title 7; Title 39; Title 40; Title 54; Title 55; Title 56; Title 65 and Title 67, relative to autonomous vehicles.

BE IT ENACTED BY THE GENERAL ASSEMBLY OF THE STATE OF TENNESSEE

SECTION 1. Tennessee Code Annotated, Section 55-4-108, is amended by designating subsection (c) as subsection (d) and adding the following new subsection (c):

For purposes of an ADS-operated vehicle, as defined by S 55-54-102, the requirements of subsection (a) are satisfied if the certificate of registration is at all times carried in or available electronically through, the vehicle to which it refers.

SECTION 2. Tennessee Code Annotated, Section 55-8-101, is amended by deleting subdivisions (17), (42), and (46), and substituting instead the following:

(17) "Driver" means:

(A) For purposes of a conventionally operated vehicle, every person who drives or is in actual physical control of a vehicle; and

(B) For purposes of an ADS-operated vehicle and when the context requires, the ADS when the ADS is engaged;

(42) "Operator" means:

(A) For purposes of a conventionally operated vehicle, every person, other than a chauffeur, who drives or is in actual physical control of a motor vehicle upon a highway or who is exercising control over or steering a vehicle being towed by a motor vehicle; and

(B) For purposes of an ADS-operated vehicle and when the context requires, the ADS when the ADS is engaged;

(46) 'Person" means a natural person, firm, co-partnership, association, corporation, or an engaged ADS;

SECTION 3. Tennessee Code Annotated, Section 55-8-101, is amended by adding the following new appropriately designated subdivisions:

( ) "Automated driving system" or 'ADS" means technology installed on a motor vehicle that has the capability to drive the vehicle on which the technology is installed in high or full automation mode, without any supervision by a human operator, with specific driving mode performance by the automated driving system of all aspects of the dynamic driving task that can be managed by a human driver, including the ability to automatically bring the motor vehicle into a minimal risk condition in the event of a critical vehicle or system failure or other emergency event;

() 'Automated-driving-system-operated vehicle" or "ADS-operated vehicle" means a vehicle equipped with an automated driving system;

() "Dynamic driving task" means all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic. "Dynamic driving task" does not include strategic functions, such as route selection and scheduling;

() "Minimal risk condition" means a low-risk operating mode in which an ADS operated vehicle when the ADS is engaged achieves a reasonably safe state upon experiencing a failure of the vehicle's ADS that renders the vehicle unable to perform the entire dynamic driving task;

SECTION 4. Tennessee Code Annotated, Section 55-8-162, is amended by adding the following new subsection:

Subsection (a) shall not apply with respect to an ADS-operated vehicle.

SECTION 5. Tennessee Code Annotated, Section 55-9-101, is amended by deleting the section and substituting instead the following:

As used in this chapter:

(1) 'Autocycle," "motor vehicle," "motorcycle," "motor-driven cycle," and "motorized bicycle" have the meanings ascribed to them in $ 55-8-101; and

(2) "Automated driving system," "ADS," and 'ADS-operated vehicle" have the meanings ascribed to them in $ 55-54-102.

SECTION 6. Tennessee Code Annotated, Section 55-9-602(a), is amended by adding the following new subdivision:

With respect to a vehicle equipped with an ADS, responsibility ascribed in this subsection (a) shall belong solely to the parent, guardian, or other human person accompanying the child in the vehicle, and not to the ADS or the owner of the ADS-operated vehicle.

SECTION 7. Tennessee Code Annotated, Section 55-9-602(9)(5), is amended by deleting the last sentence, designating the remaining language as subdivision (A), and adding the following new subdivision (B):

(B) (¡) lf no parent or legal guardian is present at the time of the violation; the driver is solely responsible for compliance with this subsection (g) if the vehicle is operated by conventional means.

(ii) lf the vehicle is operated by an ADS and:

(a) lf no parent or legal guardian is present at the time of the violation, the human person accompanying the child is solely responsible for compliance with this subsection (g);

(b) lf no parent or guardian is present at the time of the violation and more than one (1) human person accompanies the child, each person is jointly responsible for compliance with this subsection (g); or

(c) lf no human person accompanies the child; the parent or legal guardian of the child is responsible for compliance with this subsection (g).

SECTION 8. Tennessee Code Annotated, Section 55-9-603(h), is amended by adding the following new subdivision:

An ADS or an ADS-operated vehicle. Except as otherwise provided by $ 55-9-606(2), for purposes of an ADS-operated vehicle, a passenger or human operator required to be restrained by a safety belt pursuant to this section is solely responsible for the passenger's or human operator's compliance with such requirement;

SECTION 9. Tennessee Code Annotated, Section 55-9-606, is amended by deleting the section and substituting instead the following:

Notwithstanding this part to the contrary:

(1) Except as otherwise provided in subdivision (2), the operator of a passenger motor vehicle under this part shall not be fined for the failure of any passenger over sixteen (16) years of age to wear a safety belt; and

(2) For purposes of an ADS-operated vehicle and when the ADS is engaged, neither the operator nor the owner shall be fined for the failure of any passenger, regardless of age, to wear a safety belt.

