Development of Tools to Address Key Issues in Long Range Transportation Planning

Final Report

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Summary

Background

This project resulted from a compilation of three Research Problem Statements from the Tennessee Department of Transportation (TDOT):

1) Assessment of Macro Trends and Their Impact on Travel Demand

2) The Transportation Land Use Connection in Rural and Small Urban areas

3) Development of a Comprehensive Statewide Data Collection Plan

Thus, the project was design to address three key interrelated long range transportation planning topics and their associated problems: impacts of societal trends, the transportation-land use connection and the data required for conducting transportation planning.

Research Problems Initially Addressed

Projecting the demand for travel in the future is an integral aspect of the long-range transportation planning process. Long range plans developed by TDOT and the state's 11 MPOs are based on forecasting future travel patterns, defining deficiencies and identifying transportation projects/services to address these deficiencies. Inherent in the forecasting process is the assumption that future travel will represent an extrapolation of current travel, socio-demographic, economic, and technological trends. However, new paradigms may be emerging which are not simply extensions of past trends. The question then is what are the implications of these macro-trends on travel behavior and on the transportation plans developed with assumptions of continuous reliance and access to the personal mobility of the automobile? These trends are now emerging but are not formally considered in the long-range planning process.

Transportation and land use are intrinsically linked. The type of built environment that is developed on a parcel of land has transportation implications and every transportation action affects land use. TDOT helps shape land use and the built environment by providing infrastructure to improve accessibility and mobility. Land development generates travel, and travel generates the need for new facilities, which in turn increases accessibility and attracts further development. Many TDOT projects are located outside the boundaries of MPOs. In these areas it can be very difficult to coordinate transportation and land use decisions. TDOT is taking steps to enhance this coordination through the creation of the Office of Community Transportation. The planners in this new office will be able to work with local officials to develop qualitative linkages between transportation and land use planning. Unfortunately, there are currently no tools available to TDOT planners for making quantitative linkages between transportation and land use.

Data are needed for almost all aspects of transportation planning and are especially critical for travel demand analysis and modeling. This is true for TDOT at the statewide level, for MPOs at the metro area and for RPOs and others conducting planning in rural areas. Data needs include the number, purpose and mode of trips produced by households; the number of trips attracted to commercial areas; the number of trips that travel into and through an area; the number of employees working in an area; the travel speed between locations; the volume of freight that moves into, out of, and through an area; the number of long distance trips traveling into, out of, and through an area; the amount of travel generated by various sectors such as tourism; and the demographic characteristics of travelers just to name a few. The question facing the planners at TDOT and other organizations in Tennessee is, "What is the most efficient way to utilize the limited resources for acquiring the various data needed to perform transportation planning and analysis?" Unfortunately, the answer is that we don't know because no one has developed a comprehensive plan for the acquisition of planning data for Tennessee.

Solutions

These three issues are not unique to Tennessee though circumstances in the state may warrant tailored solutions. Each topic was thoroughly researched by assessing how the problems have been addressed in other states and at the national level. Particular attention was given to states with characteristics similar to Tennessee's. Interviews were conducted with those involved in these issues throughout Tennessee and when possible, quantitative data will be gathered and inventoried.

Note that in the second quarter of 2015 a request for scope revision was made to the TDOT staff sponsor. The following is an excerpt from that request, *"One finding from the recent meetings between TDOT and MPO staff on the topic of data is that there is strong interest among TN MPOs and at TDOT for a coordinated and cooperative effort to collect household and other travel survey data in Tennessee through a standardized process. This is especially the case among the smaller MPOs in the state where in most cases household travel surveys have not been conducted in the past forty plus years or have never been conducted. Given these points the project team proposes a more targeted data collection plan as the third key product of this project. We propose focusing the remaining time and financial resources allotted for the data portion of this project on the development of a Statewide Survey Data Collection Plan. This approach would be a slight change of direction for the project, but the project team believes that this would be the best use of the resources available and request that TDOT approve this change."* The revision in scope was approved by TDOT staff shortly after the request was made.

Project Objective

The objective of this research project is the development of three readily usable tools to aide TDOT and MPO planners in their efforts to conduct long range transportation planning in Tennessee.

Planned Structure of Project Results

Planned project results included the following: the creation of a brief *Planners Guide to the Implications of Emerging Societal Trends*; the development of a *Transportation – Land Use Linkage Tool Box for Rural and Small Urban Area Planning* and the completion of a *Comprehensive Statewide Transportation Planning Data Collection Plan.*

Actual Project Results

The TDOT Technical Representative for the project retired in July of 2015 and his role was not filled for some time afterwards. This was an important time in the project schedule as substantial feedback was needed from TDOT to keep the project moving forward. In October, inquiries and a request were made by the project staff regarding a no cost time extension. After several exchanges in communication the result was a request from TDOT for a presentation of the current status of the project. This was provided in late December 2015. In February of 2016 TDOT conveyed to the UT that TDOT's needs had changed, that they planned to go in a different direction with regard to this research and that the existing project tasks should be wrapped up.

The remainder of this report documents the progress made and results for each of the three major tasks. Though all three address long range planning issues each represents separate topic, so they are presented in separate sections for the sake of clarity.

I. Assessment of Macro Trends and Their Impact on Travel Demand the Problem

Projecting future travel demand is an integral aspect of the long-range transportation planning process. Long range plans developed by TDOT and the state's 11 TPOs and MPOs are based on forecasting future travel patterns, defining deficiencies, and identifying transportation projects/services to address these deficiencies. Inherent in the forecasting process is the assumption that future travel will represent an extrapolation of current travel, socio-demographic, economic, and technological trends. However, new paradigms may be emerging which are not simply extensions of past trends. The travel impacts from an ever-increasing reliance on mobile information and communication technology (ICT) devices such as smart phones and computer tablets are likely substantial. The question then becomes: what are the implications of these macro-trends on travel behavior and on the transportation plans developed with assumptions of continuous reliance and access to the personal mobility of the automobile? These trends are emerging but are not formally considered in the long-range planning process.

As Todd Litman of the Victoria Institute stated, "The Future Isn't What It Used To Be".[1] Simply stated, demographic and economic trends will affect future travel demand. A number of researchers have hypothesized that the United States has achieved peak travel measure by vehicle miles of travel (VMT) per year.[2] Given an aging population, increased health and environmental concerns, preference for urban higher-density living, a greater number of alternatives to driving, and greater reliance on ICT as a substitute for actual travel, the future demand for travel may be quite different than today. The question is: what are the implications of these trends on the traditional forecasting of travel demands?

Conventional travel demand models are used to forecast future travel demand for a period typically 20-30 years in length. As such, these models are used to define system capacity deficiencies and thus suggest future needs and potential projects. However, these models assume that factors that affect travel demand will more or less stay constant over time. Future travel is based on an extrapolation of base year trends. For example, these models use trip rates per household to estimate future area-wide trip productions and these rates are based on those observed in the survey of the base year. As such, these models do not reflect demographic and socioeconomic shifts.

Trends are emerging that suggest future travel rates might be different than those observed in the base year. This is especially true since the younger generation has been shown to travel less than preceding generations. These observations are attributed to:

- Employment opportunities—Generation X may have more limited resources, high student debt, less employment, still be living at home, etc.

- Location decisions—the younger generation shows greater preference for higher-density urban locations with less dependence on a personal vehicle
- An aging population—this population tends to drive less
- Fuel prices—there have been substantial price variations in recent years
- Greater environmental concerns—there is less interest in owning or driving a vehicle
- Less access—there is less access to an automobile, graduated driver licenses, etc.
- Technology—there is a greater reliance on communication technology, greater use of social media, etc.

Some evidence indicates people are already reducing VMT and person miles of travel (PMT) as shown in Table 1 and Figure 1.

A key question is: will information and communication technology (ICT) serve as an alternative to travel? Note the use of ICT by age groups in Table 2. But what are the implications on travel?

One consideration is that while few empirical studies have been completed, literature suggests ICT is not always an acceptable alternative to being there. Therefore, the answer to whether ICT can serve as a substitution for travel is complex. (See Table 3) The issue involves understanding the "purpose" of ICT. ICT can be a:

1. Substitution for travel—Internet banking, shopping, social contact, etc. Here, travel is reduced
2. Modification of travel—change route and time of travel; telecommuting might not reduce total number of trips, but it can change destinations (shorten them) and off-peak travel; also, freight trips might increase with the package delivery of shopping purchases
3. Neutral to travel—no change in travel
4. Complementary to travel—induce the need for more travel, such as traveling to purchase batteries for Internet purchases or browsing in-store before purchasing online

All these factors are at work, but there is still a need for travel. ICT will not be a pure substitution for travel. In fact, ICT can free up time to allow for more travel.

Overall, ICT has the potential to change the way people interact and communicate, but will this affect travel? It is not certain if the reduced travel patterns of the young are a fundamental change in travel behavior or a short-term issue. Will the young, as they age, tend to become more alike as previous generations? So far, various studies have shown mixed results on the effects of Internet use on travel. Future travel estimates may need to invoke many additional factors. The question then becomes is there a tool available to assist MPO and TPO planners in considering these changes as part of the transportation planning process? A summary of major factors affecting future travel behavior trends is presented in Appendix A.

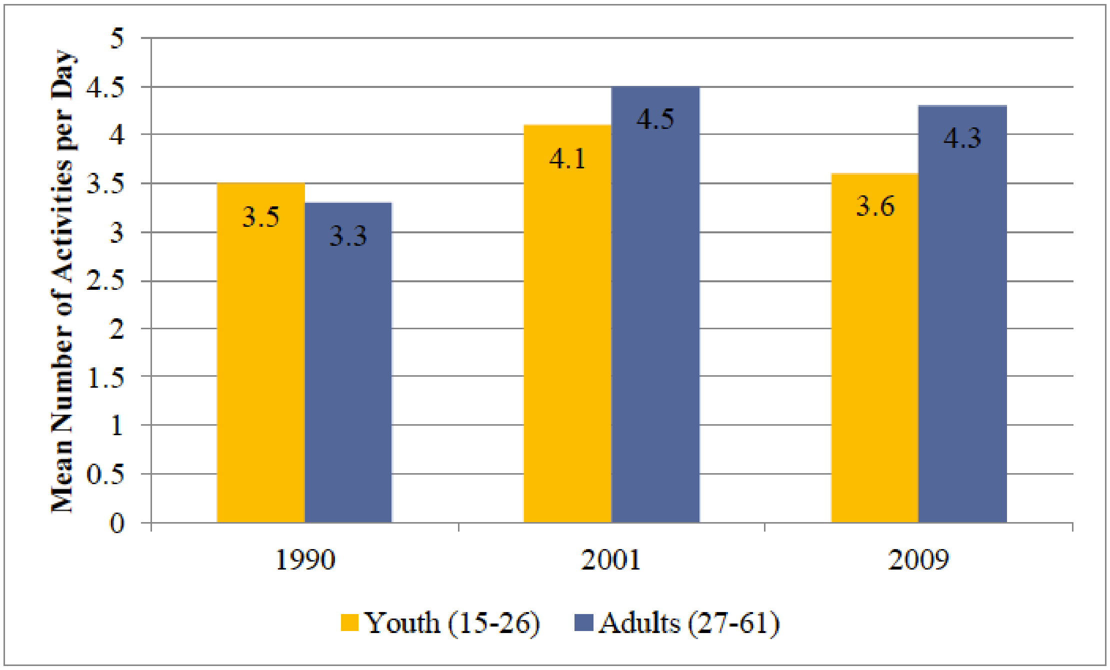
Table 1. Percent Change in VMT and PMT for NHTS Survey Years 1995, 2001 and 2009

Survey Year	Average Annual VMT (per person)			Percent Change		
	16-30	31-55	56+	16-30	31-55	56+
1995	9,872	12,446	7,081	-	-	-
2001	9,748	12,892	7,951	-1.25	3.58	12.28
2009	7,319	11,493	7,781	-24.9	-10.8	-2.06

Survey Year	Average Annual PMT (per person)			Percent Change		
	16-30	31-55	56+	16-30	31-55	56+
1995	15,524	17,041	11,309	-	-	-
2001	15,552	18,299	12,220	0.18	7.38	8.05
2009	12,253	16,214	11,704	-21.2	-11.3	-4.2

Source: The Next Generation of Travel: Research, Analysis, and Scenario Development[3]

Figure 1. Mean Number of Daily Trips by Age and year (1990, 2001, and 2009)



Source: The Next Generation of Travel Statistical Analysis[4]

Table 2. Percentage of phone users, using phone to undertake specialized uses						
	Gen Y (18 to 34)	**Gen X (35 to 46)**	**Younger Boomers (47 to 56)**	**Older Boomers (57 to 65)**	**Silent Gen (66 to 74)**	**G.I. Gen (75+)**
Send or receive text messages	94%	83%	68%	49%	27%	9%
Access the internet	63%	42%	25%	15%	17%	2%
Play a game	57%	37%	25%	11%	10%	7%
Send or receive email	52%	35%	26%	22%	14%	7%
Send or receive instant messages	46%	35%	22%	15%	13%	6%
Source: Pew Research Center's Internet & American Life Project, April 29-30, 2010						

Source: The Next Generation of Travelers Literature Scan: Technology and Transportation Behavior[5]

Table 3. Common Daily Activities and Potential Travel Impacts of Internet Use

Purpose/Activity	Examples	Potential Travel Impacts
Social/Recreational	• Movie guides/ticket purchase (Fandango) • Restaurant/club listings • Sports (fantasy baseball, poker) • Gaming and game information • Web "surfing"	• May increase or decrease recreational travel • Changes in route choice, mode, and time of day • May change daily time-use • "Appointment" Internet may increase at-home time
Communications/Social Network	• Email • Online communities (MySpace, MSN groups, Weight Watchers, etc.) • Instant messaging (IM) • Blogs/fan clubs • Personal/online dating	• Wider social networks encourage wider travel, more visiting friends • Last minute social gatherings may change number and type of visit trips • May decrease visit trips and/or increase trip length
Shopping	• eBay/classifieds • Music/software/game downloads • Movie rentals (Netflix) • Drugs, books, and music • Toys/electronics/apparel and flowers/cards/gifts, misc. • Grocery and household goods	• May increase or decrease shopping trips • Change from residential-based to commercial delivery trips
Information	• News and articles • Product research • Medical information • Directories/Resources • "Surfing"	• Fewer newspaper deliveries • Fewer library visits • May change destination and/or miles/route • Less time at destinations • More time at home
Personal Business	• Banking/bill pay/taxes • Professional services • Government services	• May decrease personal business trips • May change type and location of trips
Work and Work-Related	• Email • Distance learning, webinars • Employment search and application • Telecommuting	• Time of day • Change in number and type of work-related trips • May decrease work trips, may increase other trips
Trip Planning	• MapQuest • Traveler information sites • Airline/hotel/rental car • Google Earth	• Route choice • Mode shifts • May increase long-distance trips • May change destination choice for long-distance

Source: An Exploration of the Internet's Effect on Travel[6]

The SD Model—*Impacts 2050*

In response to providing transportation planning with the ability to reflect changes of socio-demographic factors on future transportation conditions and needs, a scenario planning strategy and System Dynamics Model (SD model) was developed as part of NCHRP Project 750: *Strategic Issues Facing Transportation: The Effects of Socio-Demographics on Future Travel Demand*.

The SD model has been developed to determine how socio-demographic changes over the next 30 to 50 years may affect travel, and it supports a scenario approach to testing these changes. The scenarios serve as a means to quickly and easily determine the effects of alterations of socio-economics on future travel outcomes. As such, it encourages consideration of uncertainty and the risks associated with planning outcomes and input policies.

The SD model has been tested in four large metro areas: Boston, Atlanta, Houston, and Detroit. Our objective is to better understand the model through sensitivity analysis, peer review, and assessment of how it might apply to the smaller Tennessee metropolitan areas. As such, the Knoxville TPO tested it for usefulness and application to a smaller regional area.

The model, with its accompanying software, *Impacts 2050*, estimates transportation impacts (automobile VMT per capita, percent car owning, percent car sharing, average car occupancy, transit modes share, walk/bike mode share, work trips per capita, non-work trips per capita, etc.) as a function of demographic factors like: population, percent under 16, percent over 75, percent Hispanic, percent low income, percent foreign born, percent in workforce, land use patterns, employment locations, transportation system characteristics, etc. "Impact 2050" predefines four default scenarios as spreadsheets (see Figure 2):

1. Momentum—gradual changes without radical shifts.
2. Technology Triumphs—technology solves all problems.
3. Global Chaos—collapse in globalism and sustainability.
4. Gentle Footprint—widespread shift to low-impact living.

The report states:

> The main purpose of the model used in this study is not to provide long-term forecasts—without a crystal ball, those forecasts would almost certainly be wrong and not very useful. Rather, the model's main purpose is to facilitate the running of many different scenarios. SD models typically do not model transport network loading explicitly but include some simple representations of network supply effects. This approach is proven to greatly reduce model run times—

typical SD models are capable of producing 50-year forecasts in less than a minute— which makes the exploration of a large number of scenario tests possible.[7]

The model enables users to:

- Examine socio-demographic trends and impact on travel demand
- Be in position to account for these trends in forecasts and plans
- Examine policy or other interventions that might offset trends

Figure 2. *Impacts 2050* Tool: Scenarios

Source: Emerging Societal Trends, Land Use Linkages, & Statewide Data Collection [PowerPoint].[8]

Eight Key Trends

As an initial step to developing relevant relationships for the SD model, the researchers conducted an analysis of relevant socio-demographic trends. Eight key trends were identified that are drawing uncertainty. They are:

1. The next 100 million—the U.S. is growing more slowly
2. The graying of America
3. The browning of America
4. The changing American workforce—the workforce is growing older, more female, and more diverse
5. The blurring of city and suburb
6. Slow growth in households
7. The Generation C—digital and mobile devices will become more ubiquitous
8. The salience of greater environmental concerns

These eight factors were then used to develop the structured relationships for the *Impacts 2050* model.

