GUIDEBOOK FOR MOBILITY MONITORING

In Small to Medium-Sized Communities

A HOW TO GUIDE

Fender Falls is the case study that will be used throughout the guidebook.

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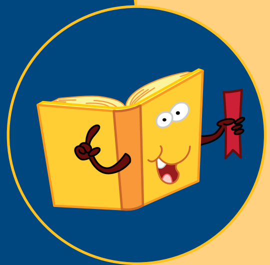

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Introduction

Transportation professionals in growing small to medium-sized communities (SMSCs) struggle with congestion issues. SMSCs are defined as communities with a population less than 200,000. Congestion in these communities is often highest along state or U.S. highways that also serve significant amounts of local travel. According to TTI's *2007 Urban Mobility Report* (*1*), there were 355 million person-hours of delay in 306 SMSCs in the United States. This equates to $6 billion in the cost of time and fuel. In Texas alone, there were 12 million person-hours of delay, equating to $212 million in the cost of time and fuel in 23 SMSCs.

While there are extensive resources and literature dedicated to measuring, monitoring, and improving large urban area congestion, there is a need for guidance for SMSCs to better understand and alleviate congestion before the problems escalate. Potential solutions and performance-measure targets are much different for small communities than those identified in the literature for urban areas.

The primary objective of TxDOT research from which this guidebook was generated was to develop and test a framework for mobility monitoring in small to medium-sized communities (*2,3*). This guidebook provides a user-friendly step-by-step process for public- and private-sector transportation professionals to implement a mobility monitoring program in their communities. A companion document located in a pocket at the back of this guidebook serves as a reference for nontechnical audiences. This guidebook, and the companion documents produced by this research effort, will be useful for state DOT staff in SMSCs as well as state DOT partnering agencies, including metropolitan planning organizations (MPOs), municipalities, and counties.

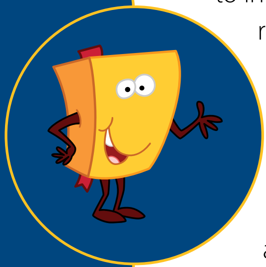
WHAT ARE MOBILITY, CONGESTION, AND RELIABILITY ANYWAY?

This guidebook provides insights to develop an ongoing mobility monitoring program for SMSCs. Mobility is the ability to reach a destination in a satisfactory time and cost (*4*). In contrast, congestion is the inability to reach a destination in a satisfactory time due to slow travel speeds. In congestion, travel times are longer and user costs are higher. Reliability is the level of consistency in transportation service (e.g., hour to hour and day to day). Travelers respond to unreliable systems by adding additional travel time to their trip. Transportation professionals seek to increase mobility, reduce congestion, and increase reliability. An illustrative comparison of mobility and reliability is shown in Figure 1.

Figure 1 shows the average mobility conditions for the reliable trips that occurred on days 1 through 5. The vertical dashed line illustrates the average travel time associated with these trips. The unreliable trips on days 6 through 10 exceed the average mobility conditions shown with the vertical line, representing increased travel time and cost.

The term "mobility" is flexible, mode neutral, and focused on providing a trip that meets the needs of the traveler. These considerations can be captured in appropriate performance measures. More detail is provided throughout this guidebook as the user walks through the steps.

WHAT IS THE OBJECTIVE OF THIS GUIDEBOOK?



The ultimate objective of this guidebook and the framework it contains is to measure mobility changes (e.g., speed or travel time changes) in a community so performance is communicated effectively and needed improvements can be implemented. The intent of this guidebook is to provide a means for SMSCs to identify congested locations and time periods, along with low-cost improvements, to reduce the onset of large-scale congestion problems. This guidebook provides a way to proactively identify and mitigate congestion difficulties before they worsen.

HOW ARE SMALL AND MEDIUM-SIZED COMMUNITIES DEFINED?

Population thresholds prompt the adoption of new planning requirements. For instance, by federal legislation, areas that exceed 50,000 in population must organize a MPO which is responsible for regional transportation planning. By legislation, areas that exceed 200,000 in population are classified as transportation management areas (TMAs) and are required to meet certain requirements including congestion management processes (CMPs). For this guidebook, "small" communities are those defined as having a population less than 100,000. "Medium-sized" communities are those having between 100,000 and 200,000 persons. As a result, this guidebook and the steps included in it are applicable to a range of populations that include cities with and without MPO representation.

WHAT EXACTLY IS THE FRAMEWORK?

The framework is a six-step process that guides users through the important considerations to develop and implement mobility monitoring programs in SMSCs. The steps are as follows, and subsequent sections of this guidebook direct the user in addressing key issues and questions at each step along the way:

- **Step 1:** Identify the Needs and Opportunities
- **Step 2:** Create a Monitoring Plan
- **Step 3:** Monitor the System
- **Step 4:** Analyze the Data
- **Step 5:** Package and Distribute the Results
- **Step 6:** Move Forward with Improvements and Continue Monitoring

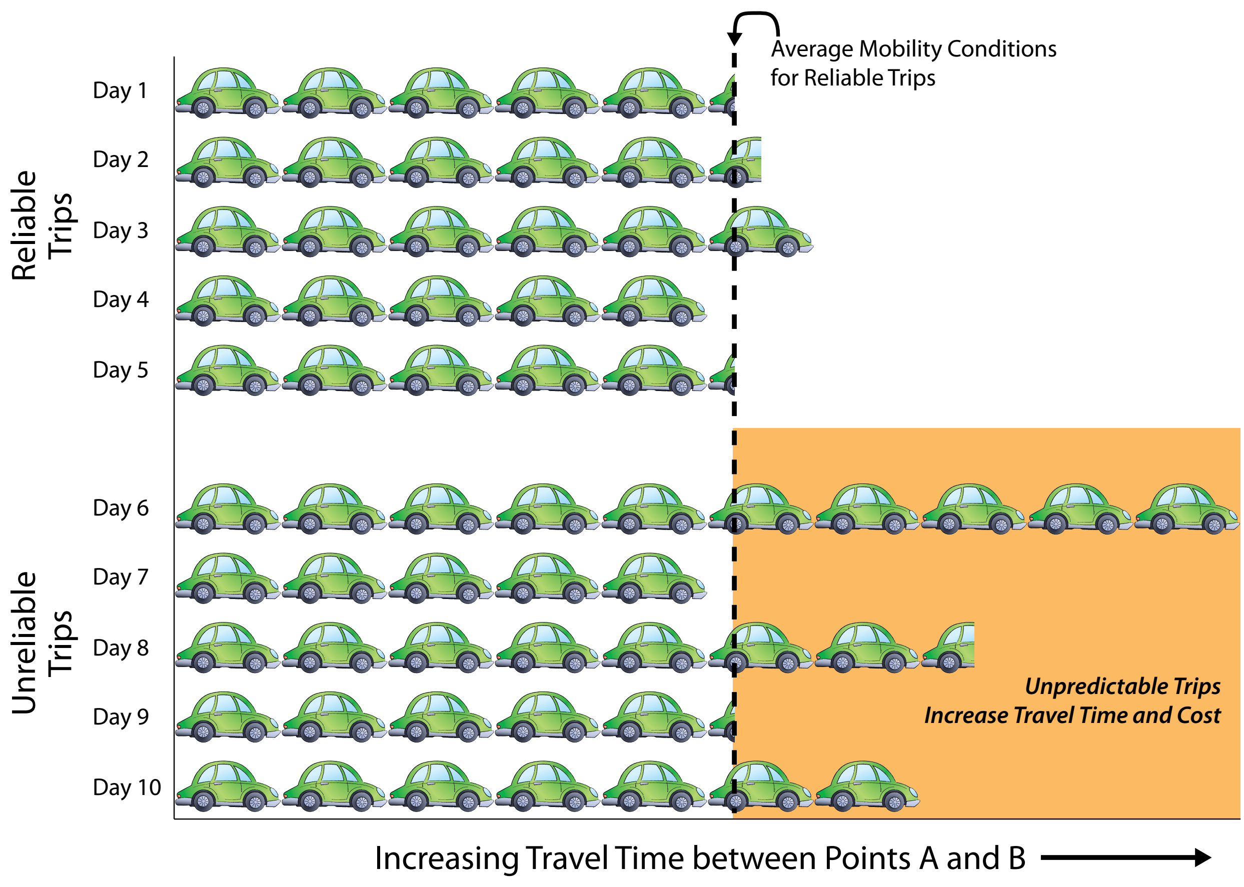


Figure 1. Illustration and comparison of mobility and reliability.

WHO CAN USE THIS GUIDEBOOK?

This guidebook is intended for practitioners responsible for implementing mobility monitoring in SMSCs. Therefore, this guidebook contains some technical detail in the steps. The companion document in the pocket at the end of guidebook serves audiences interested in less technical detail.

HOW DO I USE THIS GUIDEBOOK?

This guidebook directs you through the mobility monitoring framework where each step of the framework is presented as its own section of the guidebook. The structure of each section is similar. Each step's objective is introduced at the beginning of each section, followed by a brief description. The remainder of each section (i.e., each step in the framework) includes subsections typically presented in the form of key questions that the reader should ask at that juncture of the process. The guidebook provides useful insights to each of these questions. At the conclusion of each step, the guidebook applies that section's subject to a common example case study (Fender Falls), which is carried through the entire guidebook. At the back of the guidebook is a list of acronyms and the location where each acronym is first used.

While the guidebook was written for a technical audience, there is also information of value for those interested in less technical detail—the following paragraphs provide guidance to both audiences as they review this guidebook:

Technical Audiences

This guidebook is written for you. The guidebook uses an intentional approach to remove the overwhelming nature of the highly technical undertaking of mobility monitoring, and organizes it into more manageable and smaller sections.

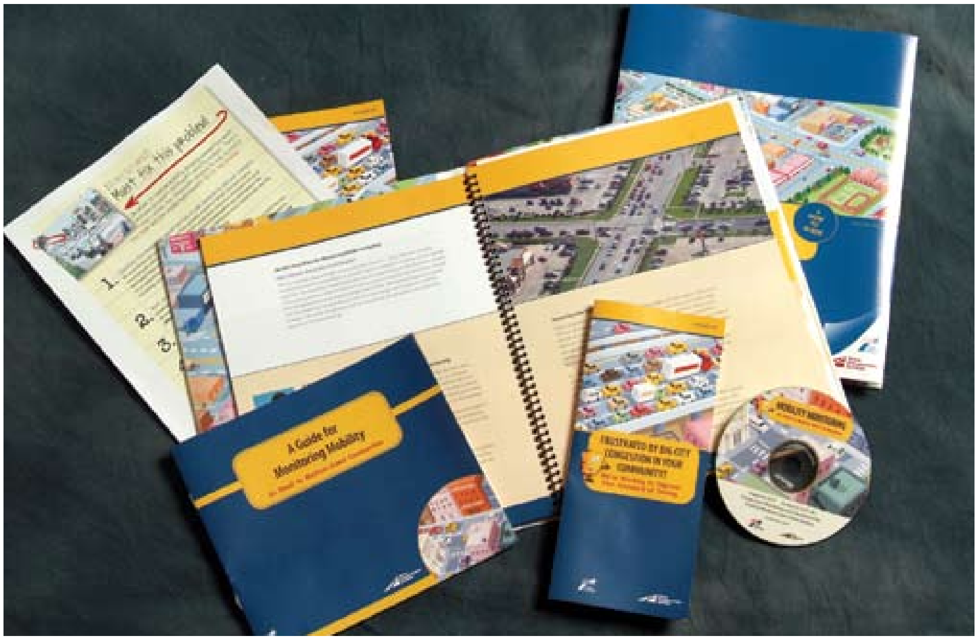
Nontechnical Audiences

This guidebook is written for a technical audience. Because the guidebook was intentionally written in a user-friendly writing style, nontechnical audiences may likely find value in skimming the guidebook. Note that parts of Step 1 and nearly all of Step 4 present and discuss highly technical material. Nontechnical audiences will likely wish to defer to their local technical staff regarding these sections. While this guidebook was written for a technical audience, the attached companion document is intended for nontechnical audiences, and it is described in the following section.

WHAT ARE THE ADDITIONAL MATERIALS INCLUDED WITH THE GUIDEBOOK?

A companion document is included with this guidebook. The companion document provides information on mobility monitoring to a broader audience that may not be interested in the level of detail shown in the guidebook. The companion document presents the highlights of the framework for general audiences. A tri-fold pamphlet is also included to provide additional information to interested citizens.