SECTION 10. Tennessee Code Annotated, Sections 55-10-101, 55-10-102, 55-10-103, 55-10-104, and 55-10-106, are all amended by adding the following new, appropriately designated subsection to each section:

With respect to an ADS-operated vehicle, as defined by S 55-54-102, the requirements of subsection (a) are satisfied if the motor vehicle's owner, or a person on behalf of the motor vehicle's owner, promptly contacts a law enforcement officer or agency to report the accident and the ADS-operated vehicle remains on the scene of the accident as otherwise required by law.

SECTION 11. Tennessee Code Annotated, Section 55-10-105, is amended by designating the existing language as subsection (a) and adding the following new subsection:

With respect to an ADS-operated vehicle, as defined by S 55-54-102, the requirements of subsection (a) are satisfied if the motor vehicle's owner, or a person on behalf of the motor vehicle's owner, promptly contacts a law enforcement officer or agency to report the accident and the ADS-operated vehicle remains on the scene of the accident as otherwise required by law.

SECTION 12. Tennessee Code Annotated, Section 55-10-107, is amended by adding the following new subsection:

With respect to an ADS-operated vehicle, as defined by S 55-54-102, the written reports required under subsection (a) must be completed by the vehicle's owner.

SECTION 13. Tennessee Code Annotated, Section 55-12-102(10), is amended by deleting the subdivision and substituting instead the following:

(10) "Operator" means:

(A) For purposes of a conventionally operated vehicle, every person who is in actual physical control of a motor vehicle whether or not licensed as an operator or chauffeur under the laws of this state; and

(B) For purposes of an ADS-operated vehicle, as defined by g 55-5a-102, and when the ADS is engaged, the ADS;

SECTION 14. Tennessee Code Annotated, Section 55-12-104, is amended by adding the following new subsection:

The owner of an ADS-operated vehicle, as defined by S 55-54-102, is solely responsible for compliance with the requirements for filing the accident report under subsection (a).

SECTION 15. Tennessee Code Annotated, Section 55-50-304, is amended by adding the following new subdivision:

An ADS or an ADS-operated vehicle, as defined by S 55-54-102, or a person operating an ADS-operated vehicle with the ADS engaged;

SECTION 16. Tennessee Code Annotated, Title 55, is amended by adding the following new chapter:

55-54-101.

This chapter shall be known and may be cited as the "Automated Vehicles Act."

55-54-102.

As used in this chapter:

(1) "Automated driving system" or “ADS" means technology installed on a motor vehicle that has the capability to drive the vehicle on which the technology is installed in high or full automation mode, without any supervision by a human operator, with specific driving mode performance by the automated driving system of all aspects of the dynamic driving task that can be managed by a human driver, including the ability to automatically bring the motor vehicle into a minimal risk condition in the event of a critical vehicle or system failure or other emergency event;

(2) "Automated-driving-system-operated vehicle" or "ADS-operated vehicle" means a vehicle equipped with an automated driving system;

(3) "Department" means the department of revenue;

(4) "Dynamic driving task" means all of the real-time operational and tactical functions required to operate a vehicle in on-road traffic. "Dynamic driving task" does not include strategic functions, such as route selection and scheduling; and

(5) "Minimal risk condition" means a low-risk operating mode in which an ADS-operated vehicle when the ADS is engaged achieves a reasonably safe state upon experiencing a failure of the vehicle's ADS that renders the vehicle unable to perform the entire dynamic driving task.

55-54-103.

An ADS-operated vehicle may drive or operate on streets and highways in this state with the ADS engaged without a human driver physically present in the vehicle if the vehicle meets the following conditions:

(1) Unless an exemption has been granted under applicable federal or state law, the vehicle is capable of being operated in compliance with applicable provisions of chapters 8, 9, and 10 of this title, and has been, at the time it was manufactured, certified by the manufacturer as being in compliance with applicable federal motor vehicle safety standards;

(2) The vehicle is capable, in the event of a failure of the automated driving system that renders that system unable to perform the entire dynamic driving task relevant to its intended operational design domain, of achieving a minimal risk condition;

(3) ls registered in accordance with chapter 4 of this title, and if registered in this state, the vehicle is identified on the registration as an ADS-operated vehicle; and

(4)(A) (i) The vehicle is covered by primary automobile liability insurance in at least five million dollars ($5,000,000) per incident for death, bodily injury, and property damage, and the automobile liability insurance satisfies the requirements of $ 56-7-1201;

(ii) Insurance required by subdivision (a)(A)(i) may be:

(a) Placed with an insurer authorized to do business in this state under title 56 or with a surplus lines insurer eligible under title 56, chapter 14;

(b) Covered by a surety bond executed and filed with the commissioner of safety; or

(c) Satisfied in accordance with S 55-12-1 1 1;

(iii) Insurance satisfying the requirements of this subdivision (4)(A) shall be deemed to satisfy the financial responsibility requirements for a motor vehicle under chapter 12 of this title;

(B) This subdivision (4) is deleted on July 1 ,2021;

(C) No later than February 1,2020, the commissioners of safety and commerce and insurance shall submit a joint report to the transportation and safety committee of the senate and the transportation committee of the house of representatives, which report shall make recommendations, including the appropriate rationale and any proposed legislation, on whether the insurance and bonding coverages and coverage amount requirements of this subdivision 4(A) should be increased, decreased, extended, or otherwise amended.