The Next 100 Million[9]

The past decade (2000-2010) has seen a decline in growth from the previous decade (1990-2000) by about 3 percent. This decrease is attributed to slower U.S. economic growth, reduced immigration, declining fertility rates among white women, and aging Baby Boomers. If relevant societal changes become permanent, this trend of slowed population growth could continue and become a long-term change.

Total population growth within the U.S. is largely a result of immigrants and their descendants as well as a decline in U.S. mortality. Moreover, the population of the U.S. is growing faster than the rest of the world's developed nations. The implications of this growth have impacts on the population of drivers as well as the overall travel and transportation demands. Drivers are older and less future drivers are being born, so the number of drivers on the road is decreasing. Additionally, there is a decrease in VMT per capita, despite the overall increase in total VMT that is a result of population growth.

The Graying of America[10]

As the generation of Baby Boomers age, the implications for transportation-related planning and policymaking increase. By 2050, researchers estimate that more than one of every five Americans will be 65+, as compared to one in every eight in 2000. These figures are significant because vehicle use is largely determined by age, and while the percentage of older people with drivers' licenses has increased, the VMT per capita overall is decreasing because older people drive less. The number of older people with a license does not matter if they are not using that license to drive. Travel demand as a whole has also gone down because as the Baby Boomers age, they are taking fewer work trips, maintaining older vehicles, carpooling, and lessening their use of transit and even limiting their automobile ownership.

The Browning of America[11]

Impacts 2050 account for race in its forecasting. As the population becomes increasingly "browner," the race variable will be very important for forecasting travel demand. In the last decade (2000-2010), the U.S. population grew by 27 million. Fifty-six percent (15.2 million) of that 27 million were Hispanic. In fact, 23 percent of children under the age of 18 are Hispanic, which is more than three times the number of Hispanics over the age of 65 (7 percent). Census Bureau estimates project that the population of Hispanic children will increase to 35 percent by 2050, and the population of Hispanics of all ages will increase to 29 percent. However, this growth will become less associated with immigration and more related to births within the U.S.

This decrease in the foreign–born Hispanic population has significant implications. The 2009 National Household Travel Survey data showed that U.S. born Hispanics have a greater propensity for trip making, have more vehicles per household, and own more new vehicles. However, foreign-born Hispanics tend more towards carpooling, walking, and transit. Based on this information, it is likely that travel demands will change; VMT per capita will increase as will auto age, and the public will use transit much more.

The Changing American Workforce [12]

The U.S. labor force has been steadily increasing over the past decades because of population growth and increased female participation. However, while the overall size of the labor force has been increasing, the number of men in the workforce has been steadily decreasing. Labor force projections are based on the civilian non-institutional population, and as the Bureau of Labor Statistics (BLS) has conducted research, they have found that as the civilian non-institutional population labor force shifts to higher age groups, it becomes more female.

However, there is a generational gap, which is due to decreased birth rates during 1965-1975. This generation is a "baby bust" generation. This is pertinent information in travel demand forecasting because as the Baby Boomers age, there are less people to fill their positions. Overall, this will cause the labor force participation rate to decline. The 2007-2009 recession caused even more individuals to drop out of the labor force, but even as the economy recovers, the workforce will continue aging. In summation, VMT per capita will decrease even though work-related VMT will increase. Moreover, the growth in work-related VMT will decline as carpooling increases.

The Blurring of City and Suburb [13]

In 2010, the number of people per square mile was 87.4, as opposed to 50.7 in 1960. However, the line between an economic center where people work and suburbs where people live is getting increasingly blurry. Both the city and the suburbs are now places where both employers and residences make their homes. This blurriness can be partially attributed to the decrease in internal migration rates. Additionally, as Baby Boomers age, they are remaining in suburb areas. These suburbs are becoming more populated with singles, empty nesters, and retirees. In contrast, Millennials have displayed a preference for big city living. This lifestyle depends less on car ownership and use and more on walking or mass public transit systems. As previously mentioned, the aging population drives less. The combination of Millennials in big cities and older people in compact suburbs means that car dependency could decrease significantly. This decrease will result in less VMT per capita and increased non-motorized and/or transit trips.

Slow Growth in Households [14]

Falling household sizes significantly impact travel demand. The decrease in household size is mainly attributed to lower fertility or fewer children, aging Baby Boomers, longer life spans, women entering the work force, and rising incomes. Economic collapses like the 2007-2009 Great Recession contribute to falling household sizes as well because single young adults moved back into the parental home. Another contributing factor for the condensed number of households has to do with the marriage rate. The age of first marriage has increased, which means fewer households are being created. As fewer households are created, fewer children are born.

The number of people as well as their ages and relationships impact transportation demand. For instance, households with children have a higher VMT than those without, but the number of households with children has been decreasing. All of these factors result in decreased VMT per capita, decreased auto ownership among young people, and higher rates of carpooling and public transit use.

The Generation C [15]

Generation C is more of a lifestyle group than a demographic group. This "generation" has reflected a growing reliance on digital and mobile devices in the way people live, work, and socialize. Some define this generation as including those who are connected, communicating, content-centric, computerized, and community-oriented, while others limit it to the hyper-connected group of 18-34 year-olds. The increased use of digital and mobile devices is reflected in travel behavior as people need to leave their homes less and less to perform certain activities. Those activities can now be performed remotely rather than face-to-face, which reduces the need for an automobile.

Researchers have been investigating whether technology will substitute for actual trips. For adults, their traffic patterns were established before the technology. However, for "digital natives," it could be a different story. Quantifying the role of social networks in changing travel behavior is difficult, but what is quite clear and demonstrable is that digital natives are delaying acquiring their drivers' licenses, driving less, and doing more activities digitally. This has the potential to reduce VMT per capita for some trip purposes and decrease car ownership.

The Salience of Greater Environmental Concerns [16]

There are generational differences about the nation's energy and environmental priorities; namely, 71 percent of Millennials are for focusing on developing alternative energy sources whereas only 47 percent of Depression era respondents agree. Millennials also favor expanding public transit systems (61 percent) and providing tax incentives for buying hybrid/electric vehicles (69 percent), whereas only 47 percent and 38 percent of Depression era babies agree, respectively. This divide is expected to decrease over time, but since more Millennials use public transit than any other generation and as the U.S. population ages and passes away, the attitudes of the Millennials on these issues will become more and more influential on travel demands. In particular, car ownership will decrease and there will be more non-vehicle and transit travel as the older generation shrinks and the younger generation expands.

These eight key socio-demographic trends were used to develop the relationships for the *Impacts 2050* model. Researchers used these eight key trends because their analysis revealed that they were the trends identified as creating uncertainty about forecasting future travel trends.

Impacts 2050 Structure

NCHRP 750 developed software called *Impacts 2050* to support application of the SD model. The model is a statistical analysis that shows how a region's population evolves over time by market segments such as age, income, race, household structure, etc. Additionally, land use, employment, and transportation supply all facilitate the estimate of travel behavior over time. With feedback loops, the model represents the dynamics of urban growth and the resulting implications on travel behavior. A spreadsheet model explicitly separates the scenarios; the Gentle Footprints model is shown in Figure 3. The spreadsheet model tracks changes over a 50-year time period. Four scenarios, as previously discussed, are predefined. Users can create new scenarios by altering the coefficients in the spreadsheet. An advantage of *Impacts 2050* is that an entire model can be run in a period of minutes.

The spreadsheet associated with each scenario represents an index value for each socio-demographic employment sector, land use sector, transport supply sector, and travel behavior subsector. As such, the spreadsheets are highly flexible to alter input variables and test alternative policies on outcomes such as adding roadway capacity or the price of gasoline. The scenario structure becomes a flexible tool to quickly explore alternative outcomes. The predesigned scenarios help frame the discussion and stimulate stakeholder dialogue.

Impacts 2050 models change in five sectors; the first, socio-demographics. This includes changes in age and household structures, race/ethnicity, acculturation and employment status, household income, and area type of residence location. The second is travel behavior, which includes changes in car ownership, work and non-work trip rates, and work and non-work mode choice (car driver, car passenger, transit, walk/bicycle). The third sector is employment; *Impacts 2050* models change in the number of jobs by retail, service, and other categories in urban, suburban, and rural area types. The fourth sector is land use, including changes in the amounts of commercial, housing, developable, and protected space in urban, suburban, and rural area types. The fifth and final sector is the transport supply, and it models changes in the amounts of freeway, arterial capacity, and regional transit services (bus, rail) in urban, suburban, and rural area types.[17]

Specific input variables with required sub-stratifications are noted in Table 5. Outputs presented as indicators are provided by year for a 50-year time period. Then, based on default variables (which can be altered, if desired, and understood), the output tables are produced, as shown in Table 6.

Appendix A contains an elaboration of travel behavior trends by *The Next Generation of Travel: Research, Analysis, and Scenario Development*.

Figure 3. *Impacts 2050* Gentle Footprints Spreadsheet Scenario

Return to Main Menu	Scenario: Gentle Footprint										
Scenario multipliers on base rates	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
SOCIO-DEMOGRAPHIC SECTOR											
Death Rate	1.00	1.00	1.00	0.95	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Birth Rate	1.00	1.00	1.00	0.80	0.80	0.70	0.70	0.70	0.60	0.60	0.60
Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Workforce Rate	1.00	1.00	1.00	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Enter Workforce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Leave Lowest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Lowest Income Group Rate	1.00	1.00	1.00	1.05	1.10	1.10	1.10	1.10	1.10	1.10	1.10
Leave Highest Income Group Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Enter Highest Income Group Rate	1.00	1.00	1.00	0.95	0.90	0.90	0.90	0.90	0.90	0.90	0.90
Foreign Inmigration Rate	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.20	1.20	1.20	1.20
Foreign Outmigration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Domestic Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Intra-Regional Migration Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Death Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Birth Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Marriage Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Divorce Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Empty Nest Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Low Income- Effect On Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
High Income- Effect On Space Per Household	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
TRAVEL BEHAVIOR SUBSECTOR											
Gasoline Price	1.00	1.00	1.00	1.25	1.50	1.75	2.00	2.25	2.50	2.75	3.00
Shared Car Fraction	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
No Car Fraction	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
Work Trip Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Nonwork Trip Rate	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Car Passenger Mode Share	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
Transit Mode Share	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
Walk/Bike Mode Share	1.00	1.00	1.00	1.10	1.20	1.30	1.40	1.50	1.50	1.50	1.50
Car Trip Distance	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.80	0.80	0.80	0.80
EMPLOYMENT SECTOR											
Job Creation Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Job Loss Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Job Move Rate	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
LAND USE SECTOR											
Residential Space Per Household	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Non-Residential Space Per Job	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Land Protection	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
TRANSPORT SUPPLY SECTOR											
Road Capacity Addition	1.00	1.00	1.00	0.95	0.90	0.85	0.80	0.75	0.70	0.65	0.60
Transit Capacity Addition	1.00	1.00	1.00	1.05	1.10	1.15	1.20	1.25	1.30	1.35	1.40
Road Vehicle Capacity Per Lane	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Transit Passenger Capacity Per Route	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
EXTERNAL INDICES FOR OTHER REGIONS OF THE US											
External Job Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Non-Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Residential Space Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
External Road Capacity Demand/Supply Ratio	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Source: *Impacts 2050*: Dynamic Analysis of Socio-Demographic & Travel Scenarios[18]

Table 4. *Impacts 2050* Input Variables with sub-Stratifications

Demographic Factors	Commuter Patterns	Land Use Factors	Transportation
Population	Matrix of percent commuter flows (urban, suburban, rural)	Space in square miles by:	Lane miles for:
Population by age: • 0-14 • 15-29 • 30-44 • 45-49 • 60-74 • 75+		Urban* non-residential	Freeway—urban, suburban, rural
Population by marriage/child status: • Single w/o children • Couple w/o children • Single w/children • Couple w/children		Urban residential	Arterial—urban, suburban, rural
Population by race and time in the country • Hispanic—Native, more than 20 yrs. or less than 20 yrs. • Black—Native, more than 20 yrs. or less than 20 yrs. • Asian—Native, more than 20 yrs. or less than 20 yrs. • Other—Native, more than 20 yrs. or less than 20 yrs.		Urban developable Urban protected Suburban non-residential Suburban residential Suburban developable	Other—urban, suburban, rural Rail route miles Non-rail route miles
Total income: • 0-35K • 36-99K • 100K+			
Employment: • Workforce • Not in workforce			
Employment by: • Urban, • Suburban • Rural* Category: • Retail • Service • Other			

*Area Type is defined by population density at the Census Tract level: urban tracts have at least 4,000 jobs/mile^2 or 10,000 residents/mile^2 inside the tract; suburban tracts are tracts that do not qualify as urban and have at least 500 jobs/mile^2 or 1,000 residents/mile^2 inside the tract; tracts that do not qualify as urban or suburban are classified as rural tracts

Table 5. Output Indicators

Output Indicators
Auto VMT per capita
Percent non-car owning
Percent car-sharing
Average car occupancy
Transit mode share
Walk/bike mode share
Work trips per capita
Non-work trips per capita
Population
Percent under age 16
Percent over age 60
Percent over age 75
Percent Hispanic
Percent low income
Percent high income
Percent foreign-born
Percent in the workforce

Table 6. Typical 2010 statistics and 2050 projections

Indicators	2010 Statistics	Atlanta 2050 Projections			
		Momentum	Tech Triumphs	Global Chaos	Gentle Footprint
Auto VMT per capita	11,115	10,251	11,461	5,451	4,167
Percent non-car owning	2.5%	3.0%	2.5%	5.2%	4.1%
Percent car-sharing	22%	22%	17%	34%	29%
Average car occupancy	1.6	1.6	1.5	1.8	1.8
Transit mode share	2%	2%	2%	2%	3%
Walk/bike mode share	11%	11%	10%	19%	22%
Work trips per capita	0.5	0.5	0.5	0.4	0.3
Non-work trips per capita	2.9	3.0	2.9	1.7	1.7
Population	5,262,023	8,225,550	7,205,888	5,694,525	7,910,911
Percent under 16	22%	23%	20%	17%	15%
Percent over age 60	14%	19%	23%	19%	27%
Percent of age 75	4%	6%	9%	4%	9%
Percent Hispanic	8%	12%	11%	11%	13%
Percent low income	32%	33%	28%	51%	36%
Percent high income	19%	27%	32%	17%	26%
Percent foreign-born	16%	13%	11%	11%	24%
Percent in workforce	47%	39%	46%	43%	48%

Sensitivity Analysis

In order to better understand the structure of the SD model, a sensitivity analysis was conducted. Sensitivity analyses were conducted for Seattle as a case study. Not all results were as expected as some variables did not significantly impact the outcome. It was noticeably difficult to adjust the input variables to achieve roadway congestion. The variables that had the greatest impact on future year socio-demographic and transportation outcomes were:

- Commuter Patterns—Urban, Suburban, & Rural
- Employment in Subarea
- Reduce—Increase Roadway, Transit Capacity
- Minorities by Race
- Couples without Children
- Urban Land Use Distribution
- Years a Minority is in Region
- Age Grouping Change
- Regional Populations

The sensitivity analysis highlights the complexity of the model with many default parameters that are difficult to understand and adjust. To a certain extent, the SD model is very sophisticated and complex.

Knoxville Case Study

With the cooperation of the Knoxville TPO, the *Impacts 2050* scenarios were tested for the Knoxville region with a 2000 population of 721,000. While the SD model documentation did not always provide a clean definition of data sources, the TPO staff attempted to replicate the required input data with local resources. The Knoxville region selected was a six-county area containing all or parts of the current TPO Planning Area. They were Anderson, Blount, Knox, Loudon, Roane, and Sevier counties. Using the definitions of land use categories as specified for the model, most of the six counties were defined as rural. The original definitions utilized for the four metropolitan area case studies were as follows:

- Urban tracts – tracts that have at least 4,000 jobs/mile^2 or 10,000 residents/mile^2 inside the tract
- Suburban tracts –tracts that do not qualify as urban and have at least 500 jobs/mile^2 or 1,000 residents/mile^2 inside the tract
- Rural tracts – tracts that do not qualify as urban or suburban

Land use data for Knoxville came from the regional ULAM model developed in 2006. Parcel data were utilized to define undevelopable and developable land. Application of NCHRP 750 in Tennessee will require the support of a detailed land use model, which is not always available to MPOs. Roadway mileage came from TDOT's TRIM database. Household employment data came from Census Data and the travel demand model currently utilized by the TPO. Data sources utilized for developing the Knoxville case study are noted in Table 7.

Results for Knoxville's 2050 scenario runs are presented in Table 8a. Knoxville's results were compared to runs completed for Atlanta and Houston (Tables 8b-c). Only the momentum scenario was considered for the comparative analysis.