There is also an interactive CD at the end of the guidebook. The CD includes presentations to both a technical and a nontechnical audience about how to implement mobility monitoring in a SMSC using the framework and techniques identified in this guidebook. The CD includes an interactive case study that allows the reader to negotiate back and forth through the steps with an example. The CD provides links to additional resources available through the Internet, all of the above products, and includes the research reports generated by the project.



Finally, the pocket at the end of the guidebook contains a one-page summary of the framework. This overview serves as a quick reference of the framework steps. It is also included electronically on the CD. The pocket serves as a place for the user to store notes and other reference materials as well.

All of these materials are available at http://mobility.tamu.edu/resources under the section heading "Mobility Monitoring in Small to Medium-Sized Communities."

Figure 2. Map of Fender Falls case study.

FENDER FALLS CASE STUDY

This case study example will be used throughout the guidebook. At the end of each step of the framework, there is a short description of how the transportation professionals in the case study community of Fender Falls are addressing the key issues presented in the current step.

Case study description

The name of the case study community is Fender Falls. Fender Falls is a medium-sized community of approximately 160,000 in Camshaft County. The region includes a large university with over 40,000 students, a community college of 12,000 students, two large high schools, three hospitals, and a one million square foot regional mall. The city recently updated its comprehensive plan, offering the opportunity to highlight important transportation concerns and issues. The community includes numerous state-maintained roadways.

The economy of the community is robust and growing rapidly. The state DOT, city, county, and MPO are interested in implementing an ongoing mobility monitoring effort to identify problem areas and potential solutions before congestion worsens.

Figure 2 shows a regional graphic of Fender Falls.

Step 1: Identify the Needs and Opportunities

STEP OBJECTIVE: To evaluate key early considerations for developing a monitoring plan within the context of the needs and opportunities in the community.

Planning is an essential component for a successful mobility monitoring effort. Proper planning is essential to ensure successful implementation of any improvement project or activity. This step encompasses considering many necessary questions to ensure your community identifies its pressing issues and embraces the monitoring opportunity.

Congestion problems do not occur overnight. Rapid economic development or lack of appropriate infrastructure often causes bottlenecks in the system. While those in your community may feel the community is suddenly losing the quality of life and unimpeded travel it previously enjoyed, the situation leading up to the cause for reduced mobility was likely in place for several months or years.

IDENTIFY PUBLIC CARES AND CONCERNS

What are community values and important concerns?

This should be the first question you ask when trying to identify improvements to a community. Because increasing demands on infrastructure are frequently growing faster than available budgets to address problems, it is critical to ensure that public service professionals are focused on issues that are perceived as problems in the community. It is common for transportation to rank high as a concern for the motoring public in growing SMSCs.

Simply watching the local print or television news media can provide you a cursory indication of community values and important concerns. You can also perform a community survey on key topics such as traffic/transportation, managing growth/development, taxes, education/schools, economy/jobs, public safety/crime, and housing, all of which also provide a good indication of community values.

What are the vision and goals of the community?

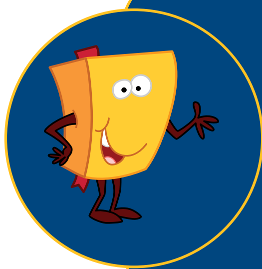
A closely related concern is knowing the vision and goals of your community. Cities and counties typically have mission statements, visions, and related strategic goals that can provide insight into the value placed on transportation in the community. It is typical that the community will have a goal or goals related directly or indirectly to transportation (e.g., providing economic opportunity, or efficient and safe travel). A good place to look for community goals related to transportation is in your city's comprehensive plan.

SMSCs frequently develop along state roadways, and mobility and safety are always state DOT strategic planning goals.

Where does transportation rank as a priority?

By investigating community values and concerns, and identifying the vision and goals of the area, you can begin to identify the answer to this question. Ultimately you want to know where transportation ranks as a priority in the community. The ongoing monitoring process will rely on goals and objectives related to transportation in promoting the need for mobility monitoring in the community.

In addition, if transportation is not a high priority and/or there are other more critical or pressing issues at the moment, that information is equally useful to you. It would be an unwise use of resources to pursue ongoing monitoring if there is no genuine long-term interest in keeping it going or adequately using the results.



Ultimately you want to know where transportation ranks as a priority in the community.

How are transportation needs identified, and what are they?

Assuming that transportation ranks high as a community concern, the next consideration for you is the identification of specific transportation needs. You will likely identify several needs from answering prior questions—needs that come from both transportation professionals and other stakeholders such as the general public. You can also identify needs by speaking with transportation professionals that work for transportation agencies (e.g., MPO, state DOT, city, and county).

There are many possible community needs, and the list will differ in each community. These needs are closely related to the next issue that must be explored—reasons for decreased mobility.

What are the typical causes of decreased mobility in SMSCs?

Your community has grown, leading to increased congestion. A typical scenario for growth in a small community could go something like the following. Economic growth causes development to rapidly grow beyond the primary retail and employment area of the community. Additional retail development brings closely spaced driveways along the roadway. Now assume the roadways have a center two-way left-turn lane (TWLTL). TWLTL sections promote additional development with uncontrolled access. As the population grows and demographics change, larger "big box" developments (e.g., Wal-Mart, Home Depot) are attracted to the community. Therefore, more development occurs. More signals are installed along the street. The rapid development continues, and transportation infrastructure is needed to keep up with the growth. This process is captured in Figure 3.

Meanwhile, truck traffic through the community continues, and perhaps rises. Local deliveries and truck traffic increase due to the increased population. With the growth of the population, congestion around schools also increases.

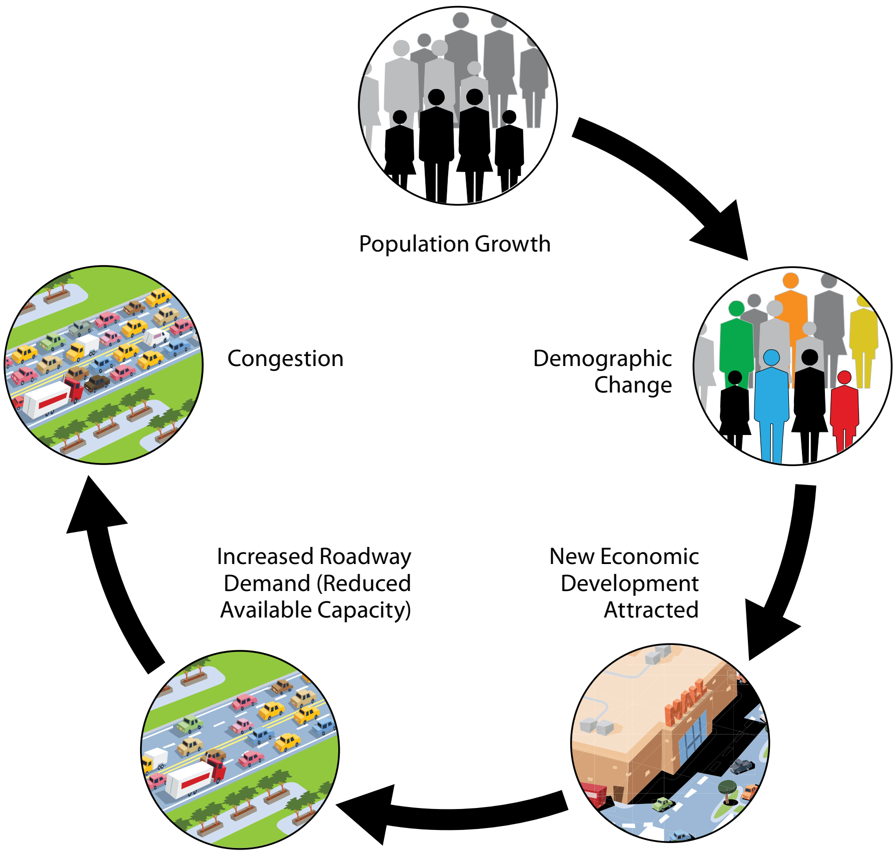


Figure 3.
Process of small community growth causing congestion.

Then comes a need to provide new and/or improved multimodal transportation options. Passenger transit services need to be expanded. Nonmotorized transportation facilities need to be expanded to fit growing needs. This may include improved or new bicycle lanes or sidewalks.

Improvements to the transportation infrastructure cause work zones, and perhaps closed roadway lanes, which contribute to the reduced mobility.

Also adding to the reduced mobility in the smaller community are special events, including festivals, fairs, or school sporting events. One can only expect these events to get larger as the community grows.

Obviously, this is an oversimplified example of typical causes of decreased mobility in a SMSC. However, it illustrates some of the key issues that lead to congestion in a community such as yours, including:

- rapid development;
- inadequate roadway capacity;
- increased traffic control (signals);
- current and increased truck traffic through or within the community;
- inadequate bicycle and pedestrian facilities;

- inadequate transit;
- special events;
- work zones; and
- lack of development regulatory controls or municipal ordinances.

An ongoing mobility monitoring process can assist you in identifying early decreases in mobility where mitigation is needed.

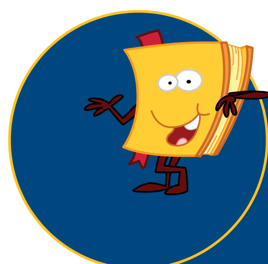
UNDERSTAND THE TRANSPORTATION BUILDING PROCESS

How can typical improvements be made?

The ultimate outcome of your mobility monitoring effort is identifying locations needing mobility improvement projects. These improvements might include optimizing traffic signal timings, restriping pavement, widening roadway, implementing low-cost widening projects at intersections, consolidating driveways, installing raised medians, and removing bottlenecks.

As a specific example, relatively low-cost projects such as signal timing improvements can typically be done within existing municipal budgets. Moderate-cost improvements such as widening projects, median installations, or intersection improvements may be expensive enough to require you to plan and prioritize them in competition with other projects in the jurisdiction (state, city, or county).

Stakeholder and public input is a necessary element of transportation improvement plans, and early and frequent input to this process on needed improvements is key in getting projects constructed. Elected officials often are local-level project champions. A mobility monitoring program can provide you with quantified evidence of areas requiring improvements—a key piece of information for project decision-makers.



How are transportation projects planned and built?

In some cases, new roads will be needed in your community. To facilitate improvement implementation, it is helpful to understand how the road building process works. Planning and constructing new-location roads is a long process. It can take 10 years or more to complete the steps of planning, design, environmental clearance, right-of-way acquisition, and construction. Improvements to existing roads may not take quite as long, depending on the scope of the improvements.

The project prioritization process provides the opportunity for input from all stakeholders including the public. As an example, more information on the TxDOT Statewide Transportation Improvement Program (STIP) can be found at http://www.dot.state.tx.us/.

The project prioritization process provides the opportunity for input from all stakeholders including the public.

Municipalities and counties budget funds for planning and building projects in your community. As cities grow, municipal roadways are typically built by developers as new development comes into the city. Some funds may be allocated to road building through the project prioritization process funded by taxes and bonds. Counties have their own revenue streams and can build needed roads they see as important.

If your community is located within an urbanized area's metropolitan planning area, transportation projects are planned and built through the MPO process. The first step of the MPO process is to get the project included in the MPO's metropolitan transportation plan (MTP). Any project that is to be built must be included in the MTP. This step is accomplished by using the MPO's project selection process to identify the project as a need in the MPO planning area. Project selection processes vary among MPOs, but are typically more quantitative in areas with greater populations.

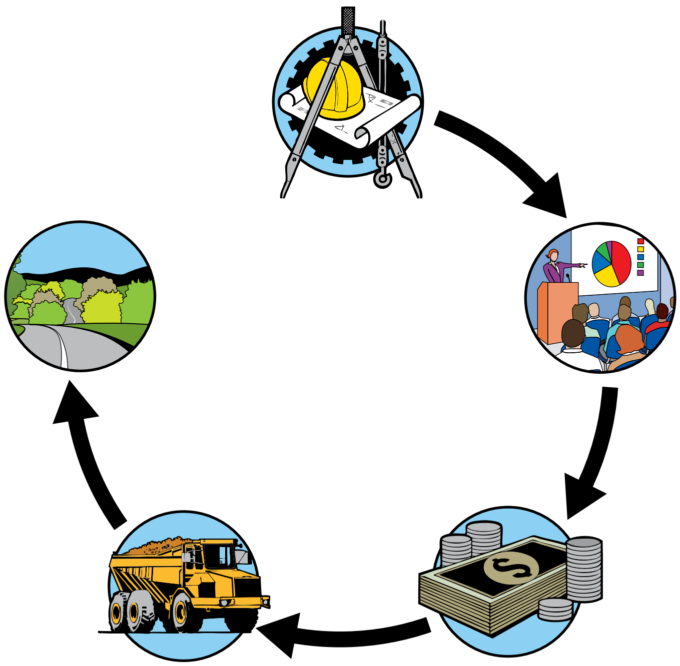


Figure 4. Graphical illustration of road building process.