55-54-104.

Notwithstanding S 55-9-105, a person who is physically inside an ADS-operated vehicle, when the ADS is engaged, may use an integrated electronic display for communication, information, and other uses enabled by the display if the display is integrated with the vehicle such that it operates and functions in coordination with such autonomous technology and disables automatically any moving images visible to the motor vehicle operator when the autonomous technology is disengaged.

55-54-105.

No political subdivision may by ordinance, resolution, or any other means prohibit or regulate within the jurisdictional boundaries of the political subdivision the use of:

(1) An ADS-operated vehicle that is operating in compliance with this chapter and otherwise complies with all laws of the political subdivision; or

(2) A motor vehicle operated at any level of autonomous technology, as defined by $ 55-9-105(c)(6)(B), not otherwise included in this chapter.

55-54-106.

(a) Liability for accidents involving an ADS-operated vehicle shall be determined in accordance with product liability law, common law, or other applicable federal or state law. Nothing in this chapter shall be construed to affect, alter or amend any right, obligation, or liability under applicable product liability law, common law, federal law, or state law.

(b) When the ADS is fully engaged, operated reasonably and in compliance with manufacturer instructions and warnings, the ADS shall be considered the driver or operator of the motor vehicle for purposes of determining:

(1) Liability of the vehicle owner or lessee for alleged personal injury, death, or property damage in an incident involving the ADS-operated vehicle; and

(2) Liability for non-conformance to applicable traffic or motor vehicle laws.

55-54-107.

(a) It is an offense for any person to knowingly operate a motor vehicle on the public roads or highways of this state without a human driver in the driver's seat of the vehicle unless satisfying the requirements of this chapter.

(b) A violation of subsection (a) is a Class A misdemeanor.

55-54-108.

Except as otherwise provided in this chapter, this chapter exclusively governs the authorization of the operation and use of an ADS-operated vehicle when the ADS is engaged and in high or full automation mode, including, but not limited to, commercial use of AĐS operated vehicles.

For motor vehicles operated at any other level of autonomous technology, as defined by $ 55-9-105(c)(6)(B), the motor vehicle and driver shall be held to the same laws as conventionally operated motor vehicles, including the financial responsibility requirements of $ 55-12-102, unless an exemption is specifically set out for a vehicle operated with any level of autonomy.

SECTION 17. This act shall take effect upon becoming a law, the public welfare requiring it.

Resources and References

Agenbroad, Josh and Ben Holland. May 8, 2014. “What's the true cost of EV charging stations?” GreenBiz. www.greenbiz.com/blog/2014/05/07/rmi-whats-true-cost-ev-charging-stations

American Association of State Highway and Transportation Officials (AASHTO). July 2014. *Preparing High-Quality NEPA Documents for Transportation Projects*. American Association of State Highway and Transportation Officials. https://environment.transportation.org/pdf/programs/pg15-1.pdf

American Public Transportation Association (APTA). October 2017. *October Transit Savings Report: Saving Money by Taking Public Transportation is a Great Halloween Treat*. https://www.apta.com/mediacenter/pressreleases/2015/Pages/151030_Transit-Savings.aspx

American Transportation Research Institute (ATRI). October 2017. *Critical Issues in the Trucking Industry - 2017*. http://atri-online.org/wp-content/uploads/2017/10/ATRI-Top-Industry-Issues-2017.pdf

Alternative Fuels Data Center (AFDC). October 2018. Alternative Fuels Data Center. *US Alternative Fueling Stations by Fuel Type*. www.afdc.energy.gov/fuels/stations_counts.html

Alternative Fuels Data Center (AFDC). November 2018. US Department of Energy. Home Page: https://afdc.energy.gov

Armstrong, Amit. January 2013. *An Integrated Approach for Building Sustainable Roads*. Federal Highway Administration. www.fhwa.dot.gov/innovativeprograms/pdfs/centers/local_aid/IntegratedApproachforBuilidingSustainableRoads.pdf

Arizona Department of Transportation (ADOT). February 2017. Public Involvement Plan. Arizona Department of Transportation. www.azdot.gov/docs/default-source/planning/public-involvement-plan888dce78c8006c57b531ff0000a35efc.pdf?sfvrsn=2

Atlanta Regional Commission (ARC). March 2018. *Atlanta Regional Truck Parking Assessment Study*. https://atlantaregional.org/wp-content/uploads/draft-atlanta-regional-truck-parking-assessment-study-report.pdf

Bacharach, Samuel. September 23, 2013. "4 Ways to Justify a Good Idea". Barcharach Leadership Group. www.inc.com/samuel-bacharach/four-ways-to-win-an-argument.html

Bansal, Nitesh. June 17, 2017. "5 major barriers facing the connected cars of the future" Venture Beat. https://venturebeat.com/2017/06/17/5-major-barriers-facing-the-future-of-connected-cars/