Table 7. Data Sources for Knoxville Scenarios, Base Year

Data	Data Source
Roadway mileage	TDOT TRIMs Data
Land Use by Area	ULAM Land Use Data—Knoxville TPO
Commuting Patterns	LEHD Destination Analysis—Knoxville TPO
Job by Industry and Area Type	LEHD Workplace Area Characteristics
	2000 Census of Population and Housing— SF3, Table P001 and Geographic Identifiers
Employment Status	2000 Census of Population and Housing— SF3, Table P043 and P008
Persons by Income Group	2000 Census of Population and Housing— SF3, Table PCT 044 and P008
Acculturation—Hispanic, African, & Asian Americans & Other	2000Census of Population and Housing— SF4, Table QT–P14
Household Structure	2000 Census of Population and Housing— SF3, Tables 09, 10, and 14
Population by Age	2000 Census of Population and Housing— SF3 Table P0008
Population by Area Type	2000 Census of Population and Houses— SF3 Table 001 and Geographic Identifiers
Community Patterns by Area Type	LEHD Destination Analysis

Table 8a: 2000 statistics and 2050 projections in Knoxville by scenario

Indicators	Knoxville 2050 Projections				
	2000 Statistics	Momentum	Tech Triumphs	Global Chaos	Gentle Footprint
Auto VMT per capita	10,382	9,201	10,309	4,881	3,705
Percent non-car owning	3.9%	3.7%	3.1%	6.7%	5.0%
Percent car-sharing	23.3%	17.7%	14.0%	29.3%	23.6%
Average car occupancy*	1.80	1.77	1.66	2.09	1.99
Transit mode share	3.9%	5.6%	5.1%	5.7%	7.4%
Walk/bike mode share	17.1%	20.2%	18.5%	35.5%	39.7%
Work trips per capita	0.60	0.44	0.51	0.38	0.31
Non-work trips per capita	2.82	3.11	3.02	1.82	1.80
Population (1000s)	721	1,389	1,222	967	1,223
Percent under 16	20%	23%	20%	17%	16%
Percent over age 60	18%	18%	23%	19%	24%
Percent of age 75	—	—	—	—	—
Percent Hispanic	1%	2%	2%	2%	2%
Percent low income	47%	31%	27%	49%	34%
Percent high income	9%	26%	32%	16%	25%
Percent foreign-born	2%	3%	2%	2%	5%
Percent in workforce	50%	38%	45%	42%	46%

*non-work only

Table 8b: 2000 statistics and 2050 projections in Atlanta by scenario

Indicators	Atlanta 2050 Projections				
	2000 Statistics	Momentum	Tech Triumphs	Global Chaos	Gentle Footprint
Auto VMT per capita	11,732	10,107	11,336	11,364	4,096
Percent non-car owning	2.4%	3.3%	2.7%	5.7%	4.3%
Percent car-sharing	22.6%	21.7%	17.3%	34.3%	28.2%
Average car occupancy*	1.82	1.77	1.68	2.09	1.98
Transit mode share	3.2%	5.1%	4.5%	4.8%	7.0%
Walk/bike mode share	16.4%	19.4%	17.9%	34.5%	38.6%
Work trips per capita	0.61	0.46	0.54	0.40	0.133
Non-work trips per capita	2.82	2.99	2.90	1.75	1.73
Population (1000s)	4,248	8,039	7,125	5,660	7,550
Percent under 16	23%	24%	20%	18%	16%
Percent over age 60	11%	18%	23%	19%	25%
Percent of age 75	—	—	—	—	—
Percent Hispanic	6%	10%	9%	9%	11%
Percent low income	31%	32%	28%	50%	35%
Percent high income	18%	27%	33%	17%	25%
Percent foreign-born	10%	9%	8%	18%	17%
Percent in workforce	51%	39%	46%	43%	47%

*non-work only

Table 8c: 2000 statistics and 2050 projections in Houston by scenario

Indicators	Houston 2050 Projections				
	2000 Statistics	Momentum	Tech Triumphs	Global Chaos	Gentle Footprint
Auto VMT per capita	9,735	8,954	10,061	4,784	3,676
Percent non-car owning	3.8%	4.4%	3.7%	6.9%	5.6%
Percent car-sharing	31.0%	29.6%	24.3%	42.9%	36.5%
Average car occupancy*	1.92	1.84	1.74	2.21	2.07
Transit mode share	4.6%	6.8%	6.3%	6.5%	8.6%
Walk/bike mode share	17.0%	19.5%	18.0%	34.3%	37.7%

Indicators	Houston 2050 Projections				
	2000 Statistics	Momentum	Tech Triumphs	Global Chaos	Gentle Footprint
Non-work trips per capita	2.75	2.78	2.69	1.63	1.60
Population (1000s)	4,715	8,872	7,823	6,184	8,440
Percent under 16	24%	24%	21%	18%	16%
Percent over age 60	11%	18%	22%	18%	25%
Percent of age 75	—	—	—	—	—
Percent Hispanic	29%	39%	38%	37%	41%
Percent low income	39%	34%	30%	52%	38%
Percent high income	15%	26%	32%	16%	24%
Percent foreign-born	19%	13%	12%	12%	23%
Percent in workforce	45%	40%	47%	43%	48%

*non-work only

City Comparisons

A comparison of Knoxville with Atlanta and Houston was conducted. Results are summarized in Table 9. Only the momentum scenario will be considered since the other scenarios have fixed relationships as established by the spreadsheets. Therefore, relative comparisons between regions will be identical.

In the base year, Knoxville has an older population with a lower percent of population under 16 and a higher percent over 60. In 2000, Knoxville had a higher low-income segment than Atlanta: 47% vs. 31%. However, by 2050, both regions were at 31%. Houston did not quite fit this pattern, only dropping from 39% to 34%. The high-income percentages were 9% for Knoxville as opposed to 15-18% for the other two regions. By 2050, all three regions are at 26-27%. Other large differences in percent Hispanic and foreign-born are not marginalized, Knoxville being much lower in both for 2000 and 2050. A key question is: how do the demographics translate into transportation characteristics?

Knoxville has the highest percent non-car ownership in 2000 at 3.9% as opposed to 3.8% for Houston and 2.4% for Atlanta. By 2050, Knoxville dropped slightly to 3.7%, Houston increased to 4.4%, and Atlanta increased to 3.3%. The percent car-sharing in both Atlanta and Houston remain relatively stable between 2000 and 2050 at 21-22% and 30-31%, respectively, while Knoxville is projected to decrease from 23% to 18%. It is not understood what drives this difference. Transit mode share increases for all three regions moving from 3-5% in 2000 to 5-7% in 2050. The walk/bike mode share is almost identical for all three regions in both 2000 and 2050. Little difference exists between the regions for

2000 and 2050 in the work trip/capita indicator. In all cases, the rate declines, but Knoxville retains at the highest rate.

With the work trip rate declining from .60 to .44 trips/capita, and considering the population and labor participation rate, Knoxville will lose about 158,000 work trips/day between 2000 and 2050. However, the non-work trip rate is projected to increase from 2.82 to 3.11, which is similar to Atlanta's increase from 2.82 to 2.99. Houston's non-work trip rate only adjusts from 2.75 to 2.78. Something is different in the Houston profile to differentiate its travel characteristics from Knoxville and Atlanta. Likewise, the percent of population in the workforce is similar for Knoxville and Atlanta from 50-51% in 2000 to 38-39% in 2050. Houston starts at 45% and declines to 40%.

A major difference is the estimate MVT/capita. In 2000, Atlanta is 1,350 miles higher than Knoxville, which in turn is 250 miles higher than Houston. By 2050, the relative differences have decreased to 900 for Atlanta. The regional comparisons do not clearly reflect causal factors. It is interesting that Knoxville, a small urban area, has trends similar to Atlanta and to lesser extents, to Houston, but for many factors they all have similar percentages in 2050. Differences between regions tend to consolidate between 2000 and 2050. Again, it needs to be recognized the transportation variables such as transit mode share or trips/capita are not input variables, but derived from the socio-demographic, commuting pattern, land use availability, and roadway miles input variables. There is no well-documented approach to calibrating the SD model for the base year. Table 9 provides a summary of the peer analysis for Knoxville vs. Atlanta and Houston.

Table 9: Comparison on Knoxville, Atlanta, & Houston 2000 to 2050 for Momentum Scenario

Heightened percentages are denoted as up (U), equal or close to equal are denoted as level (L), and lesser percentages are denoted as down (D).

A. Demographics	
1. In 2000, Knoxville has a lower percentage of population under 16 and a higher percentage over 60 years. By 2050, the differences are moderated.	
Percent of population under 16	Knoxville: 20% ➚ 23% (U)
	Atlanta: 23% ➔ 24% (L)
	Houston: 24% ➔ 24% (L)
Percent of population over 60	Knoxville: 18% ➔ 18% (L)
	Atlanta: 11% ➚ 18% (U)
	Houston: 11% ➚ 18% (U)
2. In 2000, Knoxville has a higher percentage of low- income and a lower percentage of higher income. By 2050, the differences are eliminated.	
Percent of population defined as low-income	Knoxville: 47% ➘ 31% (D)
	Atlanta: 31% ➔ 32% (L)
	Houston: 39% ➘ 34% (D)
Percent of population defined as high income	Knoxville: 9% ➚ 26% (U)
	Atlanta: 18% ➚ 27% (U)
	Houston: 15% ➚26% (U)
3. In 2000, Knoxville has a higher percentage of Hispanic and foreign-born. By 2050, the differences are remaining.	
Percent of population Hispanic	Knoxville: 1% ➔ 2% (L)
	Atlanta: 6% ➚ 10% (U)
	Houston: 29% ➚ 30% (U)

Percent of population foreign-born	Knoxville: 2% ➔ 3% (L)
	Atlanta: 10% ➔ 9% (L)
	Houston: 19% ➘ 13% (D)
4. In 2000, Knoxville had a Workforce Participate Rate similar to Atlanta and Houston. By 2050, the participation rate has declined in all 3 regions and provides a consistent percentage.	
Workforce Participation Rate	Knoxville: 50% ➘ 38% (D)
	Atlanta: 51% ➘ 39% (D)
	Houston: 45% ➘ 40% (D)
5. A substantial population increase is expected in all metropolitan areas between 2000 and 2050.	
Population increase as a percentage 2000-2050	Knoxville: 93%
	Atlanta: 89%
	Houston 88%
B. Transportation Characteristics	
1. Non-car ownership remains stable for Knoxville 2000-2050 and increases in Atlanta and Houston	
Non-car ownership percentage	Knoxville: 3.9% ➔ 3.7% (L)
	Atlanta: 2.4% ➚ 3.3% (U)
	Houston: 3.8% ➚ 4.4% (U)
2. Car-sharing declines for Knoxville 2000-2050 while remaining stable in Atlanta and Houston.	
Car-sharing percentage	Knoxville 22.3% ➘ 17.7% (D)
	Atlanta: 22.6% ➔ 21.7% (L)
	Houston: 31.0% ➔ 29.6% (L)

3. Transit mode share increases in all regions 2000-2050. By 2050, Knoxville is predicted to have a higher transit mode share than Atlanta.	
Transit mode share percentage	Knoxville: 3.9% ➚ 5.6% (U)
	Atlanta: 3.2% ➚ 5.1% (U)
	Houston: 4.6% ➚ 6.8% (U)
4. Bike/walk mode share increases in all regions between 2000 and 2050. By 2050, little difference exists between the metropolitan areas.	
Bike/walk mode share percentage	Knoxville: 17.1% ➚ 20.2% (U)
	Atlanta: 16.4% ➚ 19.4% (U)
	Houston: 17.0% ➚ 19.5% (U)
5. Between 2000-2050, the work trips per capita decrease to a similar rate in all three regions. However, non-work trips increase, with the highest rate found in Knoxville in 2050.	
Work trips per capita	Knoxville: 0.60 ➘ 0.44 (D)
	Atlanta: 0.61 ➘ 0.46 (D)
	Houston: 0.54 ➘ 0.46 (D)
Non-work trips per capita	Knoxville: 2.82 ➚ 3.11 (U)
	Atlanta: 2.82 ➚ 2.99 (U)
	Houston: 2.75 ➔ 2.78 (L)
6. VMT per capita decreases in all three regions between 2000-2050.	
VMT per capita	Knoxville: 10,382 ➘ 9,201 11.3% (D)
	Atlanta: 11,732 ➘ 10,107 13.8% (D)
	Houston: 9,732 ➘ 8,954 8.0% (D)

Knoxville Scenario Comparison

A second comparison reviewed the Knoxville results and compared them by scenario. Reference can be made to Table 8a, which was previously introduced. As expected, each scenario has a different 2050 outcome. What is interesting is that the demographic profiles are somewhat consistent while the transportation travel outputs are more variable. For example, the percent under 16 varies from 16% (gentle footprint) to 23% (momentum) in 2050 versus the 2000 value of 20%. The same two scenarios are on the extremes for the percent of population over 60 at 18% and 24%, respectfully, versus 18% for 2000. Moreover, households with children vary from the current 41% to 60% (momentum) and 51% (gentle footprint). The percent single households also increase for each scenario from a 2000 estimate of 24% to a high of 32% for the tech triumphs. However, little variation is reported for racial profiles or immigration profiles.

Yet, the low-income category drops from the current estimate for each scenario. While decreasing to 27-34% in 2050 for three scenarios, it remained at 49% for the global chaos scenario. Additionally, in 2050, the momentum scenario projects that 38% of the population will be participating in the work force versus 42-46% for the other three scenarios. By comparison, the current 2000 value is 50%. There is a substantial decline in the VMT/capita for the scenarios. The momentum projects a 2050 value of 9,201 versus a current estimate of 10,382, while estimates substantially decline to 4,881 and 3,705 for the global chaos and gentle footprint scenarios, respectively. Interestingly, the 2050 value stabilizes at 10,309 for the tech triumphs scenarios. However, at the time VMT/capita is dropping for global crisis and gentle footprint scenarios by factors of .54 and .64, the population is estimated to grow by 1.33 and 1.70, respectively.

All four scenarios project a higher 2050 population for the Knoxville region. The momentum scenario alone has the greatest increase at 668,000 in population. Transportation efficiencies are not achieved through transit mode shift, which remains in the range of only 5-7.5%. On the other hand, greater reliance is placed on the walk/bike mode. This mode is expected to increase from 17.8% to 35.6% (global chaos) and 39.7% (gentle footprint). Not only are there substantial increases for walk/bike “other trips,” but also for “work trips.” Car sharing remains flat and slightly decreases for the tech triumphs and momentum scenarios and increases for the global chaos and the gentle footprint scenarios. Car ownership otherwise is basically flat with the percent of household without a car are very similar for all scenarios and are very similar to the percent in 2000.

However, the trip rates do change with scenario, especially for non-work trips. Substantial declines in travel are achieved with much lower trip rates for global chaos and gentle footprint scenarios. The 2050 momentum scenario has higher non-work trips/capita than the base year. The big bang in 2050 for VMT/capita across scenarios comes from the trip rates. It’s hard to say if the 2050 results are logical or not, but there is variation in travel characteristics between the scenarios. All variables show a logical progression from 2000 to 2050 with no reversals or jumps in value between the years. Across the scenarios, the total area wide 2050 VMTs vary from an increase of 70% to a decrease of 40%, which demonstrates substantial change.

Knoxville Assessment of Impact 2050

Professional transportation planners for the Knoxville TPO were asked for their assessment of *Impacts 2050* and for its application to a TPO such as Knoxville. It was stated:

> Overall, there does appear to be some potential for use/application of the research report and software tool to the transportation planning process that is conducted by the TPO. One possible specific application is the upcoming major 4-year update of the TPO's Long Range Transportation Plan that is currently in the beginning stages of development. Based on an initial review, it would seem that these products could better position our agency to understand and possibly account for transportation impacts from long term socio-demographic trends. At the very least, the outputs from the *Impacts 2050* software tool can possibly assist the TPO in answering certain types of questions from our stakeholders that cannot be answered with our traditional travel demand forecasting tools. It is uncertain at this point in time, though, whether any outcomes from a potential scenario planning exercise conducted with these tools would actually result in modified project priorities or other major changes in policy decision being incorporated in the next LRTP update. Finally, some challenges were also noted in the process of developing necessary inputs for the software tool.[19]

Specific comments were:

> "The research report titled "The Effects of Socio-Demographics on Future Travel Demand" provides very good information regarding key trends and their projected impact on travel behavior in Chapter 3. This information can be very easily incorporated into the background section of our upcoming LRTP update and will help to set the context for the somewhat arcane task of trying to plan for uncertain conditions up to 25 years into the future. It will be beneficial to show our audience that these various trends will have varying levels of impacts to transportation and that they can interact with one another in multiple ways causing the need for continual updates to our plans over time…
>
> "The *Impacts 2050* software tool provides potential capability to answer questions about the relative impacts of various future socio-demographic and other trends that the existing TPO travel demand forecasting model cannot. It was noted that the scenario multipliers can be easily modified from the base "1.0" level in any of the future 5-year increments to quickly test the impact of changing a particular variable such as gasoline price on travel

demand. The TPO could also choose to preemptively develop interesting "what if" analyses of different future trends in anticipation of certain types of questions….

"The TPO's travel demand model requires various socio-economic inputs for which the *Impacts 2050* could potentially provide information. In the past the TPO staff has chosen to leave certain inputs static between the base and future years in lieu of any better information for variable such as median household income, workers per household, and students per household, which *Impacts 2050* provides output for. Another key variable of percent senior population has been projected in the past for the travel demand model, which can be compared against the outputs from *Impacts 2050*…

"The U.S. DOT has recently been placing a significant emphasis on MPOs utilizing scenario planning techniques as part of their LRTP development efforts. A more traditional scenario planning approach has been to modify assumptions about regional growth patterns and modal investment strategies, however the *Impacts 2050* tool can provide a somewhat easy way to also look at "bigger picture" scenarios affecting overall socio-demographic variables to aid in meeting federal planning requirements…

"The research report noted potential value in developing an "indicator monitoring system" and noted key indicators in terms of their impact on transportation. This exercise could be useful for the TPO in meeting emerging federal planning requirements from MAP-21 for performance based planning. The TPO could develop a mechanism to acquire data and track various indicators over time and potentially tie these to performance targets to achieve desired results for the transportation system."[20]

Areas of concern relate to:

1. Lack of good guidance or developing the input data. While Census data are required for socioeconomic data, the specific Census tables were not specified. Assumptions and estimates approaches were necessary to compile the requested inputs.
2. The model has limited spatial definitions (urban, suburban, and rural), which is best related to large metropolitan areas. The Knoxville region encompasses only 9 urban census tracts, while 69 tracts are defined as suburban and 67 tracts as rural.
3. There is no explicitly defined procedure for base year calculations. Knoxville has a base year transit mode share, estimated from socio-demographic data, which is

more than triple of what is actually experienced. There was no explicit procedure to adjust this value.