Once the project is in the MTP, it can then be programmed into the unified transportation plan (UTP). The UTP is an 11-year, statewide list of projects for which funding has been identified. Once the project is in the proper UTP level, environmental and preliminary engineering work may begin. The next step is to include the project in the MPO's transportation improvement program (TIP). The TIP is a 3- to 4-year list of projects that are ready, or very close to ready, and for which funding has been identified and reserved. Each MPO prepares a TIP, cooperatively with the local state DOT district office, on an annual or biennial cycle.

Most non-interstate highway projects are typically funded 80 percent by federal funds and 20 percent by state and/or local matching funds. In some cases, the provision of greater than 20 percent match can improve a project's competitiveness.

State roadways that are not located within an MPO's metropolitan planning area are programmed by the state DOT district office in which the project is located. This process does not include the MTP step and requires a city or county to work with the state DOT district office to identify the project as a priority. Again, providing more than the 20 percent match with local or private funds can improve the project's competitiveness. Once a project is identified as a priority by the state DOT district office, it can be included in the UTP and, at the appropriate time, in the district's TIP. Each district prepares a TIP, working cooperatively with the cities and counties in the district to program projects.

Figure 4 shows a graphical illustration of the road building process.

IDENTIFY PRIMARY USERS OF MOBILITY MONITORING INFORMATION

Who are the primary users of the mobility monitoring?

You should determine the analyses and potential targets of the mobility monitoring process early in its development. This ensures that you select appropriate performance measures to communicate to users and address the uses. The selected measures must be technically capable of illustrating the problems and the effect of the potential improvements. They must also be able to be composed into statistics that are useful for the variety of potential audiences. Understanding the users and uses will help you identify the best communication methods to use with audiences.

For mobility monitoring, your primary use will probably be the identification of locations where mobility is affected along with associated time periods. This information can assist you in targeting improvement projects. Typical users for this information are state and local engineering departments, elected officials, transit operators, and the general public.

DETERMINE THE ULTIMATE OUTCOME(S) FROM MONITORING

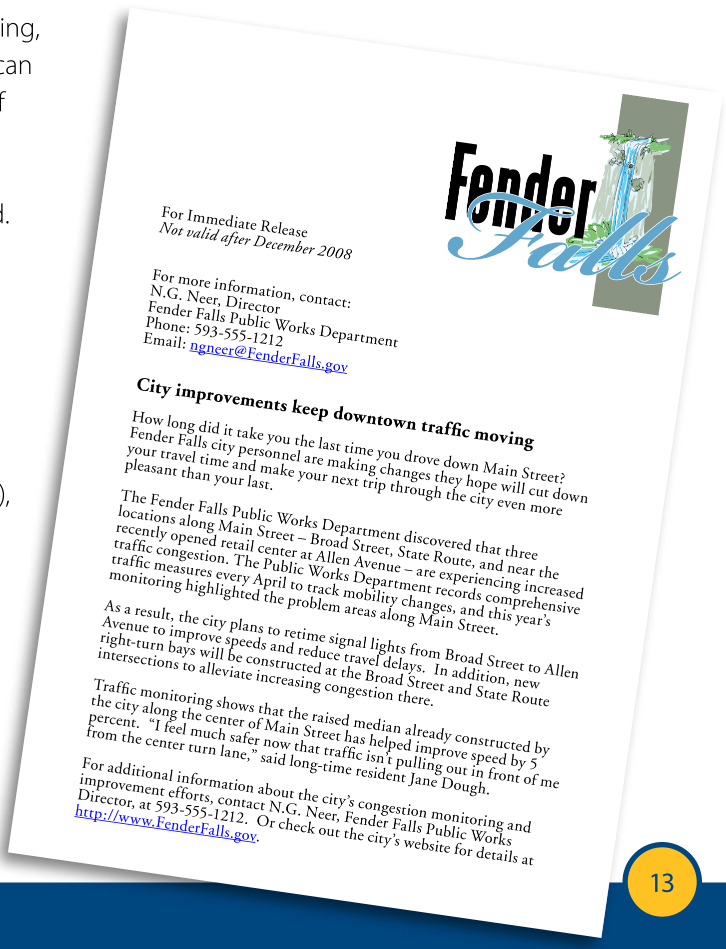
What is the end result of monitoring?

In any planning exercise, it is always helpful to think about the desired outcome at the end of the project. In this case, your desired end result of the monitoring is to improve mobility by measuring, documenting, and reporting mobility changes so needed improvements can be planned. The end result could include a prioritized list of locations requiring mobility improvements. If it is your first year of monitoring, the monitoring effort provides baseline conditions to which future monitoring efforts are compared.

What should the final press release say?

Think ahead. What would you like your press release to say when you have completed the monitoring? Keeping the end in mind is helpful. You probably want to say that you have established baseline congestion levels for future monitoring (implying the need/desire for an ongoing effort), that you have identified locations where congestion is worsening, and that you have identified the time periods of congestion. You probably will want to mention what types of measures were used and highlight some of the key statistics.

Having this content in mind prior to the start of monitoring will establish a clearer vision as you work through the steps of the framework.



Fender Falls

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For more information, contact:
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Phone: 593-555-1212
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City improvements keep downtown traffic moving

How long did it take you the last time you drove down Main Street? Fender Falls city personnel are making changes they hope will cut down your travel time and make your next trip through the city even more pleasant than your last.

The Fender Falls Public Works Department discovered that three locations along Main Street – Broad Street, State Route, and near the recently opened retail center at Allen Avenue – are experiencing increased traffic congestion. The Public Works Department records comprehensive traffic measures every April to track mobility changes, and this year's monitoring highlighted the problem areas along Main Street.

As a result, the city plans to retime signal lights from Broad Street to Allen Avenue to improve speeds and reduce travel delays. In addition, new right-turn bays will be constructed at the Broad Street and State Route intersections to alleviate increasing congestion there.

Traffic monitoring shows that the raised median already constructed by the city along the center of Main Street has helped improve speed by 5 percent. "I feel much safer now that traffic isn't pulling out in front of me from the center turn lane," said long-time resident Jane Dough.

For additional information about the city's congestion monitoring and improvement efforts, contact N.G. Neer, Fender Falls Public Works Director, at 593-555-1212. Or check out the city's website for details at http://www.FenderFalls.gov.

How will the outcomes be tied to local community mobility goals?

This part of the process ties the community values and important concerns identified earlier, along with the vision and goals of the community, to anticipated outcomes. Vision and goals are typically documented in your community's comprehensive plan or incorporated in the mission statement of the state DOT, city, or county. This step provides the opportunity to determine how the findings documented in the final press release will directly tie to your previously accepted mobility goals. The monitoring provides quantifiable evidence of where and how the goals are being pursued and satisfied.

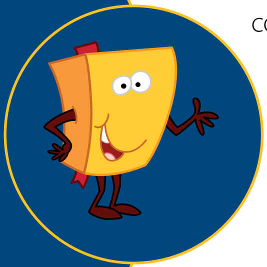
IDENTIFY HOW CONGESTION IS DEFINED BY THE USER

What is congestion, and why is defining congestion important?

It is important to understand how congestion is defined in your community because congestion differs by city size. What some would consider congestion in a small community (e.g., waiting through more than one red light) would not feel like congestion when experienced by someone from a large metropolitan area who is used to experiencing a two-hour peak period returning from work. Understanding how your community defines congestion also assists in developing performance measures that relate to these definitions.

"What gets measured gets done; what gets recognized gets done even better."

—*Anonymous*



In an earlier section of this guidebook, the definition of congestion was given as the inability to reach a destination in a satisfactory time due to slow travel speeds. Monitoring will help determine what members of your community feel is an unacceptable level of congestion (i.e., when do they feel they are in congestion?). Responses might include that they have to wait for more than one red light, or that their trip is twice as long as usual.

How do we define congestion?

Getting a sense of how your community defines congestion can be accomplished by surveying community members or a sample of individuals from the community. When communities are going through plan updates (e.g., updated city comprehensive plan), there is an opportunity to revisit how those in the community define congestion.

IDENTIFY MOBILITY PERFORMANCE MEASURES

What makes a good measure?

"What gets measured gets done; what gets recognized gets done even better." Though the speaker of these words is unknown, this person certainly understood the power of effective performance measurement. Armed with an understanding of the answers to questions posed so far, you should turn your attention to identifying what measures to select. Table 1 lists attributes of a good performance measure. Satisfying these characteristics in mobility monitoring measures will help ensure you have a successful monitoring effort.

Table 1.
Attributes of a good performance measure.

	Characteristic	Description
1.	Able to discriminate	Must be able to differentiate between the individual components that are affecting the performance of the system.
2.	Able to integrate	Must be able to integrate the sustainability aspects of environmental, social, and economic sustainability.
3.	Acceptable	The general community must assist in identifying and developing the performance measures.
4.	Accurate	Must be based on precise information, of known quality and origin.
5.	Affordable	Must be based on readily available data or data that can be obtained at a reasonable cost.
6.	Appropriate level of detail	Must be specified and used at the appropriate aggregation level for the questions it is intended to answer.
7.	Have a target	Must have a benchmark against which to compare it.
8.	Measurable	The data must be available, and the tools need to exist to perform the required calculations.
9.	Multidimensional	Must be able to be used over time frames, at different geographic areas, with different scales of aggregation, and in the context of multimodal issues.
10.	Not influenced	Must not be affected by exogenous factors that are difficult to control for, or that the planner is not even aware of.
11.	Relevant	Must be compatible with overall goals and objectives.
12.	Sensitive	Must detect a certain level of change that occurs in the transportation system.
13.	Show trends	Must be able to evaluate over time and provide early warnings about problems.
14.	Timely	Must be based on timely information that is capable of being updated at regular intervals.
15.	Understandable	Must be easy to interpret, even by the community at large.

Adapted from Reference 5

Table 2.
Basic principles for roadway mobility monitoring.

Principle 1
Mobility performance measures must be based on the measurement of travel time.

Principle 2
Multiple measures should be used to report congestion performance.

Principle 3
Traditional Highway Capacity Manual-based performance measures (volume-to-capacity ratio and level of service) should not be ignored but should serve as supplementary, not primary, measures of performance in most cases.

Principle 4
Both vehicle-based and person-based performance measures are useful and should be developed, depending on the application. Person-based measures provide a "mode-neutral" way of comparing alternatives.

Principle 5
Both mobility (outcome) and efficiency (output) performance measures are required for congestion performance monitoring. Efficiency measures should be chosen so that improvements in their values can be linked to positive changes in mobility measures.

Principle 6
Customer satisfaction measures should be included with quantitative mobility measures for monitoring congestion "outcomes."

Principle 7
Three dimensions of congestion should be tracked with congestion-related performance measures: source of congestion, temporal aspects, and spatial detail.

Principle 8
The measurement of reliability is a key aspect of roadway performance measurement, and reliability metrics should be developed and applied. Use of continuous data is the best method for developing reliability metrics, but abbreviated methods should also be explored.

Principle 9
Communication of performance measurement should be done with graphics that resonate with a variety of technical and nontechnical audiences.

Adapted from Reference 6

What kind of measures are best?

For mobility monitoring, your selected performance measures should be based upon travel time. Travel times are easily understood by both practitioners and the public. Travel times are applicable to both the traveler experience and the facility performance. Basic principles for performing roadway mobility monitoring have been documented, and principle #1 is that mobility performance be based on the measurement of travel time. Table 2 shows all of these principles.

Figure 5 shows how travel times can be developed from data, analytic methods, or a combination of these techniques. As shown in Figure 5, data may come from direct measurement (continuous probe vehicles or special studies with instrumented cars), or from indirect measurement/modeling (continuous in-pavement equipment or special studies with short-term traffic counts or forecasting models). The indirect methods require processing to obtain travel time information. As indicated in Figure 5, the travel time information is converted to performance measures with roadway information. Ultimately, the results are absolute or relative performance measures where relative measures require comparison to some base condition, usually travel time during light traffic.

The discussion above describes to you the importance of travel time measures. In addition, simple changes in traffic volume will likely provide a good measure of mobility changes in your community. One example of a volume-related mobility measure is "the percentage of the working day that is at 50 percent capacity." Such a measure would allow you to recognize smaller changes in traffic volume before roadways are at capacity, which is of particular interest in a growing community.