Bartella, Elise M. August 2012. Strategic Planning for a Sustainable Transportation System: A SWOT-Based Framework for Assessment and Implementation Guidance for Transportation Agencies. Dissertation Georgia Technical University. https://smartech.gatech.edu/bitstream/handle/1853/44855/barrella_elise_m_201208_phd.pdf?sequence=1&isAllowed=y

Benton, Ben. February 3, 2015. "Tennessee tests smart parking lots with real-time parking space information". Times Free Press. www.timesfreepress.com/news/local/story/2015/feb/03/parking-sites-project-helps-truckers-find-tim/286144/

Bomey, Nathan. January 25, 2018. "New electric cars in 2018 spark need for more charging stations". USA TODAY. www.usatoday.com/story/money/cars/2018/01/25/new-electric-cars-2018-spark-need-more-charging-stations/810137001/

Bosetti, Simone. October 2015. "Smart choices for cities Making urban freight logistics more sustainable". CIVITAS Policy Note. www.eltis.org/sites/default/files/trainingmaterials/civ_pol-an5_urban_web-1.pdf

Bowers, Fred. April 2014. *Statewide Transportation Planning for Healthy Communities*. U.S. Department of Transportation. Office of Planning, Environment, and Realty. Federal Highway Administration. Website: www.planning.dot.gov/documents/VolpeFHWA_DOT_Health.pdf

British Columbia. 2004. Dawson Creek Green Fleet Policy. British Columbia Environmental Action Tool Kit. www.ubcm.ca/assets/library/Policy~Topics/Environment/DawsonCreek-GreenVehiclePolicy2006.pdf

California Department of Transportation (CDOT). September 2007. Project Communication Handbook. California Department of Transportation Office of Project Management. www.dot.ca.gov/hq/projmgmt/documents/pchb/project_communication_handbook_2nd_ed.pdf

California Department of Transportation (CDOT). May 2013. *Effective Communication Strategies*. California Department of Transportation. www.dot.ca.gov/hq/maint/Pavement/RPC/PDF/RPC_6_Attachment_Effective_Communication_Strategies_5-8-13.pdf

California Department of Transportation (Caltrans). March 2015. *Strategic Management Plan*. http://www.dot.ca.gov/perf/library/pdf/Caltrans_Strategic_Mgmt_Plan_033015.pdf

California Department of Transportation (Caltrans). December 2015. *Road Map to Achieving Executive Orders*. http://dot.ca.gov/hq/sustainability/documents/Executive_Order_B-18_B16_Roadmap_without_Appendix.pdf
California Energy Commission (CEC). Accessed December 2018. *Infrastructure for Alternative Fuel Vehicles*. www.energy.ca.gov/reports/afvguide.html

Chicago Department of Aviation (CDA). 2016. Sustainable Airport Manual. Chicago Department of Aviation. www.flychicago.com/community/environment/sam/Pages/default.aspx

City of Knoxville. February 2015. *Knoxville Bicycle Facilities Plan*. www.knoxvilletn.gov/UserFiles/Servers/Server_109478/File/Engineering/BicyclePlan/feb2015_finalreport.pdf

City of Knoxville. 2018. *Cumberland Avenue Corridor Project Summary.* www.knoxvilletn.gov/government/city_departments_offices/redevelopment/cumberland_avenue_corridor_project

CLECAT. 2010. Logistics Best Practices Guide. The European Association for Forwarding, Transport, Logistics and Customs Services. www.clecat.org/media/sr005osust101201clecatsustlogbpg2nded.pdf

Clement, Joel. April 2014. *A Strategy for Improving the Mitigation Policies and Practices of the Department of the Interior*. A Report to The Secretary of the Interior. From Energy and Climate Change Task Force. www.doi.gov/sites/doi.gov/files/migrated/news/upload/Mitigation-Report-to-the-Secretary_FINAL_04_08_14.pdf

Chicago Metropolitan Agency for Planning (CMAP). Accessed June 10, 2018. *Invest Strategically in Transportation. Chicago Metropolitan Agency for Planning.* www.cmap.illinois.gov/about/2040/regional-mobility/invest-transportation

Colorado Department of Transportation (CODOT). 2010. *Innovative Public Involvement Technology*. Colorado Department of Transportation. www.codot.gov/programs/planning/documents/planning-process/InnovativePublicInvolvementTech.pdf

Colorado Department of Transportation (CODOT). March 2015. Statewide Transit Plan: Connecting People Across Colorado. Division of Transit and Rail, Colorado Department of Transportation. www.slvdrg.org/wp-content/uploads/2017/05/2015-Statewide-Transit-Plan.pdf

Colorado Department of Transportation (CODOT). 2016. *Colorado Department of Transportation General Aviation Airport Sustainability Tool Kit*. Colorado Department of Transportation. www.codot.gov/programs/aeronautics/SustainProg/SustainabilityManual

Colorado Department of Transportation. *Sustainability Program and Action Plan.* https://www.codot.gov/programs/environmental/Sustainability/sustainability-action-plan

Copeland, Larry. May 29, 2014. "Staggering toll: Car crashes cost $871 billion". USA Today. www.usatoday.com/story/news/nation/2014/05/29/steep-economic-toll-of-crashes/9715893/