4. Model outputs for several demographic measures have little sensitivity to varying input variables. It is not always clear how socio-demographic measures influenced transportation behavior. The SD model is more of a "black box."

Findings

Report NCHRP 750 Volume 6 and the accompanying software, *Impacts 2050*, provides valuable insights into key socio-demographic trends and the potential impacts on travel behavior. *Impacts 2050* is a flexible, sophisticated SD model which will provide outcomes over a 50 year time period for various scenarios. While four scenarios are pre-packaged—momentum, technology triumphs, global chaos, and gentle footprint—user-selected scenarios can easily be developed. A real value is that the model can be run in a matter of minutes once the input data has been collected.

It is important to recognize that *Impacts 2050* is not a travel demand model. Rather, it is designed for scenario analyses and as a means to reflect our changing socio-demographic trends. While travel demand models can be described as point models that predict a particular outcome, *Impacts 2050* is a dynamic model with feedback loops that consider a range of outcomes that can be used in a number of environments. According to NCHRP 750 report, these environments include:[21]

- Supporting long-range plan development
- Supplementing the capabilities of existing planning models
- Formalizing the consideration of uncertainty in the planning process
- Facilitating participation in the planning and decision-making processes
- Serving as a sketch-planning tool for providing quick and timely answers, as well as supporting sensitivity and exploratory analyses
- Serving as a "utility" program for providing data inputs to models and the planning process

For applications by Tennessee MPOs and TPOs, the extensive data inputs are best applied by the four largest TPOs, who have the resources to support the SD model. For selected applications, *Impacts 2050* provides the following:

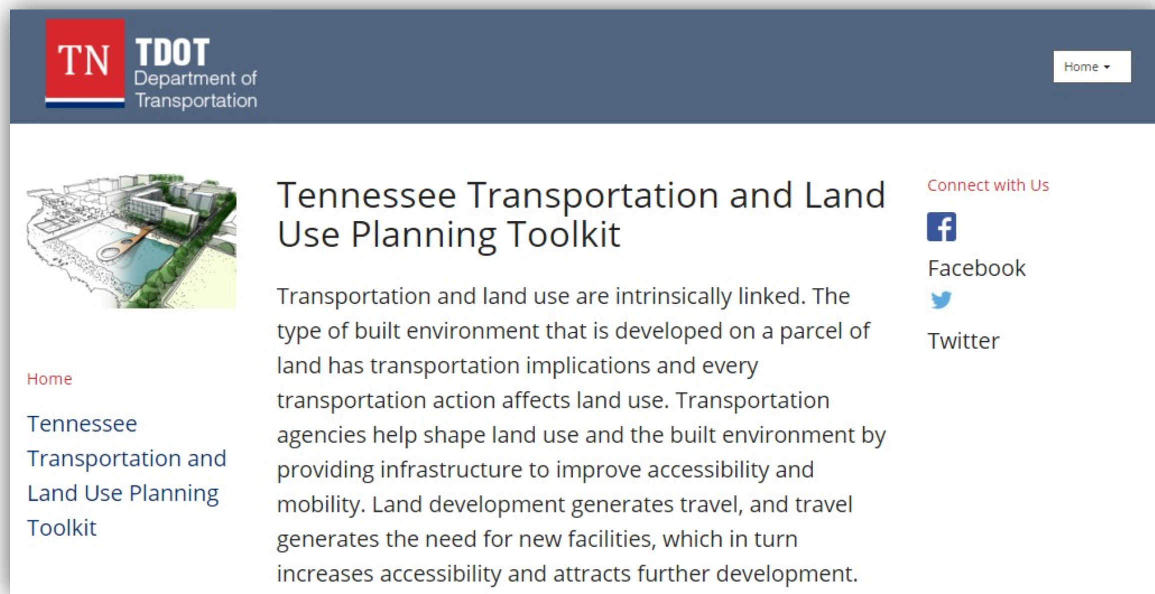
- Good information from the report/tool regarding key trends for use in LRTP narrative
- A framework for quantitative scenario planning
- Assists in assessing relative future impacts of socio-demographic trends
- Possibility of serving as basis for estimates of future socio-demographic variables

II. Tennessee Transportation and Land Use Tool Kit

The core of the tool kit is 100 plus documents organized by major and subtopics. It is comprised of resources in 6 major transportation/land use topical areas. The content of the tool kit is described here along with a number of images that illustrate the look of the website pages.

Home Page - http://www.transportplanningtoolkit.com/

The Tennessee Transportation and Land Use Planning Toolkit is designed to provide tools and information to assist Tennessee planners in making quantitative linkages between transportation and land use. When a user first accesses the website, they are directed to the Tennessee Transportation and Land Use Planning Toolkit homepage. This provides a starting place to access the various topics, as well as contact links. On this page, an overview of the purpose of the toolkit is provided. This is the page users are directed to whenever the home button is clicked.



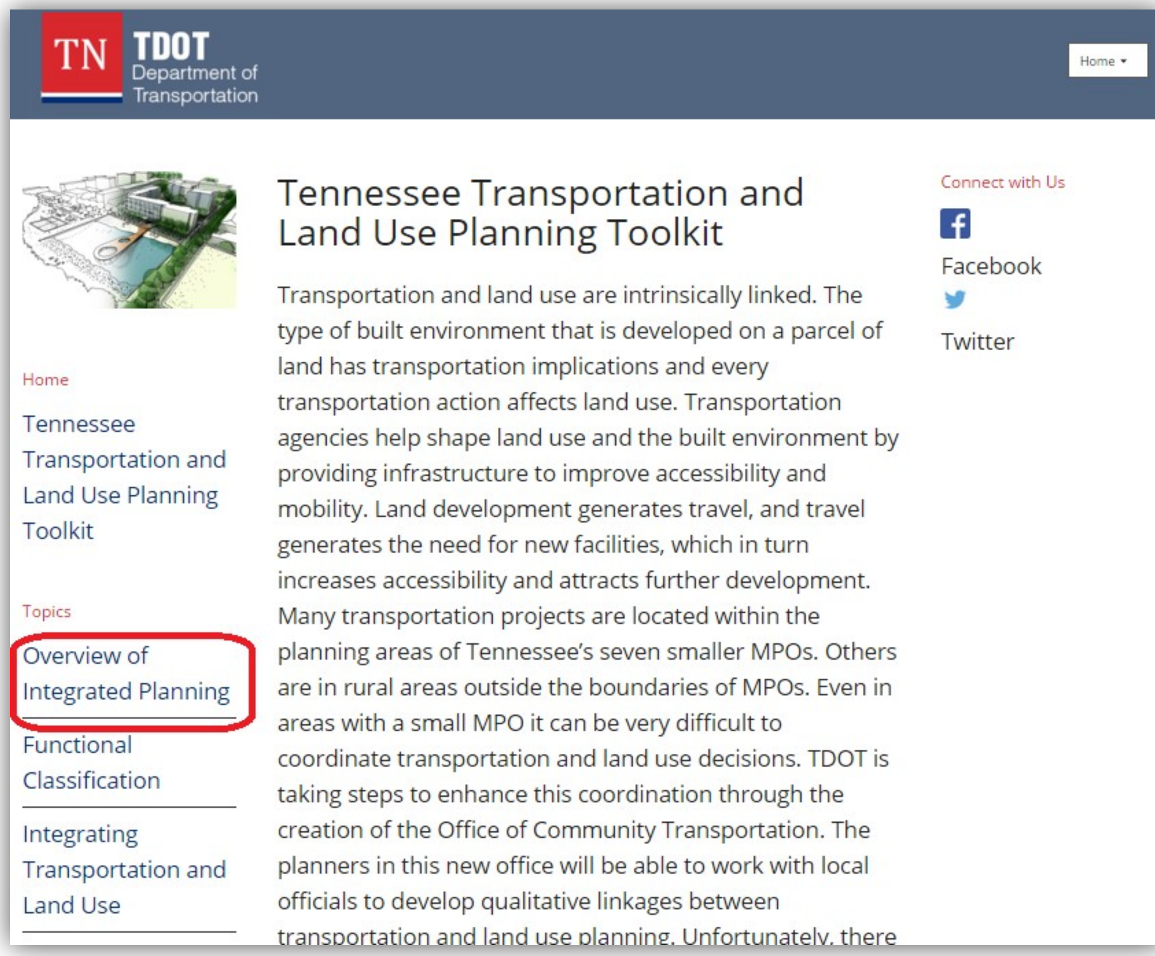
The layout of the website is divided into vertical thirds. On the left, links to topics or subtopics are provided, as well as a link back to the home page.

In the center or main body of the page is general information.

Contact information for social media accounts is provided via the Facebook and Twitter links on the right hand side, clicking either link will direct a user to the appropriate website.

Information and tools are categorized by topic. Topic summary pages provide a description of what resources are available, as well as relevant subtopics. Navigation through topics is two-fold: the user can click a topic at the left in order to access a topic summary page or alternatively, by hovering the cursor over a topic link, subtopics can be viewed within that topic. A user can return to the homepage by clicking the home button at the top right of any page. A brief summary of each topic and subtopic has been created to aid users in finding pertinent resources.

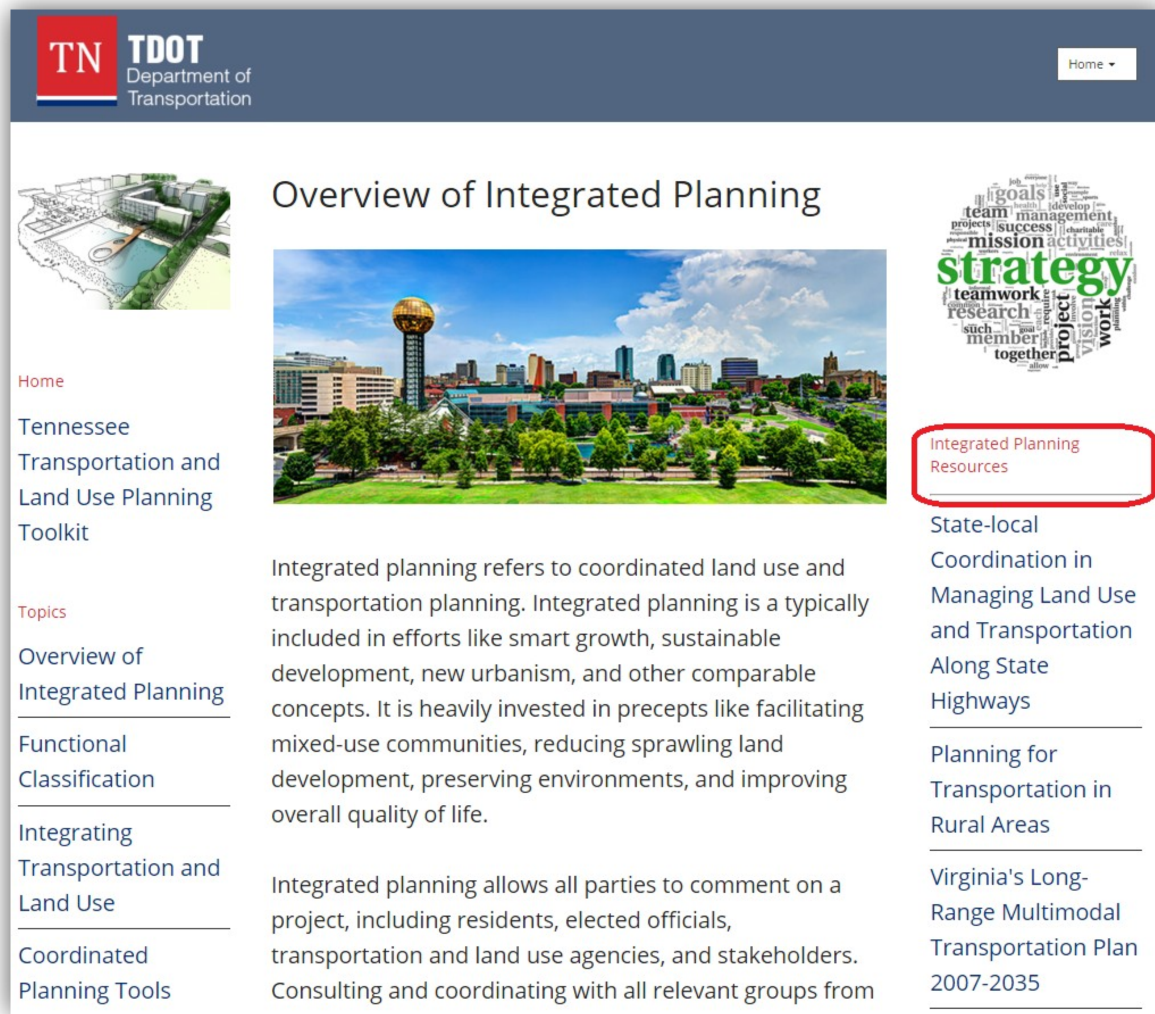
Overview of Integrated Planning



The image above displays the homepage, once the Overview of Integrated Planning link (highlighted in red) is clicked on the homepage the user is then directed to the Overview of Integrated Planning topic. This section offers resource guides, reports, strategic plans, and proposals for integrated planning. There are tools, techniques, and case studies that address how and why to integrate transportation and land use, alternative approaches to interagency interactions, activities state DOTs can engage in to facilitate integration, and the growing demand for coordination efforts between land use and transportation.

The Overview of Integrated Planning page includes information on the following topics:

- Coordinating land use policies with development
- Rural transportation planning
- Incorporating land use issues into transportation planning
- Strategic planning for future transportation needs
- Alternative approaches for integrating transportation and land use



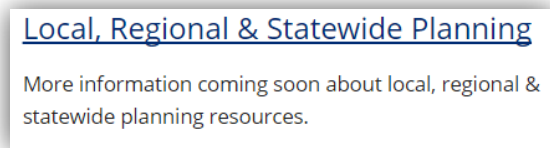
On this page, the other topics are presented on the left, as they are on the homepage. Integrated planning resources, such as relevant whitepapers or articles, are located in the column on the right. Clicking one of these links will lead the user to the resource, by opening a new tab in their web browser.

Resources available from this page include the following:

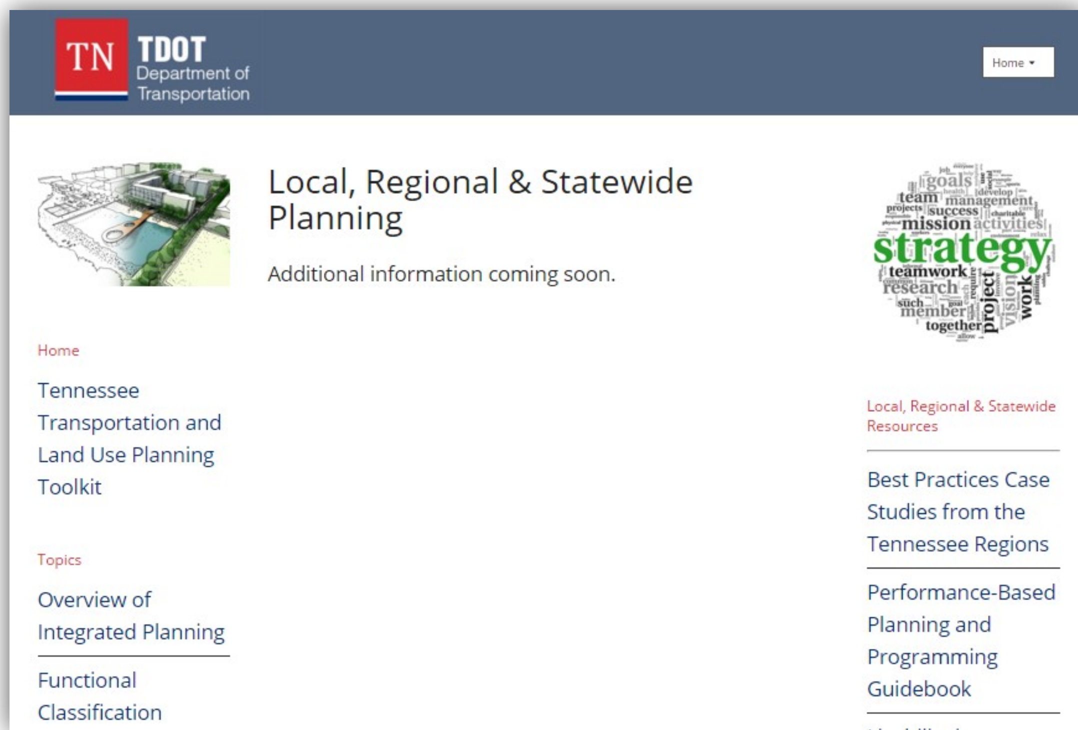
- State-local Coordination in Managing Land Use and Transportation Along State Highways

- Planning for Transportation in Rural Areas
- Virginia's Long-Range Multimodal Transportation Plan 2007-2035
- Land Use and Economic Development in Statewide Transportation Planning
- Alternative State Approaches to Transportation / Land Use Interactions
- Transportation and Land Use
- Community Transportation Digital

There is one additional subtopic on the Overview of Integrated Planning page. In addition to being accessible by hovering over the Overview of Integrated Planning link, the subtopic page is accessible from the link at the bottom of the page as shown in this screen capture:



Local, Regional, and Statewide Planning

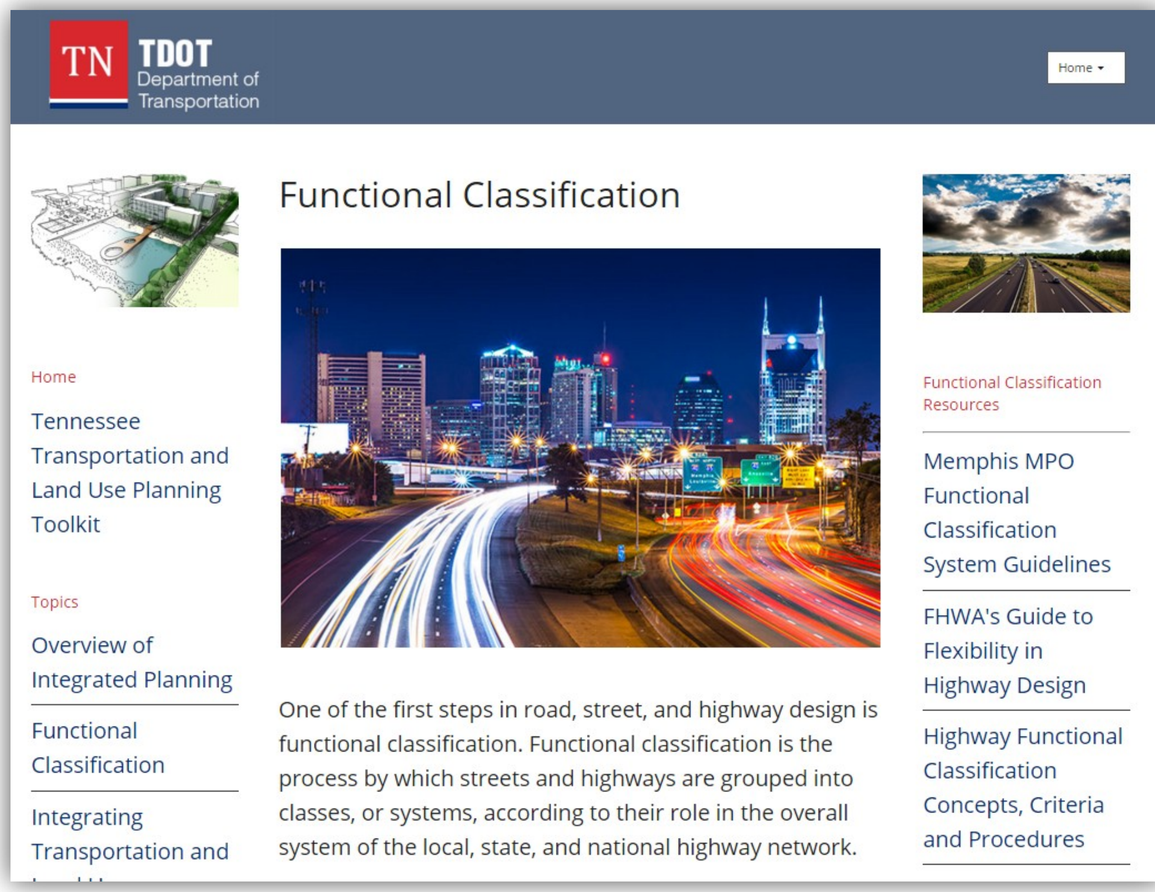


Additional resources available within this subtopic include:

- Best Practices Case Studies from the Tennessee Regions
- Performance-Based Planning and Programming Guidebook
- Livability in Transportation Guidebook

Functional Classification

This section offers definitions and examples of functional classification. Also included is information covering various aspects of this system, such as criteria for the functional classification of roadways into systems at the state and local level. There are no subtopics located within this page.

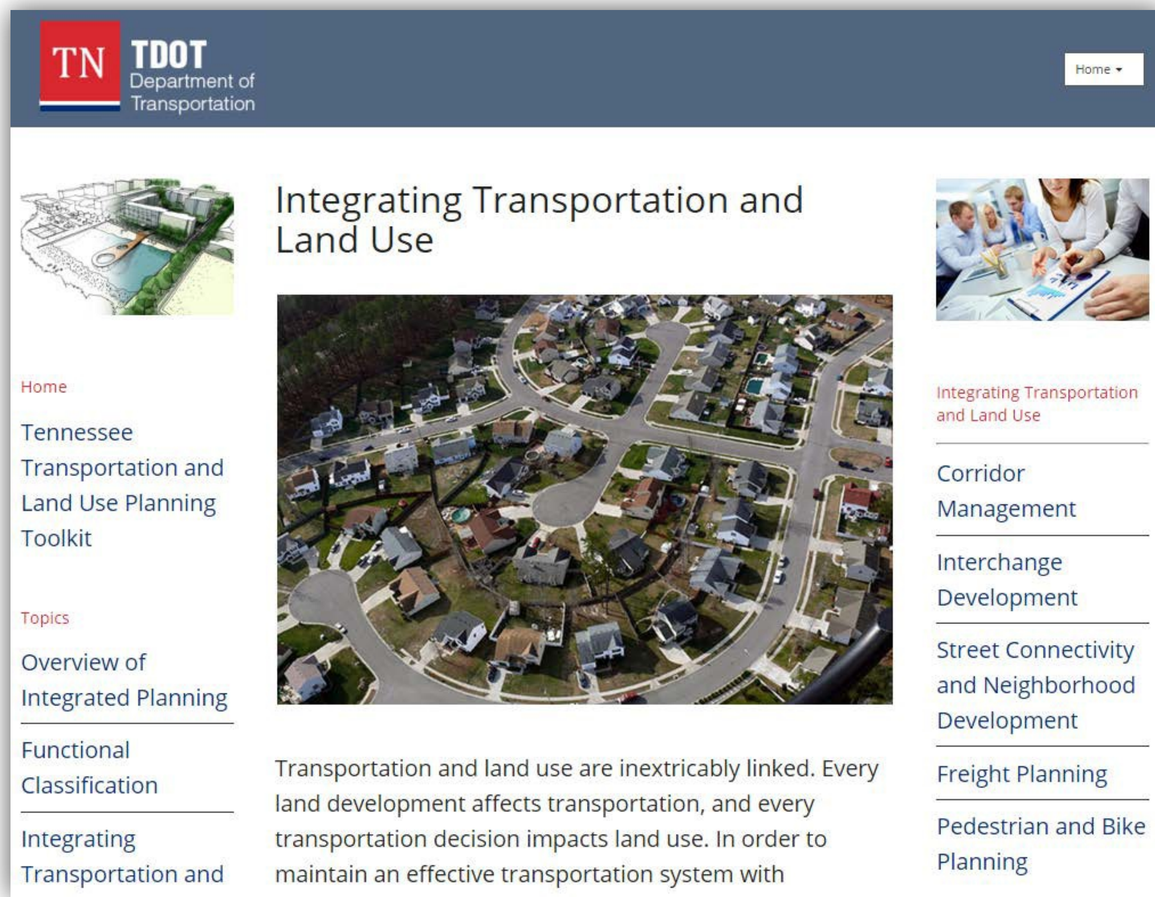


Functional classification resources that are available within this page include:

- Memphis MPO Functional Classification System Guidelines
- FHWA's Guide to Flexibility in Highway Design
- Highway Functional Classification Concepts, Criteria and Procedures
- Functional Classification Criteria MNDOT
- Hennepin County Functional Classification Guidance

Integrating Transportation and Land Use

This topic provides information and tools to aid in maintaining an effective transportation system with appropriate levels of accessibility. Planners must consider transportation and land use planning activities in conjunction. Coordinating these two planning processes will ensure an environmentally friendly, safe, and effective transportation network and built environment.



There are six subtopics within this page:

- Corridor Management
- Interchange Development
- Street Connectivity and Neighborhood Development
- Freight Planning
- Pedestrian and Bike Planning
- Local, Regional, and Statewide Planning

Each of these six subsections contains case studies, reports, strategies, programs, techniques, etc. to ensure successful integration of transportation and land use in the planning process.

The following resources are also available from this page:

- Corridor Management
- Interchange Development
- Street Connectivity and Neighborhood Development
- Freight Planning
- Pedestrian and Bike Planning

Corridor Management

This section contains the goals of corridor management: primarily to preserve safety and mobility of major thoroughfares, to identify transportation concerns and submit recommendations, to manage traffic congestion and reduce number of crashes, and to maintain and improve accessibility, capacity, and functionality. This section includes case studies, reports, recommendations, guides, etc. for planners to utilize in their transportation and land use corridor decisions.

The information available covers topics such as:

- Preserving right-of-way
- Land use strategies like access management techniques or land conservation

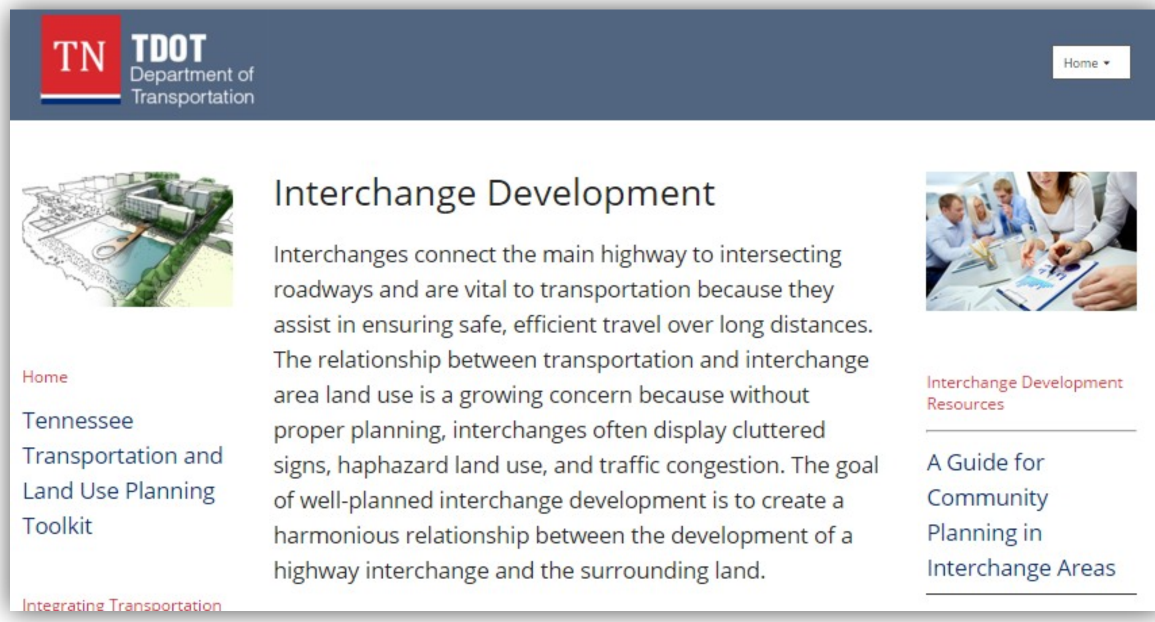
- Guidelines for development and design of transportation facilities within a corridor
- Interagency cooperation
- Managing funding

Additionally, the following resources are available for download:

- Cooperative Agreements for Corridor Management
- Route 24 Corridor Management Study
- Vermont Corridor Management Handbook
- Guide for Analysis of Corridor Management Policies and Practices
- Bluegrass Corridor Management Planning Handbook
- Managing Corridor Development
- MT 78 Corridor Study

Interchange Development

The Interchange Development subsection contains resources like guidelines and plans for interchange development. It explains the significance of and issues with interchange development, as well as the approaches to successful interchange area land use planning.



Resources available include:

- A Guide for Community Planning in Interchange Areas
- Oregon Department of Transportation: Interchange Area Management Plan Guidelines

Street Connectivity and Neighborhood Development

This subsection details street connectivity in the context of neighborhood development with resources like case studies, and guidelines. There are currently no additional resources available from this page.

Freight Planning

In this section, planners can find information on how freight operations relate to and interact with transportation systems and the environment, how to have sustainable freight operations, and how to plan for the impacts and needs of freight operations. In addition, this section identifies freight-related land use issues, key considerations, and available resources, and also provides examples and case studies from a range of urban and rural areas to demonstrate the effectiveness of various techniques.

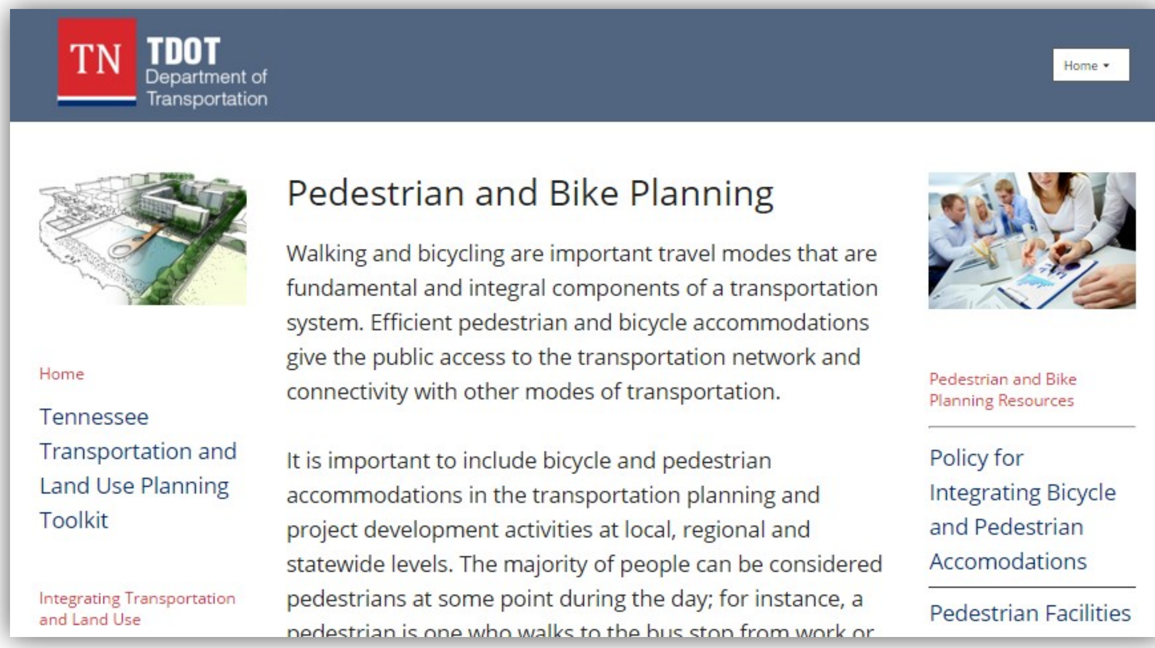
Well-integrated freight planning and land use decisions lead to:

- Reduced congestion and transportation costs
- Improved air quality and safety
- Enhanced community livability
- Improved operational efficiency
- Greater access to facilities and markets

A resource that is available within this topic is FHWA Freight and Land Use Handbook.

Pedestrian and Bike Planning

In this section, planners can find suggestions for planning principles, design guidelines, and construction, operation, and maintenance of a transportation network with pedestrian and bicycling accommodations. Such considerations will help localities, regions, and states to achieve a safe, effective, and balanced multimodal transportation system.

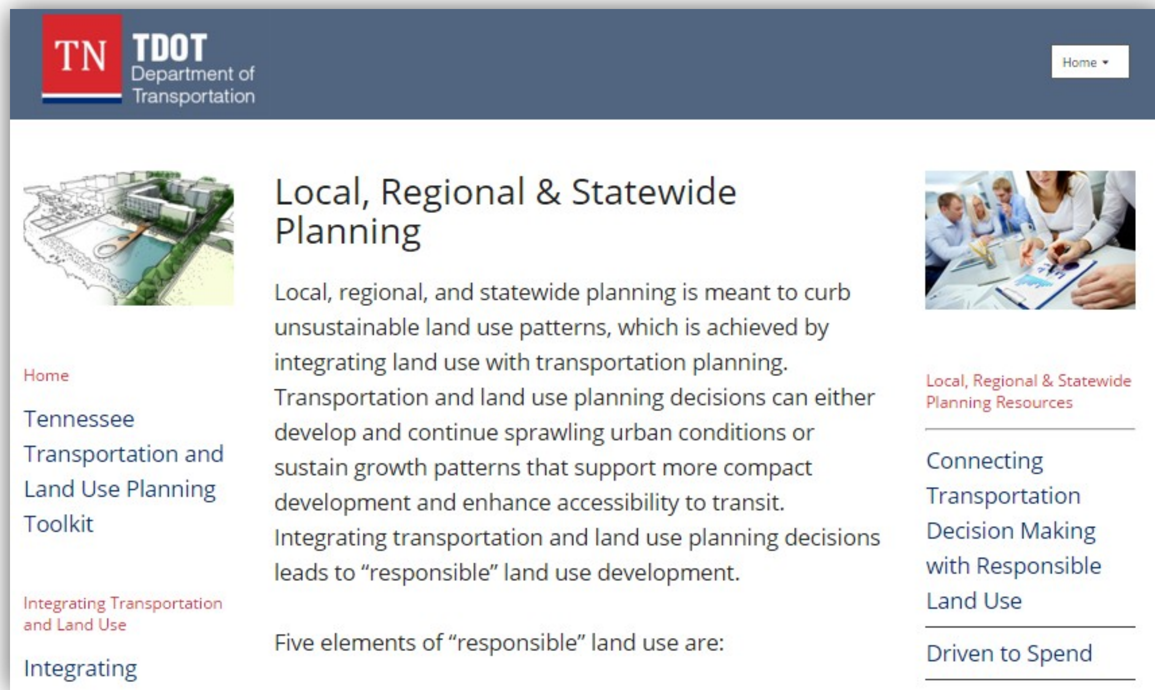


Available resources on Pedestrian and Bike Planning include:

- Policy for Integrating Bicycle and Pedestrian Accommodations
- Pedestrian Facilities Guidebook
- TDOT Bicycle and Pedestrian Policy

Local, Regional, and Statewide Planning

This section contains case studies, reports, strategies, etc. for integrating local, regional, and statewide transportation and land use planning activities. Here planners will find information that will help improve quality of life, enhance the environment, increase transportation and housing choices, lower costs, support the economy, increase the livability of an area, create an efficient and accessible transportation network, and serve the mobility needs of the public. The tools and strategies located to the right will help guide the integration of planning activities for transportation and land use.