Signalized intersections in your community also cause reduced mobility. Intersection studies that measure stopped delay at heavy turning movements may also be useful in your analysis.

How many measures are needed?

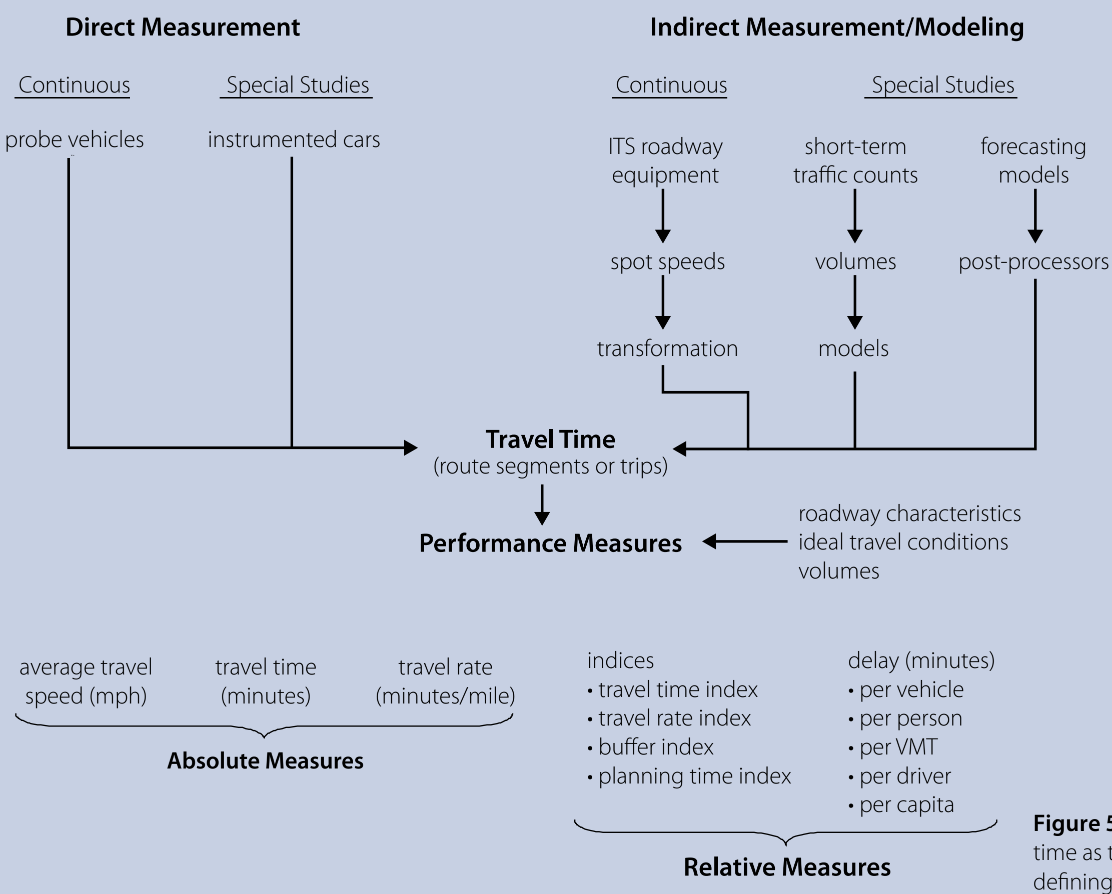
As many as you need to monitor your community and meet the needs of your stakeholders. The number of measures required for comprehensive monitoring depends on the type of analysis being performed, and it depends on what you are ultimately communicating, and to whom. In general, measures that relate to the trip experience of the individual driver resonate well with all audiences. These measures tell them exactly what they experience on the roadway. Measures that capture what is occurring at the regional or areawide level are useful because they can be used to identify how areawide congestion is changing over time.

How are measures defined?

Typical mobility monitoring data and measures include:

- average travel time;
- average travel rate;
- average speed;
- person volume;
- traffic volume;
- person-miles of travel;
- travel time index or travel rate index;
- delay per traveler;
- buffer index;
- planning time index;
- total delay;
- congested travel;
- percent of congested travel;
- percent of congested roadway;
- volume-to-capacity ratio (v/c); and
- accessibility.

Table 3 illustrates how some of the more common mobility measures are computed. The most appropriate measures for your community will depend upon your analysis level and the type of analysis you are performing. Table 4 and Table 5 recommend mobility measures for different analysis levels and types of analysis.



ITS = Intelligent Transportation System
VMT = Vehicle-miles of Travel

Figure 5. Travel time as the basis for defining mobility-based performance measures.

Adapted from Reference 7

Table 3. Quick reference guide and definitions for selected mobility measures.

Adapted from Reference 4

INDIVIDUAL MEASURES[1]	
Delay per Traveler[2]	$\text{Delay per Traveler (annual hours)} = \dfrac{\left[\text{Actual Travel Time (minutes)} - \text{FFS or PSL Travel Time (minutes)}\right] \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicles)} \times \dfrac{\text{250 weekdays}}{\text{year}} \times \dfrac{\text{hour}}{\text{60 minutes}}}{\text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicles)}}$
Travel Time	$\text{Travel Time (person – minutes)} = \text{Actual Travel Rate (minutes per mile)} \times \text{Length (miles)} \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicles)}$
Travel Time Index or Travel Rate Index[3,4]	$\text{Travel Time Index or Travel Rate Index} = \dfrac{\text{Actual Travel Rate (minutes per mile)}}{\text{FFS or PSL Travel Rate (minutes per mile)}}$
Buffer Index[3]	$\text{Buffer Index (\%)} = \left[\dfrac{\text{95th Percentile Travel Time (minutes)} - \text{Average Travel Time (minutes)}}{\text{Average Travel Time (minutes)}}\right] \times 100\%$
Planning Time Index[3]	$\text{Planning Time Index (no units)} = \dfrac{\text{95th Percentile Travel Time (minutes)}}{\text{FFS or PSL Travel Time (minutes)}}$
AREA MOBILITY MEASURES[1]	
Total Delay	$\text{Total Segment Delay (person - minutes)} = \left[\text{Actual Travel Time (minutes)} - \text{FFS or PSL Travel Time (minutes)}\right] \times \text{Vehicle Volume (vehicles)} \times \text{Vehicle Occupancy (persons/vehicles)}$
Congested Travel	$\text{Congested Travel (vehicle - miles)} = \sum \left[\text{Congested Segment Length (miles)} \times \text{Vehicle Volume (vehicles)}\right]$
Percent of Congested Travel	$\text{Percent of Congested Travel} = \left[\dfrac{\sum_{i=1}^{n}\left[\left[\text{Actual Travel Time}_i \text{ (minutes)} - \text{FFS or PSL Travel Time}_i \text{ (minutes)}\right] \times \left[\text{Vehicle Volume}_i \text{ (vehicles)} \times \text{Vehicle Occupancy}_i \text{ (persons/vehicles)}\right]\right]_{\text{Each congested segment}}}{\sum_{j=1}^{m}\left[\text{Actual Travel Rate}_j \text{ (minutes per mile)} \times \text{Length}_j \text{ (miles)} \times \text{Vehicle Volume}_j \text{ (vehicles)} \times \text{Vehicle Occupancy}_j \text{ (persons/vehicles)}\right]_{\text{All segments}}}\right] \times 100$
Congested Roadway	$\text{Congested Roadway (miles)} = \sum \text{Congested Segment Length (miles)}$
Accessibility	$\text{Accessibility (opportunities)} = \sum \text{Objective Fulfillment Opportunities (e.g., jobs) Where Travel Time} \leq \text{Target Travel Time}$

[1] "Individual" measures are those measures that relate best to the individual traveler, whereas the "area" mobility measures are more applicable beyond the individual (e.g., roadway, area, or region). Some individual measures are useful at the area level when weighted by Passenger-miles of Travel (PMT) or Vehicle-miles of Travel (VMT).

[2] As a practical matter, total delay (in person-minutes) is usually computed first (see definition in the table), and is useful as an area mobility measure. The total delay is then converted to delay per traveler (in annual hours) as shown here by dividing by the number of peak-period travelers. Note that the vehicle volumes multiplied by the vehicle occupancy do not, therefore, cancel out.

[3] Can be computed as a weighted average of all sections using VMT or PMT.

[4] Referred to as a "travel rate index" when the data source does not include incident conditions (e.g., using non-continuous data such as test vehicles for travel time estimation).

Note: FFS = Free-flow speed, PSL = Posted speed limit. Where FFS or PSL occur in the equations above, typically the prevailing travel rate (or travel time) is used during light traffic (not to be lower than the travel time at the posted speed limit).

DEFINITIONS OF MEASURES

Delay per traveler (in annual hours or daily minutes) can be used to reduce the travel delay value to a figure that is more useful in communicating with nontechnical audiences. These figures normalize the impact of mobility projects that handle much higher person-demand than alternative routes.

The **travel time** (in person-minutes) is the time required to traverse a segment or complete a trip. Times may be measured directly using field studies.

The **travel time index (TTI)** is a dimensionless quantity that compares travel conditions in the peak period to travel conditions during free-flow or posted speed limit conditions. For example, a TTI of 1.20 indicates that a trip that takes 20 minutes in the off-peak period will take 24 minutes in the peak period, or 20 percent longer. TTI reflects travelers' perceptions of travel time on the roadway, transit facility, or other transportation network element. This comparison can be based on the travel time increases relative to free-flow conditions (or the posted speed limit) and compared to the target conditions. Thus, the same index formula can be applied to various system elements with different free-flow or posted speeds.

The **travel rate index (TRI)** is similar to the TTI in that it is also a dimensionless quantity that compares travel conditions in the peak period to travel conditions during free-flow or posted speed limit conditions. However, the TTI includes incident conditions, while the TRI does not. Continuous data streams allow for the direct measurement of a TTI that includes incidents. For some applications, incident conditions would not be included. For example, when test vehicle travel time runs are performed along a section of roadway, those runs that are affected by incident conditions are normally removed. This approach provides an estimate of the non-incident travel time along the roadway. In these conditions, the computed measure would not be a TTI , but rather a TRI.

The **buffer index (BI)** is a measure of trip reliability that expresses the amount of extra "buffer" time needed to be on time for 95 percent of trips (e.g., late for work one day per month). Indexing the measure provides a time- and distance-neutral measure, but the actual minute values could be used by an individual traveler for a particular trip length or specific origin-destination pair. Continuous data sources are necessary to estimate the BI.

The **planning time index** (PTI) represents the total travel time that should be planned when an adequate buffer time is included. The planning time index differs from the buffer index in that it includes typical delay as well as unexpected delay. Thus, the planning time index compares near-worst-case travel time to a travel time in light or free-flow traffic. For example, a planning time index of 1.60 means that for a 15-minute trip in light traffic the total time that should be planned for the trip is 24 minutes (15 minutes × 1.60 = 24 minutes). The planning time index is useful because it can be directly compared to the travel time index on similar numeric scales.

The **total delay** (in vehicle-hours or person-hours) for a transit or roadway segment is the sum of time lost due to congestion. Delay can be expressed as a value relative to free-flow travel or relative to the posted speed limit. Total delay on a roadway or in an urban area is calculated as the sum of individual segment delays. This quantity is used as an estimate of the impact of improvements on transportation systems.

Congested travel is a measure that captures the extent of congestion. It estimates the extent of the system that is affected by the congestion.

The **percent of congested travel** is an extension of the congested travel measure. It also measures the extent of congestion but is computed as a ratio of the congested segment person-hours of travel to the total person-hours of travel.

Congested roadway is another measure of the extent of congestion. It is the sum of the mileage of roadways that operate under free-flow or posted speed limit conditions.

Accessibility is a measure that often accompanies mobility measures. It quantifies the extent that different opportunities can be realized. This term might describe accessibility to jobs, a transit station, or other land use or trip attractor of interest.

Adapted from Reference 4

Table 4.
Recommended mobility measures for analysis levels.

	Mobility Measures									
Analysis Area	**Travel Time**	**Travel Rate**	**Delay per Traveler**	**Travel Time Index**	**Buffer Index**	**Total Delay**	**Congested Travel**	**Percent of Congested Travel**	**Congested Roadway**	**Accessibility**
Individual locations	○		●	●	●	●				
Short roadway sections	●	●	●	●	●	●				
Long roadway sections, transit routes or trips		○	●	●	●	●				
Roadways		○	○	●	●	●				○
Sub-areas		○		●	●	●	●	●	●	●
Regional networks		○		●	●	●	●	●	●	●
Multimodal analyses		○	○	●	●	●				●

Note: ● = Primary mobility measure
○ = Secondary mobility measure
Note: Measures with delay components can be calculated relative to free-flow or posted speed conditions.