Corriere, Ferdinando and Angela Rizzo. 2012. *Sustainability in Road Design: A Methodological Proposal for the Drafting of Guideline*. Procedia - Social and Behavioral Sciences 53 (2012) 39 – 48. www.sciencedirect.com/science/article/pii/S1877042812043200

Deese, Hollie. January 26, 2018. Nashville, state at forefront of autonomous car development. The Nashville Ledger. Vol. 42, No. 4. https://www.tnledger.com/editorial/ArticleEmail.aspx?id=103661&print=1

Drive Electric Tennessee. November 2018. http://driveelectrictn.org/

Federal Aviation Administration (FAA). July 2015. Historical, Architectural, Archeological, and Cultural Resources Desk Reference. Federal Aviation Administration. www.faa.gov/about/office_org/headquarters_offices/apl/environ_policy_guidance/policy/faa_nepa_order/desk_ref/media/8-historical-architectural.pdf

Federal Aviation Administration (FAA). Accessed March 2018*. Voluntary Airport Low Emissions Program (VALE) Airports*. Federal Aviation Administration. www.faa.gov/airports/environmental/vale/

Florida Department of Transportation (FDOT). 2000. 2025 Florida Transportation Plan. Florida Department of Transportation. http://floridatransportationplan.com/

Florida Department of Transportation (FDOT). September 2007. *Performance Measures to Evaluate the Effectiveness of Public Involvement Activities in Florida*. Center for Urban Transportation Research, University of South Florida, College of Engineering for the Florida Department of Transportation. Technical memorandum #1. Contract # BD544, Work Order #21 www.cutr.usf.edu/wp-content/uploads/2012/08/Public_Involvement_Performance_Measures_Literature_Review.pdf

Florida Department of Transportation (FDOT). July 2015. *e-Construction How-To Guide*. Florida Department of Transportation. To Support FHWA EDC-3 Implementation Activities. www.fhwa.dot.gov/construction/econstruction/florida/howto.pdf

Federal Highway Administration (FHWA). 2008. *CA4PRS Software Tool*. Federal Highway Administration. www.fhwa.dot.gov/construction/ca4prsbroc.cfm

Federal Highway Administration (FHWA). April 2011. *Reclaimed Asphalt Pavement in Asphalt Mixtures: State of the Practice*. Federal Highway Administration Publication No. FHWA-HRT-11-021. www.fhwa.dot.gov/publications/research/infrastructure/pavements/11021/11021.pdf

Federal Highway Administration (FHWA). October 2012. *Towards Sustainable Pavement Systems: A Reference Document*. Federal Highway Administration. FHWA-HIF-15-002. www.fhwa.dot.gov/pavement/sustainability/ref_doc.cfm.

Federal Highway Administration (FHWA). January 2013. *An Integrated Approach for Building Sustainable Roads*. FHWA-WFL/TD-13-002. Federal Highway Administration. www.fhwa.dot.gov/innovativeprograms/pdfs/centers/local_aid/IntegratedApproachforBuilidingSustainableRoads.pdf

Federal Highway Administration (FHWA). 2015. *Infrastructure Voluntary Evaluation Sustainability Tool - INVEST*. Federal Highway Administration. www.sustainablehighways.org/

Federal Highway Administration (FHWA). June 27, 2017. *Warm Mix Asphalt Technologies and Research*. Federal Highway Administration. www.fhwa.dot.gov/pavement/asphalt/wma.cfm

Federal Highway Administration (FHWA). October 2018. *Truck Parking*. https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/

Golias, Mihalis M. December 2016. *Tennessee SmartPark Pilot*. Tennessee Department of Transportation. www.tn.gov/content/dam/tn/tdot/documents/RES2016-08.pdf

Gray, Sarah. June 2018. “A Shocking Percentage of Americans Don't Exercise Enough, CDC Says.” Fortune Magazine. www.fortune.com/2018/06/28/americans-do-not-exercise-enough-cdc/

Hamm, Trent. December 13, 2017. “Walking, Bicycling, Driving, and Cost-Effectiveness - The Simple Dollar”. The Simple Dollar Magazine. www.thesimpledollar.com/walking-bicycling-driving-and-cost-effectiveness/

Hardin, Matt. November 2018. *Major Interstates in Tennessee*. www.matthardinlaw.com/major-interstates-in-tennessee.html

Hickman, Matt. December 4, 2017. "Let's use the right-of-way in a smarter way". Mother Nature Matters. www.mnn.com/green-tech/transportation/blogs/georgia-highway-rightofway-farming-ray-anderson

Iowa Department of Transportation (IDOT). January 2018. Sustainable Bridge Design. Iowa Department of Transportation. Office of Bridges and Structures. LRFD Bridge Design Manual. Website: https://iowadot.gov/bridge/policy/02-00-00Sustain.pdf

Institute of Project Management Ireland (IPMI). March 5, 2013. *An implementation Strategy for a project, The critical steps*. Institute Project Management Ireland. www.projectmanagement.ie/blog/an-implementation-strategy-for-a-project-the-critical-steps

Ipswich Planning Board. March 2008. Sustainability, Green Design and Resource Efficiency. Ipswich, Massachusetts Planning Board. www.ipswichma.gov/DocumentCenter/View/1012/Community-Development-Plan-Amendments