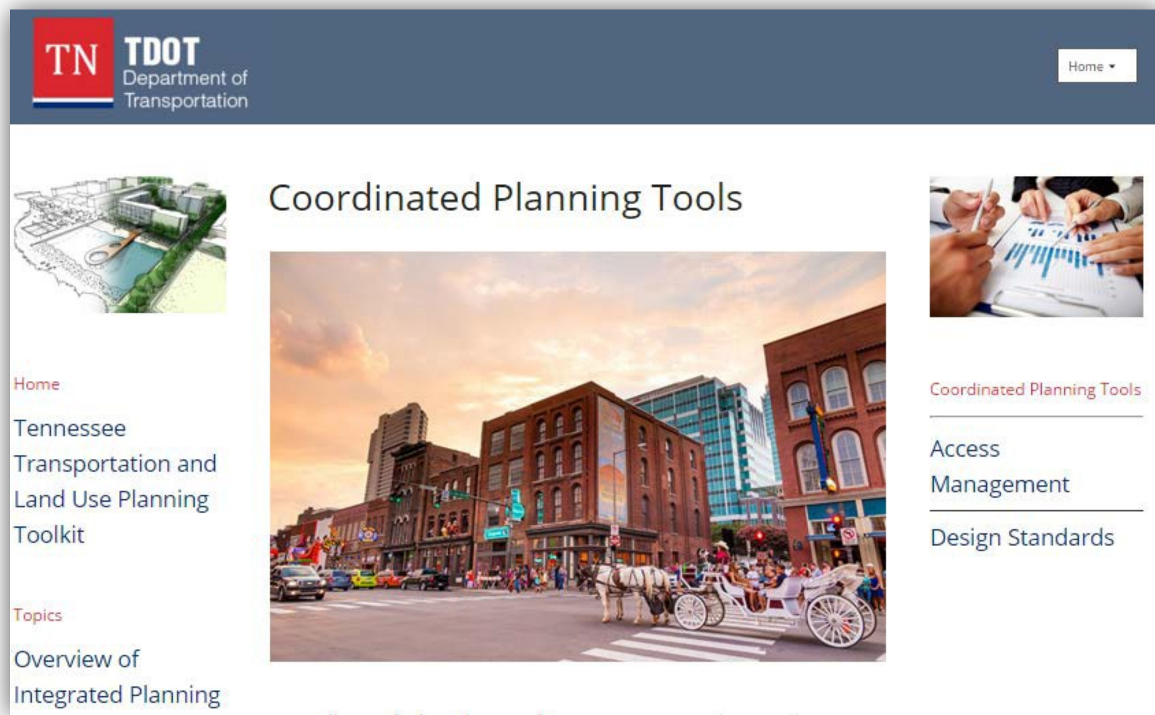
The Local, Regional, and Statewide Planning subsection contains the following resources:

- Connecting Transportation Decision Making with Responsible Land Use
- Driven to Spend
- Highways and Sprawl in North Carolina
- Integrating Land Use, Transportation and Economic Development
- Land Use and Economic Development in Statewide Transportation Planning
- Livability in Transportation Guidebook
- Smart Growth in the Southeast
- TCRP Costs of Sprawl Part A
- TCRP Costs of Sprawl Part B
- TCRP Costs of Sprawl Part C
- Where Are We Growing?

Coordinated Planning Tools

Coordinated planning tools are resources that seek to improve the functionality, safety, and usage of all roadways. Integrating the steps involved in transportation and land use planning is vital for a successful project because it ensures fluidity and synchronization.

The tools contained in this section are Access Management and Design Standards; their respective information can be found under the links to the right. Each tool offers suggestions for how to design and implement efficient and safe roadways. Included in each section are resources that contain guidelines, principles, case studies, etc. that detail the process, application, and benefits of using coordinated planning tools.

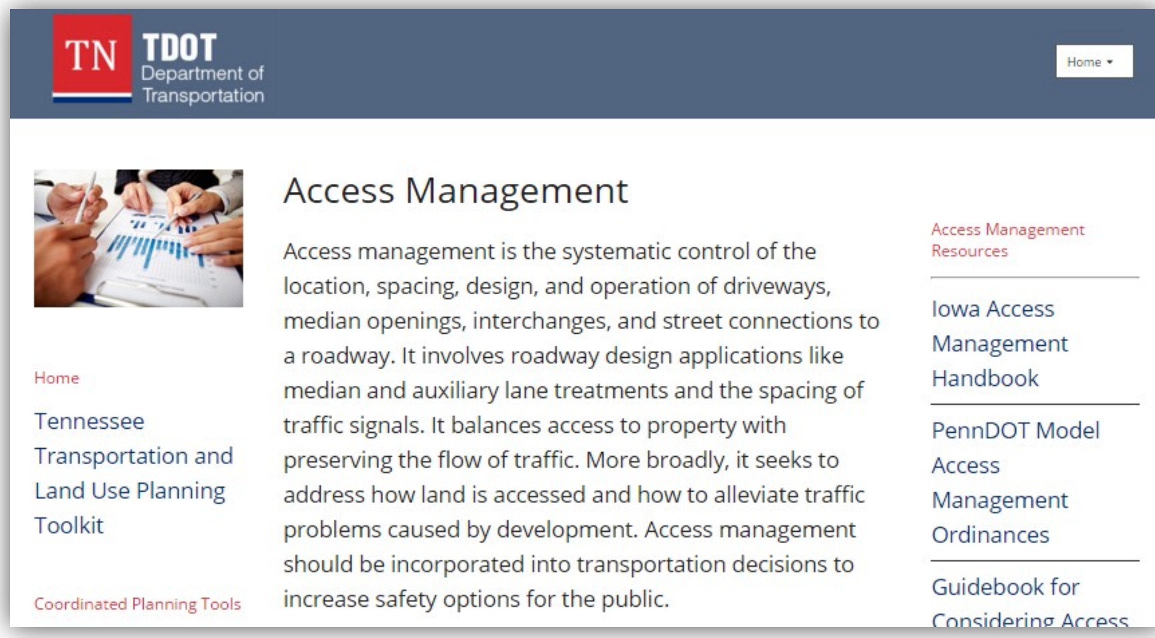


Access Management

Applying the best practices of access management benefits not only motorists, bicyclists, and pedestrians, but also business interests. Some benefits of access management include:

- Fewer delays, less fuel consumption, and fewer emissions
- Reasonable access to properties
- Maintained or increased roadway functionality
- Preserved public investment of roadway infrastructure
- Reduced future maintenance costs
- Improved appearance of transportation corridors
- Enhanced community environments and economies

The information here helps transportation and land use planners locate and apply best practices for access management. Included are strategies, case studies, access management considerations, standards, etc.



Some of the resources available include:

- Iowa Access Management Handbook
- PennDOT Model Access Management Ordinances
- Guidebook for Considering Access Management in Planning
- ALDOT Access Management Manual
- MN/DOT Access Management Manual Chapters 2-4
- VDOT Access Management Regulations
- Montana Right-of-Way Operations Manual
- Scott County Comprehensive Plan
- Montana Access Management and Land Use Planning | Policy Paper
- Access Management Plan U.S. 31W Hardin County
- Texas Department of Transportation Access Management Manual
- Radcliffe Subdivision Regulations
- Kentucky Model Access Management Ordinance
- TRB Access Management Manual

Design Standards

Design standards help create local streets that best serve the community in which they are located. This section contains example design standards that consider roadway design at the state and local level. In addition, emphasis is placed on design standards for local streets and roadways, including design considerations for roundabouts rather than conventional intersections, roadway development ordinances, and topics such as the application of road diets.

Design Standards resources include:

- VDOT Road Design Manual
- San Juan County Road Policy
- Roundabouts: An Informational Guide
- Roundabouts in the United States
- Infrastructure Improvement Requirements
- KYTC Roundabout Interim Requirements and Guidelines
- Model Design Manual for Living Streets
- Urban Street Design Guidelines: Redefining Charlotte's Streets
- Urban Street Design Guidelines: Designing Streets for Multiple Users
- Road Diets

Technical Analysis Tools

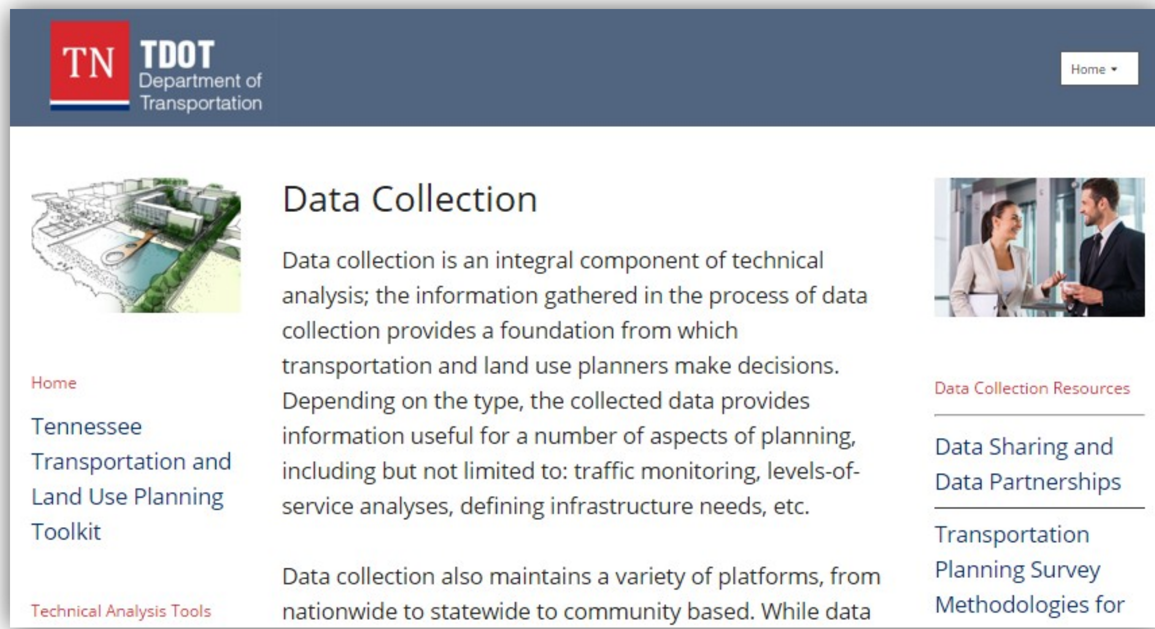
Technical analysis serves to predict potential impacts of development, understand multimodal and transit options, determine opportunities for roadway improvements, and more. The tools in this section will assist planners in conducting analyses that are detailed, efficient, and effective. Technical analysis tools will help ensure that coordinated planning projects are successful.

The technical analysis tools linked to on this page are geared towards transportation and land use planning applications. Each of the tools provide a broad range of reports and other resources that contain information about potential uses, ranges of capabilities, and case study applications. The four technical analysis tools are:

- Data Collection
- Assessment Tools
- Analytic Tools
- Scenario Planning

Data Collection

Data collection is an integral component of technical analysis; the information gathered in the process of data collection provides a foundation from which transportation and land use planners make decisions. Depending on the type, the collected data provides information useful for a number of aspects of planning, including but not limited to traffic monitoring, levels-of-service analyses, defining infrastructure needs, etc. These techniques will assist planners in the data collection aspects of their projects, which will ultimately help planners in forming decisions.

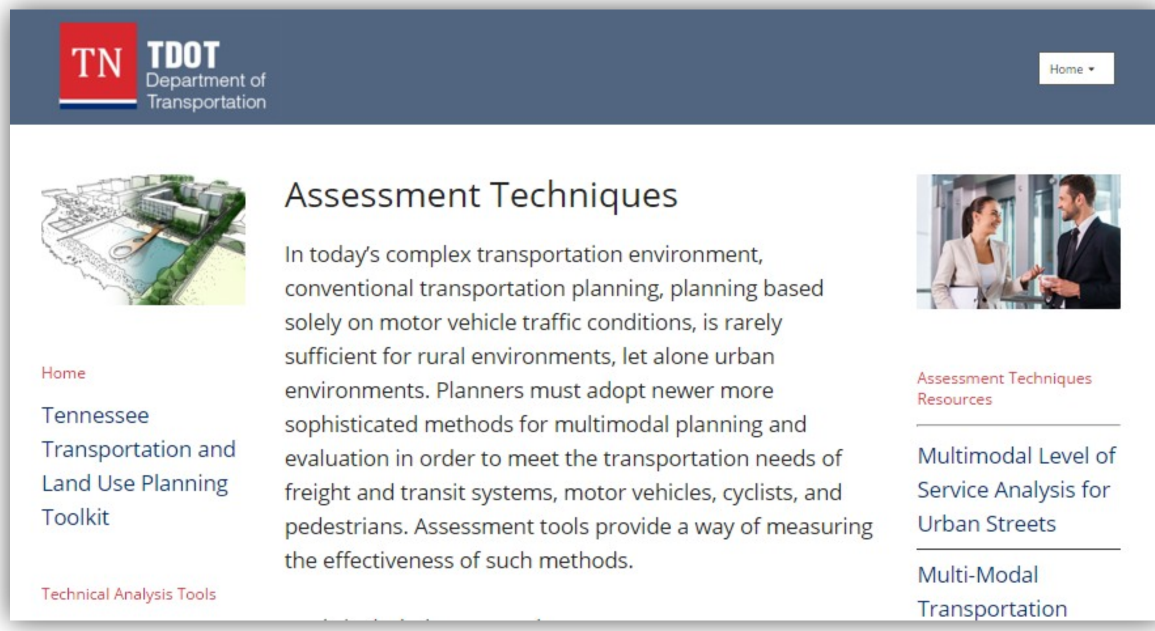


Resources that are accessible in this subsection include:

- Data Sharing and Data Partnerships
- Transportation Planning Survey Methodologies for Rural Regions
- Survey Methods for Transport Planning
- EPA's Smart Location Mapping

Assessment Techniques

Planners have to develop long and short-range plans, evaluate potential impacts, and design financial plans to fund transportation projects. All of these potential planning considerations require the assessment of current and/or future transportation conditions. The links on this page provide handbooks, case studies, analysis techniques, etc. that are pertinent to assessing current and future transportation conditions and needs. The information here assists planners in assessing the numerous and diverse facets of transportation and land use planning projects.



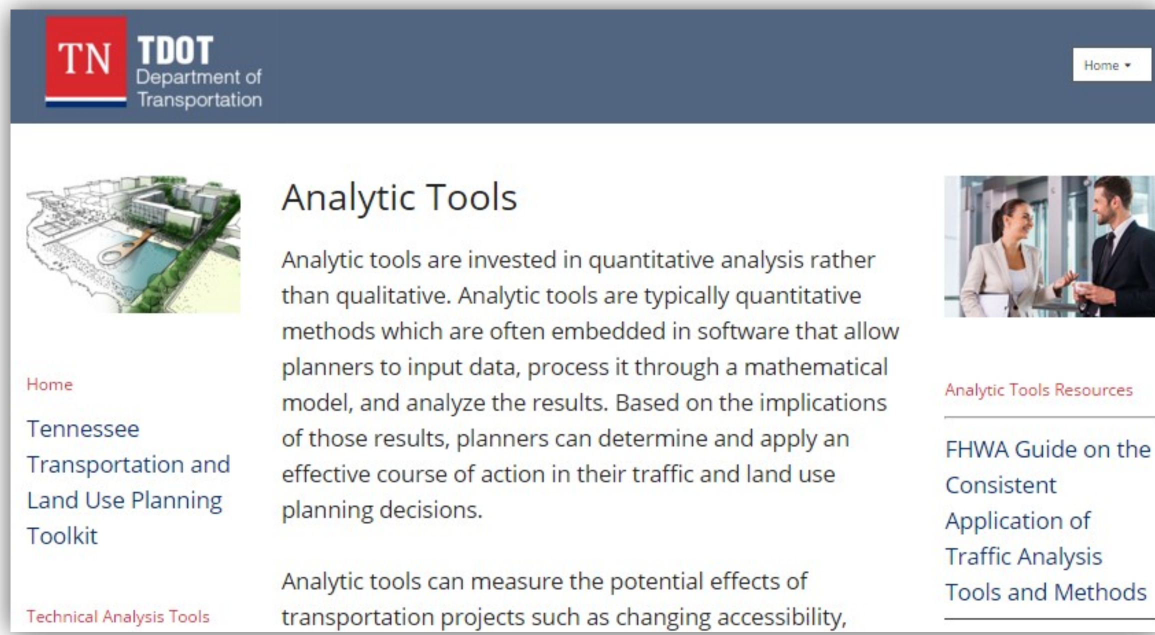
Helpful tools and information on Assessment Techniques includes the following:

- Multimodal Level of Service Analysis for Urban Streets
- Multi-Modal Transportation Planning (Principles and Practices)
- 2013 Quality Level of Service Handbook
- Use of Expert Panels in Analyzing Transportation and Land Use Alternatives
- Use of Expert Panels in Developing Land Use Forecasts
- The Built Environment Assessment Tool Manual
- Effect of Smart Growth Policies on Travel Demand
- AARP's Livability Index
- EPA's Walkability Checklist
- MN/DOT Access Management Manual Chapter 5
- Iowa DOT Guidelines for Traffic Impact Analysis
- Traffic Impact - WIS DOT
- VDOT Traffic Impact Analysis Regulations Administrative Guidelines
- VDOT Traffic Impact Analysis Regulations

Analytic Tools

Analytic tools can measure the potential effects of transportation projects such as changing accessibility, incorporating new or different transit routes, making improvements to reduce travel time, constructing or expanding new highway facilities. Analytic tools are valuable in that they allow planners to simulate the impacts from a proposed transportation design or improvement before making the decision to apply it. This allows for safer, more effective evaluation of land use and transportation planning decisions.