Adapted from Reference 4

DETERMINE A TARGET CONGESTION LEVEL FOR THE COMMUNITY, OR PORTIONS OF THE COMMUNITY

Why is setting a congestion target important?

Targets for performance measures are important for knowing whether your monitoring results (e.g., travel times, speeds, or indices) are high enough to warrant concern and the need for improvements. Your target values should be developed with input from citizens, businesses, decision-makers, and transportation professionals. The target values represent the crucial link between: 1) the vision that your community has for its transportation system, land uses, and its "quality of life" issues, and 2) the improvement strategies, programs, and projects that government agencies and private sector interests will implement.

The values are desirably the result of a process that is integrated with the development of the long-range plan, but they must be reasonable and realistic because overstatement or understatement could distort congestion assessment (*2*).

Table 5.
Recommended mobility measures for various types of analyses.

Uses of Mobility Measures	Mobility Measures: Travel Time	Travel Rate	Delay per Traveler	Travel Time Index	Buffer Index	Total Delay	Congested Travel	Percent of Congested Travel	Congested Roadway	Accessibility
Basis for government investment or policies			●	●	●	●	●	●	●	●
Basis for national, state, or regional policies and programs			●	●	●	●	●	●	●	●
Information for private sector decisions	●	●	○	●	●	○	●	●	●	
Measures of land development impact	●	●	●	●	●	●	○	○	○	●
Input for zoning decisions	●	●		●	●					●
Input for transportation models	●	●			●					
Input for air quality and energy models	●	●	●		●					
Identification of problems	●	●	●	●	●	○	○	○	○	
Base case (for comparison with improvement alternatives)			○	●	●	●	○	○	○	●
Measures of effectiveness for alternatives evaluation		●	●	●	●	●	○	○	○	●
Prioritization of improvements			●	●	●	●				○
Assessment of transit routing, scheduling, and stop placement	●	●	●	●	●	○				
Assessment of traffic controls, geometrics, and regulations	●	●			●					
Basis for real-time route choice decisions	●	●	●	●	●					

Note: ● = Primary mobility measure
○ = Secondary mobility measure

Adapted from Reference 5

IDENTIFY WHAT CONGESTION REDUCTION STRATEGIES ARE AGREEABLE TO THE COMMUNITY

What range of improvements are appropriate for smaller areas?

Now it is time for you to start building a toolbox of mobility improvements for your community. Early in the monitoring process, it is helpful to begin thinking about what types of improvement projects, programs, or policies might be in your "mobility toolbox." Upon completion of the mobility monitoring, these improvements can then be pursued in the community. Table 6 shows a relatively long list of possible improvements. Of course, not all of them will be applicable or appropriate to all communities. What might work in one community may not have the same success in another community depending upon available funding, political climate, precedent for past improvements, and the like.

Table 6.
Mobility improvement checklist for SMSCs.

Strategies	Description	Who	Hurdles	Locations	Implementation Cost / Time
Managing Demand					
Alternative Work Hours (Flex-Time)	Allow employees to work a schedule within a range of time periods.	Businesses, Travelers	None	Region	Low / Now
Telecommuting	Allow workers to change time of travel away from peak hours or eliminate trips by working from a satellite office.	Public and Private	None	Region	Low / Now, Near
Ridesharing	Create service to match potential carpoolers with database of participants.	Agencies and Businesses	None	Region	Low / Near
Local Bus Service	Provide access to and from all parts of the community.	Public Agencies	None	Region	Medium / Now, Near
Bicycle and Pedestrian Elements	Provide a nonmotorized alternative to vehicular travel.	Public Agencies	None	Region	Low-Medium / Near-Long
Increasing System Efficiency					
Traffic Signal Operation and Improvement	Maintain and improve signal systems.	Agencies	Manpower, Funding	Roads / Streets	Low / Now
Event Management	Develop special event plans for fairs, festivals, etc.	Agencies and Businesses	None	Sites	Low / Near
Technology-Based Transit Improvements	Implement automated bus tracking and passenger counters.	Public Agencies	None	Transit	Low-Medium / Near
Intersection Improvements	Provide alignments, appropriate traffic control, and proper location.	Public Agencies	None	Roadways	Low-Medium / Near
Arterial Street Access Management	Provide spacing, location, and design of driveways, medians, median openings, and traffic signals.	Public Agencies, Businesses	Site Design, Retrofit	Roadways	Medium / Near-Long

Strategies	Description	Who	Hurdles	Locations	Implementation Cost / Time
Adding Capacity					
Adding Freeway and Street Lanes	Adding lanes to existing facility.	Public Agencies	Funding	Routes	Medium-High / Near-Long
New Roadways	New highway construction.	Public Agencies	Funding	Routes	High / Long
Adding New Lanes without Widening the Roadway	Using existing pavement and restriping.	Public Agencies	Funding	Routes	Low-Medium / Near-Long
Improving Street Continuity	Continuity for all travel modes.	Public Agencies	Funding and Right-of-Way	Routes	Medium-High / Medium-Long
New Streets in New Developments	Complementary street system using the proper mix of functional streets.	Public Agencies, Private Developers	Right-of-Way / Easements	Developing Areas/Routes	Medium / Near-Long
Geometric Design and Access Standards	Ensuring proper design principles for safe, efficient, and economical movement.	Public Agencies	None	All	Medium / Near-Long
Grade Separation	Overpasses or underpasses.	Public Agencies	Costs	Routes / Interchanges	Medium-High / Near-Long
Unconventional Intersection Design	Examples include jughandles, median U-turn crossovers, and continuous flow intersections.	Public Agencies	Right-of-Way	Roadways	Medium-High / Medium-Long
Changing the Urban Scene					
Diversified Development Patterns	Ensure adequate development and access management policies.	Public Agencies and Businesses	Regulatory	Region	Unknown / Long
New Community Design (Smart Growth)	Encourage dense development in existing areas, and discourage "urban sprawl."	Public Agencies and Businesses	Regulatory	Region	Unknown / Long
Assessing the Transportation Impacts	Performing transportation impact analyses as part of permitting process.	Public Agencies	Regulatory	All	Unknown / Near
Managing Construction and Accelerated Construction					
Contracting Strategies and Accelerated Construction	Assessing incentives / disincentives on high-priority construction projects.				
"Working Day" and "Working Hours" Adjustments	Compressing project time by increasing working days/hours.	Public Agencies and Businesses	None	Roadways	Low-Medium / Now
Lane Rentals	Charges on time when a lane is closed for construction.	Public Agencies and Businesses	None	Sites	Low-Medium / Now
Work Zone Management Strategies	Methods to reduce traffic demand or change modes during construction activities.	Public Agencies and Businesses	None	Sites	Low-Medium / Now
Warranty Contracting	Allow agency to get a warranty for services and products received.	Public Agencies and Businesses	None	Region	Low / Now
Job Order Contracting (On-Call Contracting)	Give agency ability to award a competitively negotiated, firm, fixed-price contract to a contractor.	Public Agencies and Businesses	None	Sites	Low / Now
Design-Build Strategies	Allow one firm or team of firms to undertake project from design to final completion.	Public Agencies and Businesses	None	Roadways	Unknown / Now

Table 6. Mobility improvement checklist for SMSCs (continued).

Strategies	Description	Who	Hurdles	Locations	Implementation Cost / Time
Financing					
Toll Roads	Tolling roads to generate revenue for other improvements.	Public Agencies	None	Roadways	High / Long
Tax Increment Financing for Roads	Increased property tax within an "impact zone" of a road project.	Public Agencies	None	Sites	Unknown / Near
Local Option Fees and Other Local Funding	Give residents the option to support transportation programs with direct taxes or fees.	Public Agencies and Travelers	Legislative and Constitutional	Region	Unknown / Now, Near, Long
Innovative Financing — Transportation Infrastructure Finance and Innovation Act (TIFIA) Credit Assistance	Provide supplemental capital to major transportation investments of critical national importance.	Public Agencies	None	Roadways	Low / Now, Near
Innovative Financing — Road Bonds and "GARVEE" Bonds: Guaranteed Anticipated Revenue Bonds	GARVEE bonds are a means to leverage future federal highway funds in order to construct roadways.	Public Agencies	None	Roadways	Low / Now, Near
Innovative Financing — The Use of Concessions for Revenue and Federal Match	Could be used where existing services are nonexistent and the opportunity for private businesses to provide services exists.	Public Agencies	None	Sites	Unknown / Now, Near
Innovative Financing — Congestion Mitigation and Air Quality (CMAQ) Funding	Program to assist nonattainment areas in meeting 1990 air quality mandates.	Public Agencies	None	Sites, Roadways	Low / Now
Innovative Financing — Shadow Tolls	Per vehicle dollar amounts paid to a facility operator by a third party.	Public Agencies	None	Roadways	Low / Now, Near

Adapted from References 8-13

DETERMINE THE PREFERRED METHOD OF COMMUNICATION TO THE PUBLIC AND OTHER USERS

What are the most effective methods to communicate measures and results for the users/uses?

Tables, maps, and graphics are all effective in communicating your monitoring results to different audiences. While tables of data can be effective in communicating results, providing congestion severity by location on maps or over time through trend analyses are visually effective. Step 5 of the framework (Package and Distribute the Results) will describe specific examples of communication tools. At this point in the process, it is important to understand what uses/users will require communication tools so you can begin formulating the best methods of presentation to those audiences.

IDENTIFY FUNDING SOURCE FOR ONGOING MONITORING

How will the monitoring process be planned and programmed to ensure implementation and future monitoring?

Ongoing mobility monitoring is essential for you to identify and track changes. Ensuring your monitoring is adequately supported and funded can help guarantee ongoing success.

The responsibility for congestion monitoring may rest with one agency or be shared among many agencies. For areas with an MPO, the MPO is the likely office of primary responsibility. The MPO is responsible for regional planning and executes this work through the unified planning work program (UPWP). The UPWP is an annual MPO document that reflects local priorities by identifying both the transportation planning work to be undertaken over the next one- to two-year period and the performing agency within the metropolitan planning area as defined by 23 Code of Federal Regulations (CFR) 450.314. MPO staff may not be directly involved in congestion monitoring. More likely, other agencies or contractors will collect and analyze data. Probable agencies include the state DOT local district office, the state DOT office that coordinates statewide data collection, or local county or municipality organizations. You may need to make agreements between agencies to share ongoing monitoring costs and resources.

APPLICATION TO FENDER FALLS CASE STUDY

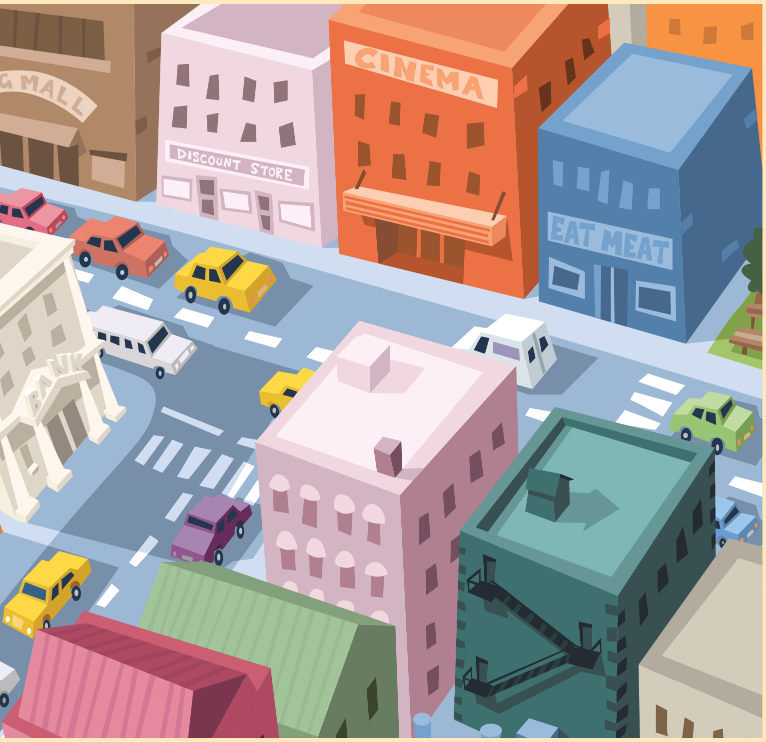
Identify the needs and opportunities

The public works director of Fender Falls, N.G. Neer, recognizes the importance of performing ongoing mobility monitoring. Because of its rapid growth, the community is experiencing reduced mobility along a number of key roadways. Fender Falls recently completed a comprehensive plan update, and transportation was a high concern for residents. Identified needs include additional transit service, bicycle lanes, upgraded and new sidewalks to facilitate pedestrian traffic, improved automobile traffic flow (signal optimization), increased roadway capacity (roadway widening projects or new roadways), and roadway maintenance improvements.