Jaber, David. November 2009. "The Language of Sustainability: Why Words Matter." GreenBiz. www.greenbiz.com/blog/2009/11/18/language-sustainability-why-words-matter

Jones, Mike. Accessed December 2018. *Guidelines for Alternative Fuel Infrastructure Program*. Maryland Energy Administration. https://energy.maryland.gov/transportation/Documents/Guidelines.pdf

Kingsbury, Kathleen. May 20, 2008. "The Value of a Human Life: $129,000". Time Magazine. www.content.time.com/time/health/article/0,8599,1808049,00.html

Knoxville Regional Transportation Planning Organization (KRTPO). Accessed November 2018. *Complete Streets Design Guidelines*. Gresham Smith and Partners. https://knoxtrans.org/plans/complete_streets/guidelines.pdf

Korkmaz, Kasim Armagan. December 2012. *Implementation of Sustainability in Bridge Design, Construction and Maintenance*. Michigan State University School of Planning, Design and Construction. www.michigan.gov/documents/mdot/RC-1586_413209_7.pdf

LaBelle, Jim. (September 2015) *Off-Peak Delivery: A Pilot Project for the Chicago Region*. Urban Transportation Center. College of Urban Planning and Public Affairs at the University of Illinois - Chicago. https://utc.uic.edu/wp-content/uploads/Off-Peak-Delivery-Report.pdf

League of American Bicyclists (LAB). November 2018. https://www.bikeleague.org/
Lindskog, Helena. January 2004. *Smart Communities Initiatives*. Linkoping University. http://heldag.com/articles/Smart%20communities%20april%202004.pdf

MassDOT. May 18, 2012. "Transit Working Group". Massachusetts Department of Transportation, Rail and Transit Division. www.massdot.state.ma.us/Portals/12/docs/TWG_White_Paper051812.pdf

Mass Transit Magazine. November 2018. www.masstransitmag.com

Melaina, M. and M. Penev. September 2013. *Hydrogen Station Cost Estimates: Comparing Hydrogen Station Cost Calculator Results with other Recent Estimates.* National Renewable Energy Laboratory. NREL/TP-5400-56412. www.nrel.gov/docs/fy13osti/56412.pdf

Mid-Atlantic Freight Coalition (MAFC). February 2017. *An Evaluation of Vacant Urban Land for Truck Parking*. www.midamericafreight.org/wp-content/uploads/MAFC-White-Paper_Truck-Parking.pdf+&cd=1&hl=en&ct=clnk&gl=us

Mobility Lab. *What is TDM?* Accessed December 2018. Arlington County Commuter Services (ACCS). https://mobilitylab.org/

Motza, Maryann and Dean J. Conder. October 2012. *Sustainability through Contract Drafting and Management*. Government Finance Review. www.gfoa.org/sites/default/files/GFR_OCT_12_42.pdf

Nashville Metropolitan Planning Organization (NMPO). Accessed November 2018. *Complete Streets*. www.nashvillempo.org/regional_plan/roadways/complete_streets.aspx

National Cooperative Highway Research Program (NCHRP). 2011. Report 708: A Guidebook for Sustainability Performance Measurement for Transportation Agencies. National Cooperative Highway Research Program. https://ssti.us/wp/wp-content/uploads/2011/11/nchrp_rpt_708.pdf

National Center for Sustainable Transportation (NCST). March 2015. *Sustainable Transportation Curricula*. National Center for Sustainable Transportation. https://ncst.ucdavis.edu/wp-content/uploads/2015/04/04-28-2015-ncst-education-report-final-042415-2.pdf

National Safety Council (NSC). November 2018. www.pedbikeinfo.org/data/faq_details.cfm?id=42

New Jersey Office of Clean Energy (NJOCE). Accessed December 2018. *AFV Infrastructure Guide*. New Jersey Board of Public Utilities (BPU), Office of Clean Energy. www.njcleanenergy.com/files/file/AFV/infraguide.pdf

North Carolina Department of Transportation (NCDOT). October 2005. *Achieving a Seamless Transportation System for North Carolina: A Framework for Collaboration*. North Carolina Department of Transportation. https://connect.ncdot.gov/projects/planning/TPB%20Documents/Framework%20for%20Collaboration.pdf

North Carolina Department of Transportation (NCDOT). March 2018. Public Transportation Statewide Strategic Plan. Public Transit Division, North Carolina Department of Transportation. www.ncdot.gov/nctransit/strategicplan/

North Carolina Department of Transportation (NCDOT). Accessed June 8, 2018. *Strategic Transportation Investments*. North Carolina Department of Transportation. www.ncdot.gov/strategictransportationinvestments/

North Carolina Department of Transportation (NCDOT). Accessed March 2018. *Green Ports Strategies*. https://www.ncdot.gov/initiatives-policies/Transportation/freight/Documents/NC_Maritime_final_report_2012-06-26.pdf

North Central Texas Council of Governments (NCTCOG). 2012. *Roadmap to a Sustainable Public Right-of-Way.* North Central Texas Council of Governments. www.nctcog.org/envir/SEEDevEx/pubworks/ROW/documents/Roadmap%20to%20a%20Sustainable%20Right%20of%20Way%20-%20final%20draft.pdf