The analytic tools presented in this section largely focus on models and tools to analyze land use impacts. The resources here provide an overview of traffic forecasting tools at the system and project level and of the use of transferable parameters. Included in the reports are case studies and guidelines highlighting procedural regulations, applications of appropriate modeling and analysis software, and other useful analytic tools.



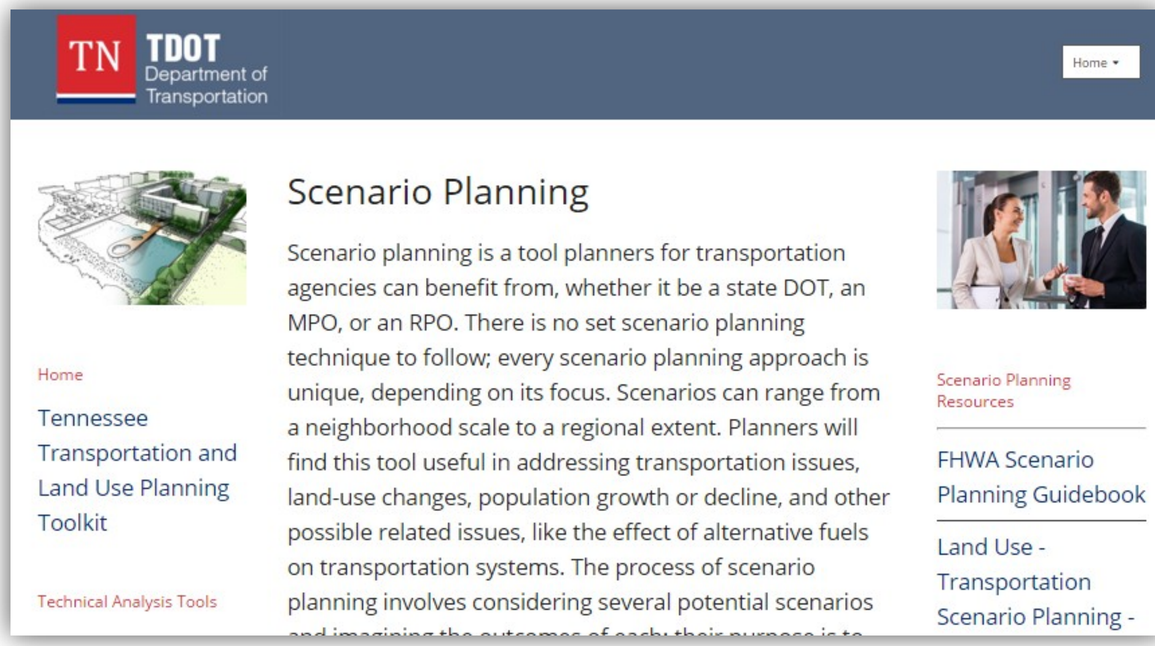
Resources accessible through this subtopic include:

- FHWA Guide on the Consistent Application of Traffic Analysis Tools and Methods
- Assessment of Local Models and Tools for Analyzing Smart Growth Strategies
- Land Use Impacts of Transportation: A Guidebook
- Analytical Travel Forecasting Approaches for Project-Level Planning and Design
- Linking Land Use, Transportation and Travel Behavior in Ohio
- Long-Distance and Rural Travel Transferable Parameters for Statewide Travel Forecasting Models

Scenario Planning

Scenario planning is a tool planners for transportation agencies can benefit from, whether it is a state DOT, an MPO, or an RPO. There is no set scenario planning technique to follow; every scenario planning approach is unique, depending on its focus.

This section features links that define the components of a comprehensive scenario analysis. Included are case studies of several applications of regional scenario planning efforts. This section also suggests potential scenario themes, reveals important gaps in scenario planning, and provides examples of opportunities for implementing a scenario planning approach.



Tools and information about Scenario Planning can be found at the following:

- FHWA Scenario Planning Guidebook
- Land Use - Transportation Scenario Planning - Promise and Reality
- Regional Visioning and Scenario Planning
- Scenario Planning in Middle Tennessee
- Central Hamilton County Scenario Planning Study
- Envision Utah

Health and Transportation

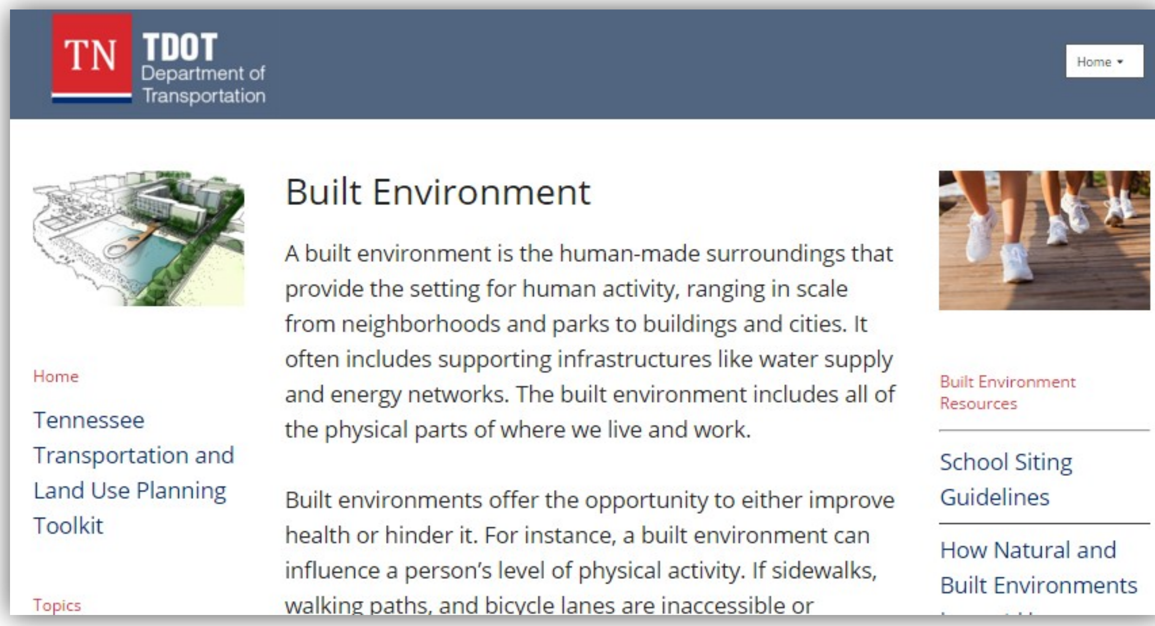
Without careful planning, communities can experience unhealthy affects like gas emissions, higher levels of contamination in the soil, reduced air and water quality, etc. In order to combat negative implications, planners must incorporate health considerations into transportation and land use planning decisions.

In this section, planners will find information on how to take proactive steps in the planning process to prevent making decisions with unhealthy effects on a community. The subsection entitled “Built Environment” explains how the public’s health is influenced and impacted by the built environment that surrounds it. There are strategies, techniques, and suggestions for creating, maintaining, and/or improving the built environment.

Built Environment

A built environment is the human-made surroundings that provide the setting for human activity, ranging in scale from neighborhoods and parks to buildings and cities. It often includes supporting infrastructures like water supply and energy networks. The built environment includes all of the physical parts of where we live and work. The type of built environments within a community impacts the overall quality of life and health of its residents.

In this subsection, planners will find strategies, techniques, and suggestions for creating built environments. The reports and case studies provide information that can be used to maintain, improve, or create a built environment that is safe, efficient, and healthy.



Resources located on this page include:

- School Siting Guidelines
- How Natural and Built Environments Impact Human Health
- Intersections Health and the Built Environment

III. Survey Data Collection Plan

As noted in the introductory pages to this report the emphasis of the third major task of this project changed from a the development of a more comprehensive data collection plan for long range transportation planning in Tennessee to a more focused effort designed to create a survey data collection plan. The revised goal for this task was to outline a plan collecting survey data in a standardized way on a regular cycle across the state of Tennessee for use by TDOT, MPOs and RPOs. Meetings were held with Tennessee transportation planners to discuss agency interest and the feasibility of this concept. Once the interest and feasibility were confirmed the next step was to gather information in some detail about how planners in other states have approached this issue. During the course of this research sub task the team became aware of the availability of an outside expert who could provide insights on this concept from the perspective of a data collection contractor. This perspective was believed to be very important, thus a budget revision and no cost time extension was requested in part to bring this expert onto the team as a subcontractor. The consideration of this request resulted in the decision to end the project without the completion of additional work. Thus, a survey plan was not completed. The information reported here is a summary of what was found regarding survey initiatives in other states.

California Household Travel Survey

The 2010-2012 California Household Travel Survey was a statewide, collaborative effort led by the California Department of Transportation (Caltrans). The effort was jointly funded by the California Strategic Growth Council, the California Energy Commission, and eight transportation planning agencies throughout the state. The scope of the survey efforts extended to all counties within the state. The overriding goal of the survey was to create a coherent and practical survey that met the data needs of all stakeholders. To this end, representatives from these stakeholders, and other MPOs, formed a steering committee that oversaw the entire survey process, with final say in the survey methodology. Survey questions were based on data needs among all stakeholders; however, an option to purchase additional samples was available to each organization. A vendor was contracted to provide the technical work and the majority of the labor effort required by the survey, in accordance with the design approved by the stakeholder committees.

A database containing addresses was purchased from a vendor to serve as the survey population. Survey sample recruitment was carried out through informational letters mailed to households chosen from this database, with recruitment interviews being completed through computer assisted telephone interviews (CATI) or on the internet. The

Steering Committee placed emphasis on demographic groups that were considered difficult to reach, and some presorting from the address database helped to explicitly target the desired demographic groups.

Approximately 42,000 households were successfully recruited into the survey. These households were then mailed survey materials including a paper travel diary. The primary survey instrument consisted of a paper travel diary along with a demographic and socio-economic questionnaire. A subsample of approximately 13% (around 5,400 households) was chosen to receive a GPS recording device. The primary purpose of this GPS subsample was to collect data that would aid in the estimation of underreporting for the non-GPS households. Monetary incentives were provided to demographic groups that were considered hard-to-reach, or of special interest, as well as all households who received a GPS device to encourage participation.

Each household was assigned a specific travel day, with the entire effort covering a full 366 days (2012 being a leap year). Holidays and other times of the variation were included in the survey, with no exclusions. All data collection was in adherence to practices developed by the steering committee and subject matter experts, with on-going reviews of data by both Caltrans and the vendor. Data retrieval was the purview of the vendor and was conducted through three modes: CATI, a website, and mailing completed materials back to the vendor. Final data processing was undertaken by the vendor, with quality control checking provided by Caltrans, and the data deliverable disseminated to stakeholder agencies.

Due to its complexity and comprehensiveness, the stakeholders made several discoveries that were not anticipated. One of issues identified was the under-representation of cellphone-only households. The main sampling effort was directed at households for which a landline was attached. This particular group of cellphone-only households is estimated to be growing among younger adults, poorer households, and mobile households, thus leading to some exclusion of these groups. Language limitations also affected the survey, approximately 1.4% of all sampled households were unable to be recruited as the predominant language was neither English nor Spanish. It was determined that for such situations the cost and effort needed to translate the array of survey materials into a language used by very small portions of the population exceeded the utility of any data that could be gleaned from this group.

Effort was put into developing a list of findings for the survey, to better inform future efforts. The complexity and scope of the survey was viewed as a valuable addition to planning throughout the state of California. The single survey effort allowed certain costs to be streamlined, only one contractor was needed, different agencies were able to share data and build working relationships with each other, and the cost of survey development was split among many parties instead of being borne by one single entity. However, there were a few recommendations that the survey coordinators suggested. The first issue concerned ensuring that any contracts awarded to vendors allowed more flexibility in scope, especially in long timeframe surveys such as CHTS. Secondly, it was decided that more time between a survey pre-test and the primary effort was needed in order to thoroughly review needed adjustments. This relates to the number of entities that were involved, as each needed to review the detailed design, methodology, and results in addition to their regular work loads. Third, the team thought a more public outreach and branding campaign could have bolstered awareness of the survey. The assumption here is the more familiar the public is with a survey effort; the more willing they might be to participate. Additionally, there was a major desire to transition to a continuous survey process rather than the discrete system used. It is believed that this would drastically reduce start-up costs and speed up survey execution. There were two full years between the launch of the CHTS and the beginning of the primary statewide survey process; this could have been reduced if the initial framework had already been in place. Last, the authors of the report expressed a strong desire to include new technologies, such as smartphone applications and web-based travel diaries, into the process with the goal of increasing accuracy among trip reporting.

Ohio Household Travel Survey

In 2015 the Ohio Department of Transportation (ODOT) and the 17 metropolitan planning organizations (MPOs) in Ohio conducted a pilot study for a continuous, smartphone-based household travel survey. The pilot survey, which allowed testing of the survey methodology, has been successfully completed and the first wave of the full survey is scheduled to begin in mid-2016. Contact was made with Ms. Rebekah Anderson, Project Manager with ODOT, who provided more detail on these efforts. The impetus behind the survey is to update travel data to better inform statewide travel demand forecasting models. Administration of the effort is the responsibility of an oversight committee consisting of ODOT and MPO personnel along with consultants. The committee also provides direction and input regarding survey instrument questions, methodology, and completeness of results. Approximately 1/10th of the state will be surveyed each year for the next ten years (2016 – 2026), with a target sample of 2,300 households per year, for a minimum of 23,000 households for the duration of the survey. MPOs are given the option to purchase additional household samples for their region, so the final number of households participating in the survey will vary upward.

Households were recruited via postcard mailings, which invited them to download the survey app. Each household was also assigned a specific week (seven days) in which to record their trips. Ms. Anderson stated that initial recruitment was very successful; reaching the pilot survey quota in only four of the five weeks budgeted for the task. Of the households successfully recruited, fully 90% were retained for the duration of the survey.

The pilot survey was conducted through the use of a smartphone application and a website, in place of traditional paper travel diaries and telephone interviews. Recruited households that did not have a smartphone were eligible to be sent a working smartphone for the course of their participation in the survey. A vendor was chosen to develop the application as well as an online portal that would serve as a diary for those who did not have or wish to borrow a smartphone. The application was designed for iOS and Android, with development for other operating systems considered unnecessary.

Once the application was installed, detailed location data is recorded automatically; when the user is recorded as stationary for a predetermined amount of a time a stop is recorded. The mobile application syncs data to the survey's website automatically to maintain an off-device record of the trip. The application then shows the recorded trip to the user and prompts for trip information. The user is able to enter trip information on the app or on the website at a later time. Lastly, data collection and analysis are performed by the vendor through the online interface, with ODOT personnel performing quality checks.

While the primary survey effort is just now beginning, the results from the pilot study provided a great deal of information for the planning and execution of the first year's effort. For the pilot study there were a total of 937 households successfully recruited. Since the survey was conducted through the use of a mobile application, the majority of household trip and demographic data was collected through this method, however approximately 10% of respondent households used the online travel diary. Considerable financial savings were realized by not having to contract with a call service or develop and print a paper travel diary. Additionally, all data collection from the travel survey is effectively instantaneous over the internet, reducing time spent on waiting for diary returns. The use of a smartphone application allowed the survey to be extended far beyond a traditional one or two day effort, allowing a greater amount of data to be collected and true weekly patterns of travel to emerge.

Households who did not have a smartphone, could receive one from the survey team. This phone was then returned at the end of the survey. ODOT stated that smartphone return rates were on par with traditional GPS data loggers, and that few phones were lost in the process. The designers of the application insisted that trip recording be automated to some degree, as to reduce the possibility of participants forgetting to record trip information. The survey investigators stated that 90% of participants remained active in the survey effort for the entire seven day period, perhaps due to this automated nature of the application.

Florida Household Travel Survey

The Florida Department of Transportation (FDOT) and Florida MPOs are in the process of launching multiple new survey efforts. Contact was made with Mr. Thomas Hill, State Modeling Manager for FDOT, who explained that the state purchased the National Household Travel Survey (NHTS) add-on samples for 2009, but found that the data collected by NHTS was not always applicable for the different travel demand and planning models in use among the MPOs. In order to collect relevant data for each MPO, it was decided that MPOs would conduct any necessary surveys (household travel, transit, etc.) within their own regions while FDOT would conduct a household travel survey for all areas of the state not within MPO boundaries. MPOs would have full control over the type and composition of their surveys, while FDOT would function as a coordinator of all the survey efforts, and providing any assistance or support needed by the MPOs. There are no current plans for this to be a recurring effort. While the FDOT survey has not begun as of March 2016, Mr. Hill estimated that it will launch in mid-2016.