N.G. Neer
Director,
Public Works
Department

Understand the transportation building process

Because of its population, Fender Falls has an MPO. The MPO will work to include needed improvements into the MTP and UTP based upon the results of the monitoring. The monitoring process will provide quantified results identifying roadways that would benefit from transportation improvements.



Identify primary users of mobility monitoring

Neer has identified several individuals at the transportation agencies (state DOT, county, transit operators, MPO, Council of Governments, school districts) in the region who could use the results of the monitoring effort. Staff within the transportation agencies can use the results to identify locations for possible improvements. Neer has identified other stakeholders, including elected officials, who will also be interested in the results of the monitoring for funding and policy direction.

Determine the ultimate outcome(s) from monitoring

Fender Falls, the state DOT, and other partnering transportation agencies in the region determined the monitoring process would be a useful tool for identifying locations for needed improvements as well as establishing baseline traffic conditions in the region. Thinking forward to the press release, staff at all of the transportation agencies see monitoring as a way to document an analytical process for transportation project identification and selection. This information, as well as suggested locations for improvements, can be communicated in the future press release.

Identify how congestion is defined by the user

Neer organized a small community charrette that provided goals for mobility and tolerance of congestion in Fender Falls. Several individuals voiced their frustrations of increased congestion and reduced mobility. One participant noted that she has had to wait for more than one green light to get through some signals along Alternator Avenue.

From the discussion in the charrette, the transportation professionals of Fender Falls decided that congestion was defined in the community when drivers have to wait for more than one signal cycle, and also when travel times are 50 percent more than usual.

Identify mobility performance measures

The transportation professionals in Fender Falls ultimately identified travel time measures as the best indicators to communicate mobility conditions. Group members identified speed, travel time, and the travel rate index (i.e., actual conditions relative to free-flow conditions) as easy to measure and communicate.

Determine a target congestion level for the community, or portions of the community

From the discussion in the charrette, the community seems to accept some congestion and understands that not all congestion can be eliminated. Decision-makers have selected the travel rate index as a congestion measure. Transportation professionals in Fender Falls have identified any link with a TRI of 1.50 as congested. This value shows that a trip in the peak period is 50 percent more congested than the off-peak period.

Decision-makers also selected a 50 percent capacity target to identify how measured traffic volumes relate to available capacity. They felt that this capacity target would capture when areas in their community are approaching capacity, and they recognize that future monitoring can allow for refinements of this target, if necessary.

Fender Falls has not performed a monitoring effort yet, but will leverage existing data sources (e.g., state DOT traffic counts). It intends to use the results of the initial monitoring as a benchmark for existing conditions—increases in travel rate index values in future monitoring efforts will also be used to identify congestion areas that are growing.

Identify what congestion reduction strategies are agreeable to the community

N.G. Neer understands the substantial benefit produced with little cost by optimizing signals. Neer hopes to use the mobility monitoring effort to identify locations for signalization improvements. Neer also recognizes that significant delay is caused at intersections in the community because of a lack of turn lanes and/or existing turn lane capacity. Neer's hope is to use the monitoring effort to identify signalized intersections that would benefit from low-cost turn-lane improvements.

Determine the preferred method of communication to the public and other users

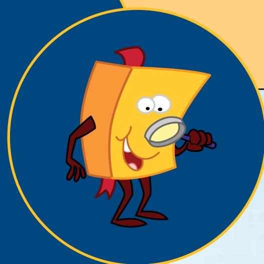
The public information officer of Fender Falls, N. Pho, recognizes that all audiences will benefit from graphics showing how traffic volumes change throughout the day by location. Community decision-makers are interested in graphics that show traffic volumes on a map. Pho indicates that graphics showing travel rate indices along each roadway for each peak period will also be of interest to technical and nontechnical audiences. Tables summarizing TRI values by location are desired.

Identify funding source for ongoing monitoring

All the transportation agencies in Fender Falls are interested in seeing the monitoring continue. Fender Falls, Camshaft County, the state DOT, and the MPO have agreed to financially support the monitoring effort, and the MPO has committed to programming it on the yearly unified planning work program — the annual MPO document identifying both transportation planning activities and the performing agencies. The MPO will lead the effort of contracting the data collection and analysis of the data.

Step 2: Create a Monitoring Plan

STEP OBJECTIVE: To create a comprehensive mobility monitoring plan to collect the necessary information along primary roadways and during crucial time frames.



After completing Step 1 of the framework, you are armed with the necessary information to move forward in creating a monitoring plan customized to your community needs. Step 2 includes consideration of the types of data that are necessary to satisfy your desired outcomes identified in Step 1. This step also ensures that the primary roadways are identified for monitoring and that the most crucial time frames are included. This step concludes with identification of how frequently the monitoring will be performed.

DETERMINE THE BEST METHOD(S) FOR MEASURING MOBILITY IN THE COMMUNITY

What data are necessary to quantify desired mobility measures?

In Step 1 of this framework, you identified what you would like to ultimately know as a result of the monitoring process. You considered what your press release would say at the conclusion of the monitoring. You also considered how the outcomes would be tied to local community mobility goals. Given what you learned in Step 1, this step is the time to consider what data you need to reach those outcomes.

Data, and the measures they support, tell a mobility story over time as they are monitored. Some of these data directly provide a measure for mobility monitoring (e.g., traffic volume, speed), while other measures require additional information to compute performance measures (e.g., travel rate indices computed with free-flow travel rate, peak-period travel rate, and traffic volume).

Typical data include hourly volumes (peak and off-peak), speed, and travel time. Other useful data you will want to collect include incident information, weather information, and road work information. Incidents, weather, and road work certainly affect mobility; therefore, information about these sources of reduced mobility should be recorded during the data collection periods.

What are available data sources?

SMSCs require the responsible allocation of their limited funds. Therefore, it is imperative to consider existing data sources that can be "borrowed" for mobility monitoring purposes. Typically, SMSCs will not have dedicated traffic monitoring instrumentation in the field.

State DOTs maintain automatic traffic recorders (ATRs) on state-maintained facilities. There are usually only a few of these count stations in larger communities, but their locations should be identified because they can provide you a data source that does not require additional field data collection. State DOTs also supplement continuous traffic counts with vehicle classification counts. You should contact your state DOT to identify available data.

State DOTs conduct yearly monitoring and reporting of traffic conditions throughout the state. ATR data support this reporting need. The largest foundations of traffic data are frequently collected with pneumatic tubes. Local agencies in your area may also perform traffic counts as part of existing efforts to monitor transportation demand. It is important that you check with state, city, and county representatives in your community to identify other traffic count data sources that may exist. If an MPO is present, you should also check with MPO personnel to see if they have traffic count data available, or if they are planning any upcoming counts.

Signalized intersections in the community are another possible data source. Some signal systems have the ability to save the volume data obtained from the detectors. Because these systems are already in place, this provides a possible "free" data source. However, you should investigate the quality of signal data prior to using it in your analysis.

Another example is obtaining travel time data from existing probe vehicles in the traffic stream. Before intelligent transportation systems were implemented in larger cities, many locations used travel time data from fleet buses or municipal fleet vehicles. These vehicles already have the ability to collect travel time data used for fleet management and logistics, so the data could be used for initial travel time estimates as well. Obviously these vehicles do not truly represent the traffic stream operations because of their unique operations (e.g., buses stop to drop off and pick up passengers), but they can provide you an estimate of travel times and can provide a starting point for monitoring in SMSCs.

There are likely many fleet vehicles (public or private) that may operate in your community. You should consider them as possible data sources. When considering the use of probe vehicle data sources, you should ask these questions of the possible data providers:

- Are the data available?
- Are the data stored?
- If the data are stored, how aggregate are the data (e.g., saved to 5-minutes, or daily summaries)?
- What, if any, quality control is performed on the data?
- Are data errors, or suspicious data, noted in any way?
- For existing fleet vehicles, is it possible to train the drivers to obtain data that suit the mobility monitoring effort, while ensuring they remain able to perform their primary function/service?

What monitoring methods are best for the community?

Now that you have decided what type of data are needed and what type of data may already be available, it is time to consider what data collection activities you may need to perform. To get a complete mobility picture, it is not likely that you will be able to use existing data sources for everything. Obtaining a complete mobility monitoring picture in your community will likely include three types of studies:

- Roadway Studies — Studies that encompass analysis along an entire roadway. Travel time runs and a videolog are examples.
- Point Studies — Studies that include data collection at a specific location. Volume counts, classification counts, and occupancy counts are all examples of point studies.
- Special Studies — Studies that do not necessarily occur at the "roadway" or "point" level. A stopped delay study is an example of a mobility monitoring special study.

Examples of these different studies are described on the following pages.

Travel Time Runs

So far, this guidebook has shown you how travel time is an important mobility measure that is easily communicated and understood by all audiences. Therefore, you will need to estimate travel time or speed along your primary roadways. In a SMSC, measurement of travel times is typically collected with what is called a "test vehicle." With this method, drivers use a data collection vehicle within which an observer records cumulative travel time at predefined checkpoints (i.e., intersections) along a route. Note that because these vehicles are instrumented and sent into the traffic stream, they are sometimes referred to as "active" test vehicles. In contrast, "passive" probe vehicles are already in the traffic stream for other purposes.

There are three levels of instrumentation you can use to measure travel time with a test vehicle:

Manual – manually recording elapsed time at predefined checkpoints using a passenger in the test vehicle;

Distance Measuring Instrument (DMI) – determining travel time along a roadway based upon speed and distance information provided by an electronic DMI connected to the transmission of the test vehicle; and

Global Positioning System (GPS) – determines test vehicle position and speed by using signals from earth-orbiting satellites.

For each of these methods, two persons are recommended in each test vehicle. These techniques and much more detail on developing a plan for travel time data collection are available in the FHWA's *Travel Time Data Collection Handbook* (*14*). The handbook is a comprehensive resource. It includes sections on developing a data collection schedule, developing equipment checklists, developing data collection forms, and performing trial runs, as well as many other sections that will assist you.

Research has shown that many areas perform travel time data collection for mobility monitoring, and they often use transportation agency staff to cut costs (*2*). As an example, you could provide the instrumentation equipment to employees to use on daily commutes to capture mobility information during the peak periods of the day.

Table 7 provides a summary of characteristics of the three instrumentation techniques. Manual techniques are the least costly, but they produce less detailed information. GPS techniques are becoming less costly and more attractive, especially with the increased use of personal data assistants (PDAs), which can be used to collect travel time data.

Table 7.
Comparison of test vehicle travel time data collection techniques.

Instrumentation Level	Costs			Skill Level		Level of Data Detail	Data Accuracy	Automation Potential
	Capital	Data Collection	Data Reduction	Data Collection	Data Reduction			
Manual:								
Pen and Paper	Low	Moderate	High	Low	Moderate	Low	Low	Low
Tape Recorder	Low	Low	High	Low	Moderate	Low	Low	Low
DMI	High	Low	Low	Moderate	Low	High	Moderate	High
GPS	High	Low	Low	Moderate	Low	High	High	High

Note: Rating scale (high, moderate, low) is relative among the instrumentation levels shown.

Adapted from Reference 14

There are other methods of performing travel time data along a roadway, including license-plate matching or automatic vehicle identification. License-plate matching involves matching a license plate from an upstream location with a downstream location. As with the test-vehicle method, there are either manual or automated procedures. Typically license-plate matching studies are relatively costly and would likely be cost-prohibitive in your SMSC.

Another possibility is the use of automatic vehicle identification (AVI). Identification is typically in the form of toll-tags that can be read and anonymously identified at two locations along a roadway, and a travel time is then computed between the two locations. These systems can be rather costly and might only be cost-effective in your community if your community is adjacent to a large city or metropolitan area that has already invested in the necessary infrastructure.

The *Travel Time Data Collection Handbook* (*14*) discusses license-plate matching and AVI techniques in more detail for your consideration.