North Carolina Department of Transportation (NCDOT). *Greening North Carolina Travel and Tourism: Tips for Sustainable Practices in Tourism.* Accessed March 2018. http://www.ecu.edu/cs-acad/sustainabletourism/upload/N-C-Green-Travel-Sustainability-Tips-8.pdf

Oregon Department of Transportation (ODOT). 2010. Sustainability Plan. Oregon Department of Transportation. www.oregon.gov/ODOT/Programs/TDD%20Documents/ODOT-Sustainability-Plan-Volume-2.pdf

Oregon Department of Transportation (ODOT). *Sustainability Progress Report. https://www.oregon.gov/ODOT/Programs/TDD%20Documents/ODOT-Sustainability-Progress-Report-2016.pdf*

Organisation for Economic Cooperation and Development (OECD). 2001. *Policies to Enhance Sustainable Development*. Organisation for Economic Cooperation and Development. Meeting of the OECD Council at Ministerial Level. www.oecd.org/greengrowth/1869800.pdf

Ovy, Danny. July 31, 2018. “Alternative Fuels and Emerging fuels” AEN News. Alternative Energies.Net. www.alternative-energies.net/green-fuels-and-emerging-fuels/

Pelzer, Jeremy. October 2013. “Proposed left-lane truck ban could help keep traffic moving, studies show, but uncertainties remain.” City of Cleveland Ohio OPEN POLITICS. www.cleveland.com/open/index.ssf/2013/10/proposed_left-lane_truck_ban_c.html

Perk, Victoria. December 2015. Capturing the Benefits of Complete Streets. National Center for Transit Research. BDV26-977-04

www.nctr.usf.edu/wp-content/uploads/2016/01/NCTR-977-04-Capturing-the-Benefits-of-Complete-Streets-2015-1.pdf

Pula, Kevin. June 2015. *On Track: How States Fund and Support Public Transportation*. National Conference of State Legislatures. www.ncsl.org/Portals/1/Documents/transportation/ontrack.pdf

Roth, JD. June 15, 2011. "The Costs and Savings of Bicycle Commuting". Forbes Magazine. www.forbes.com/sites/moneybuilder/2011/06/15/the-costs-and-savings-of-bicycle-commuting/

Schinella, Tony. May 28, 2013. Maintenance Costs for Complete Streets Project: Multi-Millions. Patch.com. https://patch.com/new-hampshire/concord-nh/maintenance-costs-for-complete-streets-project-in-the42be279155

Smart Growth America (SGA). March 2017. *Creating Value: Assessing the Return on Investment in Complete Streets.* Webinar. https://smartgrowthamerica.org/app/uploads/2017/03/Creating-Value-Assessing-the-Return-on-Investment-in-Complete-Streets.pdf

Smart Growth American (SGA). November 2018. Website: https://smartgrowthamerica.org

Sørensen, Claus Hedegaard, et. al. 2013. "National sustainable transport planning – concepts". Technical University of Denmark. http://orbit.dtu.dk/files/92811333/National_sustainable_transport_planning_concepts_and_practices.pdfand practices

Tennessee Clean Fuels (TCF). November 2018. *Pending Alternative Fuel Corridors in Tennessee*. http://www.tncleanfuels.org/2017/12/18/pending-alt-fuel-corridors-in-tennessee/

Tennessee Clean Fuels (TCF). November 2018. www.tncleanfuels.org/2017/12/18/pending-alt-fuel-corridors-in-tennessee/

Tennessee Department of Transportation. Accessed December 2018. The Statewide Transportation Demand Management (TDM) Plan for Tennessee Nonattainment and Maintenance Areas. Long Range Planning Division. www.tn.gov/content/dam/tn/tdot/long-range-planning/TDOT_Statewide%20TDM%20Plan_FINAL%20DRAFT%20v3.pdf),

Tennessee Department of Transportation (TDOT). November 2018. *Welcome Center and Rest Areas.* www.tn.gov/tdot/maintenance/welcome-center---rest-areas.html

Tennessee Department of Transportation (TDOT). 2016. *Community Transportation Planning Grant Fact Sheet.* Tennessee Department of Transportation Long-Range Planning Division.

www.tn.gov/content/dam/tn/tdot/documents/TDOT_CTPG_FactSheets_CompleteStreets.pdf

Tennessee Environmental Council. *Sustainable Tennessee Agenda, A Project of Tennessee Environmental Council*. https://www.tectn.org/sustainable-tennessee-agenda.html

Texas Department of Transportation (TxDOT). 2009. *Developing sustainable transportation performance measures for TxDOT's strategic plan: technical report.*

Texas Department of Transportation (TxDOT). 2007. *Strategic Plan. https://ftp.dot.state.tx.us/pub/txdot-info/lao/strategic_plan2007.pdf*

Townsend, Sian. Accessed June 2, 2018."Making sense of customer feedback". Inside Intercomm. https://blog.intercom.com/how-to-make-sense-customer-feedback/

Transportation Research Board (TRB). July 2004. *Integrating Sustainability into the Transportation Planning Process*. Transportation Research Board. Committee for the Conference on Introducing Sustainability into Surface Transportation Planning. http://onlinepubs.trb.org/onlinepubs/conf/CP37.pdf