Households are to be recruited through an existing FDOT contract with a demographic research vendor, who will supply a list of addresses matching desired demographic and geographic constraints. These households will then be mailed informational packets with instructions in English and Spanish on how to download the survey smartphone application. This application will be the only survey instrument used, as FDOT decided on a paperless effort. Therefore, households that lack a smartphone will be excluded from the household travel survey.

The smartphone application was built by a third-party vendor and was designed around a modular programming framework, which allows survey questions and parameters to be modified with a minimal amount of effort. FDOT insisted on the modular design to provide a common platform for the various MPO survey efforts. MPOs are encouraged, but not required, to use this application to conduct their own surveys. The application is currently fully functional and awaiting deployment.

Location data for each day is automatically recorded once the user has launched the application. The application monitors the position of the smartphone, when movement beyond a small geographic zone or at speeds greater than a few miles per hour is detected and then location data is logged. When the application detects that movement has ended, a trip is recorded and the user is prompted to enter detailed information about the trip into the application, with the option to postpone data entry until a more convenient time. A survey website displays individual trips that have been recorded from the user and any trip attributes entered. At this point, the user has an opportunity to correct any data previously entered before final submission. Once submitted the data is collected over the internet by the vendor, with FDOT in control of the data quality checking and processing. The survey results will be used to update and refine FDOT’s statewide travel model.

FDOT estimates that exclusively using a smartphone application will result in drastic financial savings, compared to traditional telephone and paper surveys, as no call centers are needed nor are scripts and diaries printed for the effort. By designing the application to be modular, Mr. Hill estimates that it will continue to be a useful survey framework for many years and that its value will far exceed any development costs. It is important to note that the application was created for both the Android and iOS operating systems, as together these cover the vast majority of all smartphone users. One potential problem with this approach was identified as the exclusion of non-smartphone users from the study. This subgroup likely contains certain populations that may be more marginalized by the lack of inclusion, such as the elderly, the poor, and minorities.

Utah Travel Study

The Utah Travel Study was a comprehensive suite of surveys undertaken in 2012 by the Utah Department of Transportation (UDOT) and several MPOs, transit authorities, and regional councils of government. The state was divided into regions, according to the organization serving that region. UDOT was responsible for the more rural areas, while MPOs and councils of governments took responsibility for the urban areas. The core of the effort was a household travel diary, with seven other surveys complementing the effort. The eight surveys were: a household travel diary, a long distance travel debrief, a college travel diary, a bike/pedestrian debrief, a bike/pedestrian barriers survey, an attitude debrief, an on-board transit survey (only for the SunTran system and service area), and a residential choice stated preference survey. This suite of surveys was intended to inform regional and statewide transportation planning among the stakeholders.

The sampling unit was an individual address. These addresses were chosen by the vendor using the United States Postal Service's Computerized Delivery Sequence database. Invited households were randomly selected among all existing residential addresses proportionally to the number households in each region. A packet containing more instructions and information on how to access an online travel diary along with the indicated travel day was mailed to each successfully recruited household.

The household travel diary survey consisted of three separate sections. The first was household demographic information. The second was the travel diary, which recorded all travel for all members of the household for one of 33 predetermined days. For the last part, each household in the survey was assigned one of three debriefs: attitudes and opinions, long distance travel, and a walk/bike survey. The attitudes and opinion debrief was designed to gauge public opinion on land use, transportation utilization, and other region-specific questions. Attitudes were measured via the strength of participant agreement with a series of statements. These statements varied among the survey regions as each organization had differing priorities and data needs. The long distance travel debrief was also used as a separate survey; a household that was not assigned this debrief may have been recruited at a later date to complete the survey independently. The survey defined a long distance trip as being over 40 miles in length and collected data from participants for all trips of this length. The walk/bike debrief measured respondent utilization of walking or biking as a mode of travel.

At the end of the household travel diary survey, participants were asked to provide a valid email address if they wished to participate in further surveys. Those who did, approximately 84% of the total participating households, received additional surveys. Those who did not already complete the long distance travel survey could do so at this stage. The walk/bike debrief had measured current usage, while the full bike/pedestrian barriers survey asked respondents to identify physical barriers impeding bicycle usage/walking as well as any unsafe areas or ways to improve existing infrastructure. Additionally, a residential choice survey was conducted. This survey asked residents about current housing and neighborhood characteristics, as well as ideal preferences for these characteristics, providing in-depth insights into housing trends and preferences in the state of Utah.

The college travel diary survey was limited to eight participating college campuses. The core of the survey was similar to the household travel diary survey, albeit somewhat shortened. The scope of the survey measured the trips of the student population between home and school, as well as other travel habits and attitudes towards transportation issues. Like the other surveys, the college travel diary was submitted online.

Data collection for the household travel diary survey, and all other surveys, was conducted through the vendor using a website or a toll-free telephone number, with UDOT and representatives from each organization providing quality assurance. An incentive, in the form of a $10 Amazon.com gift card, was offered to households that completed their household travel diary and their assigned debrief survey, while households that volunteered to participate in further surveys were offered additional incentives. The final datasets were then disseminated to the stakeholder organizations.

According to the survey report, the partnership with the MPOs proved to be a valuable asset to the Utah survey efforts. The MPOs facilitated regional planning discussions and were able to add their input in to the survey. This ensured that the results will be both applicable and used by stakeholders. Survey participants were offered a range of completion options: internet, telephone, and mail-back. This allowed respondents to select the method that was most convenient for them. Furthermore, Spanish translations of the survey materials and completion methods were readily available to all who requested it, allowing a more comfortable effort for those households where English is not the primary language. The final response rate exceeded estimates, and it is perhaps worth mentioning that the Utah study is the only one discussed that gave an incentive to all households who completed the household travel survey. Lastly, to reduce the level of partially completed surveys, those households were contacted and offered an increased incentive to complete their survey. This follow-up approach also helped keep survey costs down as the households being targeted had already been successfully recruited.

Massachusetts Travel Survey

The Massachusetts Travel Survey was finalized in 2012 and covered a data collection effort from 2010 to 2011. It was a collaborative effort between the Massachusetts Department of Transportation (MassDOT) and MPOs within the state. The design of the survey was approved by both the MPOs and MassDOT, with the goal of gathering data for use in updated statewide planning models. MassDOT provided the administration for the project with the MPOs providing data needs and input. MassDOT was also the coordinating office among the vendors used on the project. The type of survey chosen was a traditional household travel survey with a paper travel diary. A subsample of the households recruited would also use a GPS logging device. This subsample would then be used to estimate the level of underreporting that could be expected by the non-GPS households. A pre-survey, using the planned methodology of the full effort, was conducted with a statewide sample allowing a test run of the planned procedures before the full survey began.

The dataset used for the sample was provided by a vendor and based on U.S. Census data at the tract and block level. Households were recruited through a stratified approach, in which the vendor divided the survey universe into separate groups (or strata). Census blocks or tracts containing a higher percentage of a desired group allowed the survey to oversample certain geographic or demographic strata. Introductory mailings were sent out to prospective households, followed up with a reminder postcard. Participating households were then recruited into the survey and sent materials, including the paper travel diary. Households were asked to report their travel for an assigned 24-hour period. The timeframe of the survey occurred between June 2010 and November 2011. Travel days were evenly distributed among each weekday; weekends were not included in the survey. GPS logging devices were also sent to a subset of these households. The GPS devices were sent and retrieved by a separate survey vendor. GPS households differed from non-GPS households in that they were requested to use the GPS device for two weekdays instead of one. Those GPS households whose travel day fell on a Friday were asked to record their travel for the entire week, Monday thru Thursday, as well.

Data retrieval was handled via mail back or computer assisted telephone interviews. Telephone retrieval was attempted the day after the scheduled travel day, or at an agreed upon time. The completed surveys were returned almost equally through both modes of collection. Data processing was ongoing throughout the effort and subject to a quality control process implemented by MassDOT. GPS households reported their travel patterns via telephone, while mailing back their GPS units, allowing a review of what was reported by telephone versus what the GPS data logger registered. This allowed some adjustments to be made for perceived versus actual trips for the non-GPS households. GPS households also received a $25 per household member incentive for their participation. Once data had been processed and weighted using MassDOT's methods, it was then finalized and delivered to MassDOT and the MPOs.

The Massachusetts Travel Survey collected data about 37,023 individuals in 15,033 households was collected. The average household size was listed at two individuals and formed 32.1% of surveyed households, while households containing just one member formed another 28%. Slightly more females (53%) than males (47%) were surveyed. The coordinators of the survey encountered several issues and areas that need improvement moving forward. One of the most important issues discussed is the growing resistance displayed by the average U.S. household to surveys in general and telephone surveys in particular. Household travel survey efforts, like that in Massachusetts, are complex and require a certain investment of time in order to complete, especially in households where English is not the primary language. This led to difficulty in meeting survey participation quotas, requiring a longer recruitment effort.

One of the recommendations for further improvement was a more concerted effort to reach the Hispanic population. This subgroup was found to be most likely to not respond, possibly because of language issues. Public outreach, such community media and messaging efforts, were highlighted as possible solutions. It was postulated that underreporting of trips may be exacerbated because of the paper travel diary format of the survey. Memory fatigue can reduce the accuracy of trip times and places when the respondent is filling out the paper diary hours later than when the trip was taken. Lastly, the use of in-person follow-up interviews was suggested to ascertain why some household chose to not respond. The cost of this level of interview is high but it was estimated that by sampling the non-responder group, some measure of correction could be calculated to assist in counteracting this missing information.

Connecticut Statewide Transportation Survey Pilot Study

The Connecticut Department of Transportation (CTDOT) and the Connecticut Joint Highway Research Advisory Council (JHRAC) sponsored a research pilot study to examine the feasibility of a full-scale statewide transportation study effort. The sponsors created a Technical Advisory Council that oversaw, designed, and implemented the pilot study. This council was composed of CTDOT planning staff as well as MPO planning staff, in order to accommodate a wide range of views and data concerns. The technical work was performed through the Connecticut Transportation Institute at the University of Connecticut under the supervision of the Technical Advisory Council.

The study was designed to test an alternative way of conducting a travel study beyond using traditional paper travel diaries and mailings. It was decided that the survey would be administered through an internet travel diary that was designed and programmed by the research team and hosted on a University of Connecticut server. No physical mailings or paper diaries were distributed during the study; everything from recruitment to data collection was conducted through the web interface.

Recruitment was carried out through mass emails, connections at the sponsoring organizations, as well as working with several large employers to recruit their employees. The total number of households that completed the entire survey numbered approximately 679. The distribution of the sample, while being statewide, was concentrated within a specific geographical location. It was presumed that this is the result of the limited recruiting efforts. The survey instrument contained questions concerning demographics and housing situation, and also asked participants to report on their travel for the previous day; there were no pre-assigned travel days. The online survey was open to the participants for approximately one month.

Data collection efforts were conducted through the web interface. No vendor was used, as the questionnaire was programmed and deployed using in-house resources. Therefore, the research team had access to all of the raw data as it was filled out by participants. This raw data was then processed into two separate databases: person, or demographic data, and trip data. The final datasets were then delivered to the sponsoring agencies and the methods and tools used recorded to inform future survey efforts.

Results for the pilot survey indicated that the survey website was accessed the most between the hours of 9:00 AM and 11:00 AM and 1:00 PM and 3:00 PM. There was a definite geographic bias detected in the location of participants who successfully completed the pilot questionnaire. Of all recruited participants, only 993 of 1,519 successfully completed all questions. Gender participation was also found to be significantly biased with nearly 60% of participants listing themselves as female. The study team found that the code used to create the online survey required much more effort and time to complete than originally anticipated, which led to delays in deployment. Some lessons learned indicate that more infrastructure was needed to support the website, as many participants complained about latency or unavailability when attempting to log on. It was suggested that the latency issue could be addressed through deploying the survey through a high-traffic, high bandwidth cloud hosting environment such as Amazon Webservices. The primary advantage to this approach is that additional server capacity can be added dynamically in the event of a possible traffic overload. Additionally, the use of a pre-packaged survey code would greatly speed up website deployment through the avoidance of custom software coding.

Appendix A

Assessment of Macro Trends and Their Impact on Travel Demand

Summary of Key Points[22]

This appendix provides a list of summary points and conclusions on Travel Behavior Trends drawn from the literature scan on *The Next Generation of Travel: Research, Analysis, and Scenario Development*.

Demographic Trends

- Between 2000 and 2009, the U.S. population increased by 8.8 percent, in large part due to immigration. It is expected that as the population grows, annual VMT will increase.
- New immigrants have accounted for most of the population growth in the U.S (The Brookings Institute, 2010). They have more children and at an earlier age (Pew Research Center, 2008). They travel fewer miles, make fewer vehicle trips, and take transit, walk and bike more (Contrino, McGuckin, 2009), and Hispanic immigrants carpool more; however, research has shown that new immigrants will eventually begin to travel more like U.S. born residents, purchase cars and ultimately contribute to increases in VMT.
- By 2050, the population of those over 65 is expected to double. Many older adults want to age in place; currently, eighty percent of adults 65 and older live in car-dependent suburban and rural communities. Of those 65 and older, ten percent use transit and about nine percent walk (NHTS, 2009). Most stop driving when they become visually impaired.
- Women continue to drive less than men; however, they are more likely to demonstrate greater trip chaining behavior when it involves their commute and transport of children. In families of 2 working parents, women made 62.3 percent of the trips to drop off a child compared to 38.7 percent made by men (Murakami, McGuckin, 1999 NHTS).
- Age and income continue to have the greatest impact on the number of miles someone travels. Income also affects other variables that have been shown to increase travel, such as vehicle ownership, education and worker status.

Trends in Trip Making

- Since 1995, VMT and PMT among younger populations under the age of 30 have shown substantial declines. It should be noted that the 2009 survey data was collected in 2008, at the onset of the Recession.

- Weekend travel and non-work related trips are increasing, possibly as a result of increases in trip chaining and a growing aging population who are retired but are still driving.

Telecommuting

- Significantly more people telecommute today than in the past, a 92% increase from 1980 to 2000. Telecommuters make up about 4% on the Nation's workforce; and it is a trend that is expected to increase in jobs where it is an option, as younger generations of workers seek a work/life balance and are easily adaptable to new technologies.

Vehicle Ownership

- The number of households without vehicles has declined to about 8% of all households (although, this percentage has increased slightly over the past decade), it raises the question as to whether owning a vehicle should remain a key determinant of future VMT growth, and additionally, to whether younger generations might be more willing to car pool or car share, or be more likely to use other modes of transportation rather than own a vehicle.

Economic Effects

- The trade-off between household spending on housing vs. transportation costs, further impacts a household's ability to spend on transportation[22], which may limit their travel.
- People who are heavy users of transit spend less of their household budget on transportation, which could account for an increase in transit use in recessionary times.
- The further people live from an employment center, the more they will spend on transportation, which may limit their travel for other purposes.
- People who are unemployed often drive less.
- In the past decade, the percentage of two and three vehicle households has decreased; a possible indicator of the recession's effect on households reducing their transportation costs.
- The price of transportation may have an effect on increases or decreases in VMT, as noted in history, when gasoline prices have increased growth in VMT slows or decreases. For instance, the most recent recession may have led to a drop in personal VMT, as seasonally adjusted VMT fell by 1.2 billion monthly from December 2007 to June 2008, and then grew by 200 million monthly from July 2008 and December 2009.

- The recession may have a stronger effect on younger generations, who have experienced higher than average levels of unemployment and delayed entrance into the workforce.

Regulatory Effects

- The introduction of graduated licensing and the phasing out of driver's education in public high schools may have led to declines in the number of young people applying for licenses.
- Employer and public subsidization of public transit may have increased the use of public transit.

Location

- Suburban metropolitan areas have grown substantially over the past few decades, especially in the Nation's Southern and Western areas, most likely due to the tremendous growth in workplaces locating in these areas, and the availability of affordable housing. Much of today's travel is suburb to suburb and these areas are seen as car dependent.
- Most roadways are now carrying more shopping, errands and social/recreational travel, especially those serving regional malls or recreational areas.
- Currently, two-thirds of the nation's population lives in large metropolitan areas, which include a combination of cities, suburbs and rural areas. (The Brookings Institute, 2010).
- As young people become accustomed to living in large metropolitan areas with more public transit and land use that supports other travel options, their use of other modes may increase, and they may drive less.
- If the trend towards multigenerational housing increases because of their economic circumstances, young people may become more apt to carpool with friends and family.

Technology

- Telecommuting has grown partly due to the spread of high-speed Internet and better remote access systems.
- Online shopping has nearly tripled between 2002 and 2008, from $72 billion to $214 billion. Online shopping has mixed effects on personal travel, and its effects on VMT are believed to be tightly correlated with age and household income.
- The popularity of social networking sites has grown from a few million users in 2004 to more than 800 million people worldwide in 2010. The effect of high usage

of these sites and other digital platforms on personal travel is not yet well understood.

- The mobile Internet increases travel mobility as many activities, such as shopping, working and socializing can now be undertaken on the go in almost any location.
- Younger people (< 40) are more frequent users of the Internet than older age groups.
- Data from NHTS shows that in urban areas, there may be a link between high Internet usage and increased VMT, whereas in rural areas (primarily among younger populations), high Internet usage is linked to less VMT.
- Innovations in payment systems have led to improvements in efficiency in the collection of tolls and payments for public transit.
- GPS and ITS technologies further improve efficiency with the provision of better, specialized, real time data.
- Hybrid, electric and other fuel efficient vehicles will become more prevalent and less expensive over the next few years; this improvement in average fuel efficiency lowers the marginal cost of driving, which may lead to an increase in VMT.
- Currently, the largest segment of hybrid car owners is the Baby Boomers; however, this may be primarily an issue of affordability. It will be important to track the car buying preferences of Generation Y, as they will make up about forty percent of car buyers within 10 years.

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