Videolog

Communities are ever-changing. A videolog is a simple way for you to document the conditions along the roadways when mobility monitoring data are collected. You should take narrated video along all the roadways studied in the monitoring effort. Your video should include narration of the posted speeds, number of lanes, whether there is a median present, signalized intersections, primary cross-streets, primary driveways, work zones, school speed zones, and general geometry.

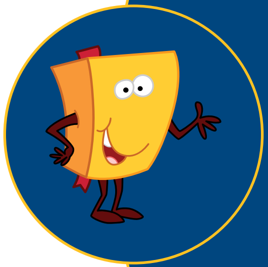
Volume Counts

You will probably need to collect some traffic count data above and beyond any existing data. You should collect at least 48 continuous hours of data along the key roadways in the community. Typically you will want to collect volume data along the roadway between the major intersections (e.g., state-maintained, numbered roadways). Tuesday through Thursday provides typical data in a given week, and April and October are the typical months in a given year. Following this guidance will allow you to miss weekends or holidays when traffic patterns are atypical. Collecting in April and October also misses the summer months, and ensures school is in session to provide more representative traffic counts.

Of course, the guidance above is to capture “typical” travel conditions. You may have an interest in performing mobility monitoring for a special event or other festival that occurs outside of these typical days or months.

Classification Counts

You may be interested in the vehicle mix of traffic along the key roadways you want to monitor. For example, maybe you are interested in how truck traffic has increased. FHWA requires states to report vehicle classification in 13 classes, a majority of which are various large truck configurations. Vehicle classification of most interest in a SMSC would likely be passenger cars (including pickup trucks), buses, single-unit trucks (e.g., UPS trucks), and semi-trailer trucks (e.g., 18-wheelers). You can likely obtain classification data from the state DOT. Alternatively, classification data can be collected manually. If there is a MPO in your region, you should check with staff there, as they sometimes perform classification counts for travel models.



Vehicle classification of most interest in a SMSC would likely be passenger cars (including pickup trucks), buses, single-unit trucks (e.g., UPS trucks), and semi-trailer trucks (e.g., 18-wheelers).

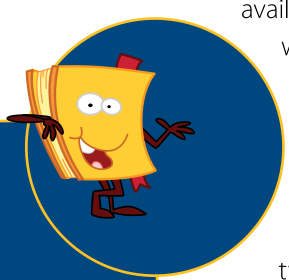
Occupancy Counts

The average vehicle occupancy (AVO) is the average number of persons in a vehicle. Transportation efficiency and mobility are best communicated in person movement, rather than vehicular movement. You can convert vehicles to persons by multiplying vehicles by average vehicle occupancy. AVO measurement is probably not as critical a measure in a SMSC until a region reaches the Transportation Management Area size (i.e., greater than 200,000 persons). AVO data can be collected manually in the field. Research has been performed that highlights best practices for determining vehicle occupancy for SMSCs (*15*). As with classification counts, if there is a MPO in your region, you should check with staff there, as they sometimes perform occupancy counts for travel models and related analyses.

Stopped Delay Study

Your travel time data collection effort will ultimately provide travel time and speed information along the key links of interest. In addition, you may have specific turning maneuvers at congested intersections of interest. You can perform a stopped delay study at such intersections. Over time, repeated stopped delay studies will allow you to quantify the delay changes as a result of increased traffic and/or transportation improvements.

A stopped delay study estimates the time motorists spend stopped at an intersection before performing an intersection maneuver. Therefore, if travel time information is available along one roadway (e.g., northbound), and travel time information is available along another intersecting roadway (e.g., westbound), the stopped delay could be estimated on the northbound to westbound left-turning maneuver. You can add this intersection travel time information to the link travel time estimates from each roadway to obtain an estimate of the trip travel time along the entire trip that includes two roadway links and an intersection.



A stopped delay study estimates the time motorists spend stopped at an intersection before performing an intersection maneuver.

You can find more information about intersection studies in the Institute of Transportation Engineers *Manual of Transportation Engineering Studies* (*16*).

In some cases when the stopped delay queue extends through several signals, or simply cannot be counted due to sight restrictions, you can perform travel time runs through the intersection turning movement to obtain a direct measurement of travel time through the intersection.

Ensure Key Locations in the Community Are Covered

Are key community bottlenecks covered in the monitoring plan?

Through meetings with local peers, and from your own experiences, the primary roadways for monitoring in your community can be identified. If the number of roadway to monitor is cost prohibitive, then sampling should be performed. The *Travel Time Data Collection Handbook* provides information on how to sample the number of roadways to ensure that reliable, timely data exist for severely congested segments, and that the remaining, less critical segments are sampled on a less frequent basis.

The handbook also suggests that you could use one or more of the following factors for prioritizing your data collection (*14*):

- perceived bottlenecks or congested conditions;
- percent change in congestion level (if available);
- average daily traffic volume per lane; or
- average daily traffic volume.

Ensure Key Time Frames Are Covered

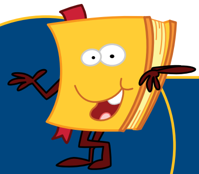
Are key time frames covered in the monitoring plan?

Travel time data are commonly used to represent typical annual conditions, and should be collected during months that have typical or average traffic volume patterns. This is why Tuesday through Thursday are the best weekdays to collect data. This is also why the months of April and October are recommended. Of course, holidays and special events should be avoided if you want to obtain average conditions.

The time periods in a day define when travel time data will be collected. Like all other elements of the study scope, the time periods will be determined by your study objectives. For travel time studies that are focused on identifying mobility trends and problems in SMSCs, the following time periods can be considered (*adapted from 15*):

- *Morning Peak Period* — encompasses all congestion during the peak morning commute, typically sometime between the hours of 6 a.m. and 9 a.m.
- *Off-peak Period* — includes periods of free-flow traffic during the middle of the day or late in the evening, typically between 10 a.m. and 11 a.m., 1 p.m. and 3 p.m., or after 7 p.m. For off-peak monitoring, the hours between 11 a.m. to 1 p.m. should be avoided if "lunch hour" traffic is significant. Off-peak travel times are used to establish free-flow conditions for calculating mobility measures.
- *Evening Peak Period* — encompasses all congestion during the peak evening commute, typically sometime between the hours of 4 p.m. and 7 p.m.
- *"Lunch Hour"* — typically includes the hours between 11 a.m. to 1 p.m., and can be the largest traffic period in some communities.
- *Special Events* — includes weekend festivals, fairs, or sporting events. You want to capture data at times when event-goers are arriving or departing en masse.
- *Weekend* — in addition to weekend monitoring due to special events, there may be a need to monitor weekends due to significant retail.

You should match the time periods for data collection to local traffic conditions and congestion patterns for the geographic area under consideration.



You should match the time periods for data collection to local traffic conditions and congestion patterns for the geographic area under consideration.

Identify How Often the Monitoring Will Be Performed

How frequent should the monitoring be?

This is a function of your budget and equipment resources. To be effective, mobility monitoring must be performed on a periodic basis so changes in mobility can be tracked over time. Re-evaluating mobility provides you the opportunity to identify where mobility is becoming worse or where it may be increasing due to mobility improvements. Annual monitoring would provide an appropriate level of data. Monitoring frequencies greater than five years may not provide your community enough clarity regarding mobility changes. Of course, the frequency of the monitoring will go back to your goals and objectives of the monitoring.

N.G. Neer
Director,
Public Works Department

APPLICATION TO FENDER FALLS CASE STUDY

Determine the best method(s) for measuring mobility in the community

In Step 1, N.G. Neer and other transportation professionals in Fender Falls decided upon travel time measures including speed, travel time, and travel rate indices. To compute these measures, N.G. Neer decided that directional traffic volume data will be collected along each roadway between major cross streets (i.e., approximately four or five locations per roadway). Travel time data are necessary; therefore, travel time runs will be performed. No intersection studies are needed. A narrated videolog will be recorded on all roadways.

N.G. Neer knows the state DOT collects traffic data on an annual basis at selected locations across the state. Neer will leverage available data from the state DOT for the monitoring effort. Neer will also check with the MPO to identify data from local studies that they may have available.

Ensure key locations in the community are covered

Most of the congested roadways in Fender Falls are numbered state-maintained facilities that become congested for a short period of time during the typical peak commuting period. These bottlenecks and signalized streets are known. Eleven such roadways are selected for monitoring.

Ensure key time frames are covered

Daily congestion in Fender Falls is relatively short. It occurs only from about 7:50 a.m. to 8:10 a.m. and again at approximately 4:55 p.m. to 5:15 p.m. With this in mind, N.G. Neer decides to perform travel time runs from 7:00 a.m. to 10:00 a.m. and from 4:00 p.m. to 6:00 p.m. Neer selects these time periods because they capture the congested time periods of the day. These data collection time periods provide ample time on each side of the existing congested time periods to monitor changes in the duration of the congestion period from year-to-year.

N.G. Neer has planned the morning travel time runs to allow collection of off-peak traffic conditions. After the congestion subsides around 8:10 a.m., there will be approximately 1.5 hours of off-peak runs. Neer will use these travel time runs to estimate free-flow conditions for travel rate index calculation.

Neer plans to collect data for one day along each roadway.

Identify how often the monitoring will be performed

The city, county, state DOT, and MPO support the monitoring effort. The MPO agreed to place it on the UPWP each year with funding coming from the city, county, state DOT, and MPO. To save costs, the MPO agrees to coordinate with employees of various transportation agencies in Fender Falls and train them to do some of the travel time runs.

Because of the anticipated benefits, N.G. Neer desires an annual monitoring program.

Step 3: Monitor the System

STEP OBJECTIVE: To implement the monitoring plan developed in Step 2.

In Step 2 you prepared a mobility monitoring plan customized to the needs of your community. Step 3 simply implements that plan. In this step you are carrying out the process of monitoring your system. If this is the first time the monitoring has been performed in your community, the monitoring results will provide mobility benchmarks to which future monitoring efforts will be compared.

MEASURE CHANGES

What is the action plan?

It is now time to implement the data collection as you planned in Step 2. Six typical data collection efforts were described in Step 2 to guide the development of your plan. The data collection efforts are:

1. travel time runs,
2. videolog,
3. volume counts,
4. classification counts,
5. occupancy counts, and
6. stopped delay studies.

In Step 2, you identified where and when each of these studies would be performed.

The data collection process for your mobility monitoring can be extensive. Here are a few tips to ensure success and help avoid frustrations.

- Train your drivers on equipment use and driving technique.
- Drive the roadways with your drivers so they know the location of all checkpoints and the turnaround locations.
- Provide travel time data collection forms to your drivers that they can fill out before and after the run to highlight traffic queues, run numbers, run start times, record weather conditions, and make other comments (see *Travel Time Data Collection Handbook* for a sample). These forms will be invaluable for data reduction.
- Ensure your data collection personnel arrive early to the site to allow time for equipment setup. Synchronize/check time stamps for each driver (laptops when using GPS or DMI, stopwatches for the manual method).
- Coordinate a location to meet after each period of travel time data collection to share experiences and coordinate how any issues will be consistently resolved. This is also the time for you to get each driver's data, review it, and back it up (if electronic data files).
- Ensure your pneumatic tubes for volume counts are securely fastened. If you are collecting pneumatic tube counts on the days of your test vehicle runs, inform your drivers to keep an eye on the tubes and notify you if they appear loose or are completely detached.
- Run your vehicles in a continuous circuit. As an example, when five vehicles are used, three vehicles can start at the end of the roadway in the peak direction, and two vehicles can start in the off-peak direction. Figure 6 shows three cars queued on-site near a driveway. The vehicles will turn right to enter the roadway in the peak direction at their assigned headways to perform their travel time runs. When two vehicles queue at an endpoint, the second vehicle should wait two or three minutes before beginning the next run (depending on the length of the roadway and congestion level).