US Census Bureau. 2018. www.census.gov/

US Department of Energy (USDOE). April 2013. Alternative Fuel Infrastructure Expansion: Costs, Resources, Production Capacity, and Retail Availability for Low-Carbon Scenarios. US Department of Energy Office of Energy, Efficiency and Renewable Energy. www.nrel.gov/docs/fy13osti/55640.pdf

US Department of Energy (USDOE). September 2014. *Costs Associated with Compressed Natural Gas Vehicle Fueling Infrastructure.* https://afdc.energy.gov/files/u/publication/cng_infrastructure_costs.pdf

US Department of Energy (USDOE). August 2014. *Costs Associated with Propane Vehicle Fueling Infrastructure.* https://afdc.energy.gov/files/u/publication/propane_costs.pdf

US Department of Energy (USDOE). 2017. Energy Efficient Mobility Systems 2017 Annual Progress Report. www.energy.gov/sites/prod/files/2018/05/f51/EEMS_FY2017_APR_Final.pdf

U.S. Department of Energy (USDOE). 2017. 2017 Annual Report. USDOT Vehicle Technologies Office - Energy Efficient Mobility Systems (EEMS) Program.

US Department of Transportation (USDOT). 2010. Comprehensive Procurement Guidelines for Products Containing Recovered Materials. Code of Federal Regulations: 40 CFR 247. US

Department of Transportation. www.transit.dot.gov/funding/procurement/third-party-procurement/recycled-products

US Department of Transportation (USDOT). June 2013. *Chapter 350: Telework Policy*. US DOT Departmental Personnel Manual. www.transportation.gov/sites/dot.gov/files/docs/DOT%20Telework%20Policy%2009-11-15.pdf

US Department of Transportation (USDOT). June 2014. Strategic Sustainability Performance Plan. United States Department of Transportation. www.transportation.gov/mission/sustainability/dot-strategic-sustainability-performance-plan

US Department of Transportation (USDOT). August 2015. *Jason's Law Truck Parking Survey Results and Comparative Analysis*. US Department of Transportation Federal Highway Administration Office of freight Management and Operations. https://ops.fhwa.dot.gov/freight/infrastructure/truck_parking/jasons_law/truckparkingsurvey/jasons_law.pdf

US Department of Transportation (USDOT). August 2016. Sustainable Acquisition Policy. United States Department of Transportation. www.transportation.gov/mission/sustainability/sustainable-acquisition

US Department of Transportation (USDOT). January 3, 2017. *Round Two: Seven Finalists Create Plans to Implement Their Visions*. US Department of Transportation. www.transportation.gov/smartcity/7-finalists-cities

US Department of Transportation (USDOT). June 2017. *National Coalition on Truck Parking: Activity Report 2015-2016*. https://ops.fhwa.dot.gov/publications/fhwahop17026/fhwahop17026.pdf

US Department of Transportation (USDOT). Accessed March 2018. *Federal Highway Administration Motor Vehicle Management Manual*. Federal Highway Administration Department of Transportation. www.fhwa.dot.gov/legsregs/directives/orders/m43401a/

US General Accountability Office (USGAO). September 2012. Key Considerations for Implementing Interagency Collaborative Mechanisms. United States Government Accountability Office. Report to Congressional Requesters. www.gao.gov/assets/650/648934.pdf

Virginia Department of Transportation (VDOT). 2016. *Business Plan Update*. Virginia Department of Transportation. www.virginiadot.org/about/resources/FY2016_Business_Plan.pdf

Virginia Department of Veterans Affairs. Strategic Sustainability Performance Plan. https://www.energy.va.gov/docs/VAsspp2011.pdf

Volpe Center. March 2012. *Trends in Statewide Long-Range Transportation Plans*. Office of Planning Federal Highway Administration US Department of Transportation. www.planning.dot.gov/documents/State_plans_report_508_A.PDF

Washington State Department of Transportation (WSDOT). Accessed December 2018. CTR Overview. www.wsdot.wa.gov/Transit/CTR/overview.htm

Washington State Department of Transportation (WSDOT). *Regional Greenhouse Gas and Vehicle Miles Traveled Reduction Strategies*. http://www.wsdot.wa.gov/publications/manuals/fulltext/M3122/WSPTP.pdf

Wikipedia. November 2018. https://en.wikipedia.org/wiki/Complete_streets#Design_elements

Williams, Kristine. June 2014. Multimodal Transportation Best Practices and Model Elements. National Center for Transportation Research. PROJECT NO. BDK85-977-49. www.fdot.gov/research/Completed_Proj/Summary_PL/FDOT-BDK85-977-49-rpt.pdf

Wilmot, Chester. April 2009. *Impact of Left Lane Truck Restriction Strategies on Multilane Highways in Louisiana—A Literature Review*. Louisiana Transportation Research Center. www.ltrc.lsu.edu/pdf/2009/tar_09_1ta.pdf

World Commission on Environment and Development (WCED). 1987. Report of the World Commission on Environment and Development: Our Common Future. World Commission on Environment and Development. www.un-documents.net/our-common-future.pdf