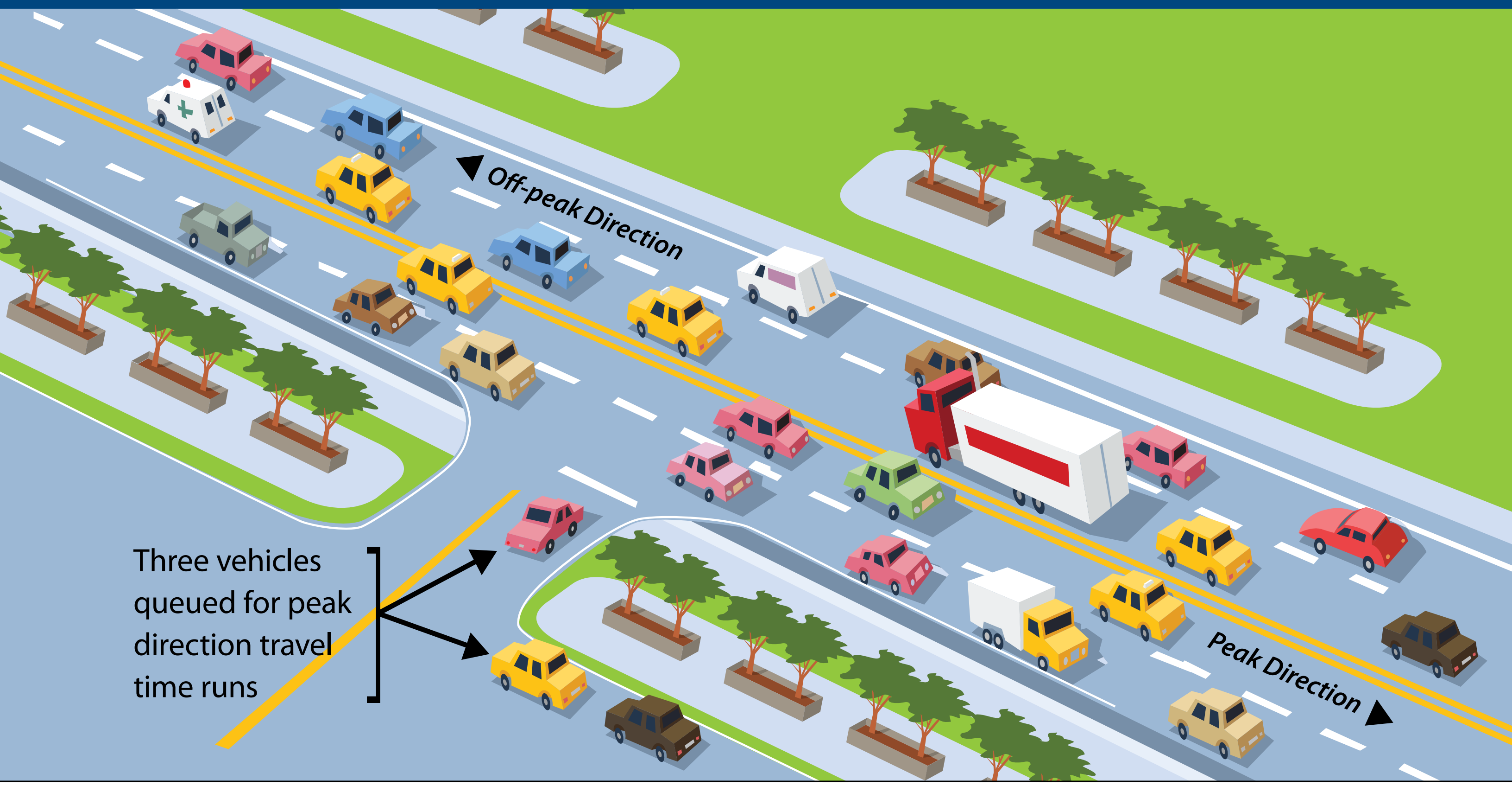


Figure 6. Illustration of travel time study test vehicle deployment at run initiation.

Are the necessary data being collected?

Data will be collected or estimated by implementing your plan. Typical data elements include hourly volumes (peak and off-peak), speed, travel time, average vehicle occupancy, and vehicle classification. Other useful data elements include incident information, weather information, and road work information, which should be documented for the days and time periods of data collection. Your test vehicle drivers can record this type of information before and/or after each travel time run.

What are the benefits of creating a videolog of the physical environment, and how is it done?

A very useful part of the data collection effort is creating a videolog of the physical environment. This is a narrated video you can take out the front windshield of the vehicle. The physical environment might also provide other vantage points for taking video (e.g., overpasses, pedestrian bridges, buildings, hills). You might want to include key developments or undeveloped properties along the side of the road in your log. The video is best recorded with two individuals so that the passenger can narrate and record the video. The video camera can be mounted to the vehicle's dashboard.

The video narrator should verbally document cross-streets, roadway geometry, land use, posted speed limits, school speed zones/limits, construction zones/limits, primary driveways, signalized intersection locations, primary cross-street locations, and other features of interest.

APPLICATION TO FENDER FALLS CASE STUDY

N.G. Neer
Director,
Public Works
Department

Measure mobility changes

Per the plan N.G. Neer developed in Step 2, transportation professionals in Fender Falls collected volume data along the 11 roadways identified for analysis. Travel time data were collected during the periods identified in the plan. Fifteen-minute directional volume counts were collected at approximately five locations on each roadway. The roadways are between 6 and 10 miles in length.

A videolog of all the roadways was recorded. Figure 7 shows the video camera mounted to the windshield.

The transportation professionals in Fender Falls decided that mobility monitoring will be performed on an annual basis as determined in the mobility monitoring plan.

Classification counts, average vehicle occupancy counts, and stopped delay studies were not performed.

Figure 7. Video camera shown mounted to the windshield and a screen shot of the videolog taken from a point farther down Alternator Avenue.

Step 4: Analyze the Data

STEP OBJECTIVE: To process and perform analysis of the mobility monitoring data to produce measurements and trends in selected mobility measures.

COMPUTE MOBILITY PERFORMANCE MEASURES

I've collected my data, now what do I do?

After the data collection dust settles, the office phase of data reduction, analysis, and interpretation begins.

Often there is "paralysis by analysis" in answering questions such as whether you have enough data to calculate the performance measures the way you desire or whether you change your performance measures to satisfy your data. The important step is just to begin your analysis with the data you collected. Note your data gaps so they can be addressed and filled in future monitoring cycles. Begin to report your community's mobility, and begin to track trends.

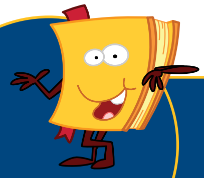
Once you have worked through your first cycle of the monitoring process, you will begin to identify data templates or organization standards that work best for you and your staff. Be aware that your first time through the monitoring process will be more labor intensive than successive analysis cycles.

What tools should I use?

Spreadsheets will likely be the most common and most familiar tool to use. They allow you to organize your data systematically (e.g., by location, by route, or by time of day). Once a template is established, it is easy to copy formulas across data. Spreadsheets also offer the capability to create graphical views of data, commonly referred to as graphs or charts. These graphics will be the most powerful tools you will have to convey the meaning and value of your data to stakeholders and elected officials.

Take great care and time when working with your datasets to maintain accuracy, to document your approach, and to achieve consistent and accurate results. It is best to keep back-up copies of the original data. Use these to create new files where data are organized better or more logically and where calculations and charts are created.

Adopt a folder organization and/or a filenaming convention that will help you easily access your data files and spreadsheets. Suggestions are to organize by year, roadway or location, and type of data. Figure 8 shows a file structure with these suggestions. Within spreadsheet files, you can choose colors for sheet tabs to differentiate sheet types – data or chart/graph. An example is shown in Figure 9.



Take great care and time when working with your datasets to maintain accuracy, to document your approach, and to achieve consistent and accurate results.

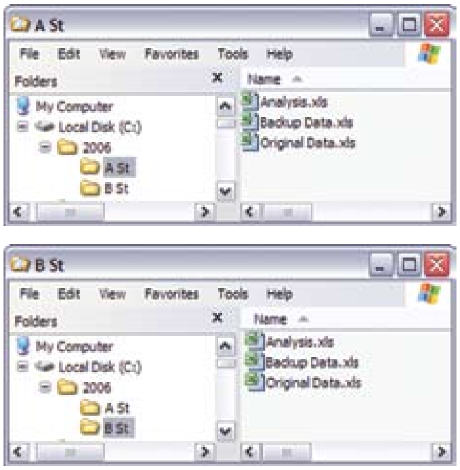


Figure 8. Representation of file management folder organization.

Figure 9. Example spreadsheet organization using color tabs.

Is it important to be consistent?

The answer is a qualified "YES!" You should strive to be consistent in all of your calculations in your current monitoring year and with past monitoring. Being consistent reduces some of the necessary data interpretation, ruling out changes to the process.

However, as discussed later in the guidebook, there is a need to seek improvements and refinements to your monitoring process. You learn from your own experience as you proceed through the process. Other external factors may necessitate changes to your process such as technology improvements or improved and expanded data sources.

How do I compute traffic volumes and create descriptive characteristics?

Typically, traffic volumes will have been collected from short-term axle counts using pneumatic tubes stretched across the road. A first pass at analyzing traffic volumes is to divide the recorded axle counts by 2, the typical number of axles on passenger vehicles. The axle factor increases if more large trucks are in the traffic stream. Vehicle classification counts are used to generate a more accurate axle factor through application of office procedures.

Direction	Peak Hourly Volume	
EB	2,160	
WB	1,440	
Total	3,600	
D	0.60	*= 2,160 / 3,600*

Figure 10. Directional factor calculation example.

The average daily traffic (ADT) is calculated by dividing the sum of the 24-hour volumes by the number of 24-hour periods. An ADT, by definition, is the amount of traffic in both directions. Total ADT is a useful statistic to assess relative level of demand on surface streets. The directional ADT should be recorded also.

The term *K*-factor represents the amount of daily traffic occurring during the peak hour of congestion. For example, if the traffic volume in the peak hour is 3,600 vehicles and ADT is 42,000 vehicles, the *K*-factor is 0.09 — or, 9 percent of the daily volume occurs in the highest peak hour.

Time Ending	15-min Volume	
5:15	1,100	*Highest 15-min period*
5:30	925	
5:45	850	
6:00	725	
Total	3,600	*Highest hourly volume*
PHF	0.82	*= 3,600 / (4 x 1,100)*

Figure 11. Peak-hour factor calculation example.

The directional factor (*D*) is the ratio of the directional volume within the peak hour. For the example in Figure 10, when eastbound (EB) traffic is 2,160 vehicles and westbound (WB) traffic is 1,440 vehicles, the directional factor is 0.60 EB, meaning that 60 percent of the bi-directional traffic was traveling in the eastbound direction in the peak hour.

When 15-minute volumes are collected, the peak-hour factor (PHF) is calculated as the ratio of the highest 15-minute volume in the highest hourly volume. In the example shown in Figure 11, the highest hour total volume is 3,600 vehicles. Dividing the highest hourly volume (3,600) by the hourly estimate of the highest 15-minute volume ($4 \times 1,100$) yields a PHF of 0.82.

Table 8.
Estimated hourly lane capacity values.

General Physical Characteristics		Estimated Hourly Lane Capacity (vphpl)
Land Use	**Signal Density**	
Rural	Limited	2,000
Fringe	Moderately Spaced	1,800
Urban	Closely Spaced	1,600

Targets can be applied against the volume data to graphically show how traffic volumes relate to the available roadway capacity. These targets represent performance targets and should be designated in Step 1. A 50 percent capacity target may be an appropriate initial target for small and medium-sized communities. The percent of time during the day above this target can be reported and compared to past or future measurements.

What are and how do I compute traffic volume target?

The roadway capacity can be estimated using Table 8. The physical characteristics, land use, and signal density affect hourly lane capacity measured in vehicles per hour per lane (vphpl). The estimate is a subjective assessment. Retain your documentation on how the estimate was generated. More detailed roadway capacity estimates may be calculated using *Highway Capacity Manual* (*17*) procedures.

For example, the estimated capacity on an urban section of roadway with closely spaced signals for volume data collected in 15-minute intervals is calculated:

Lane Capacity	x	Number of Lanes	x	Interval Adjustment	x	Target Factor	=	Estimated Roadway Capacity Target
1,600 vphpl	x	3 lanes, Eastbound	x	$\frac{\text{1 hour}}{\text{4 (15-min periods)}}$	x	½ capacity	=	600 vehicles per 15-minutes

Care should be taken to ensure that the capacity target is related to the interval of measurement. If hourly volumes are reported, no conversion (1 hr ÷ 4 [15-min periods]) is required.

How do I compute a travel rate index?

The travel rate index is a measure of rate of travel compared to a free-flow travel rate and does not include travel time data where nonrecurring congestion, such as congestion due to traffic incidents, was present. See Table 3 for the travel rate index equation. There is no consistent, single definition for the free-flow travel rate. Free-flow travel rate can be defined through use of posted speed limits or a statistical percentile of measurements (*4*). The travel rate index is calculated most frequently over the length of a roadway. It could be determined for roadway segments or links. Figure 12 shows the relationship between a roadway and the segments or links that combine to define the roadway.

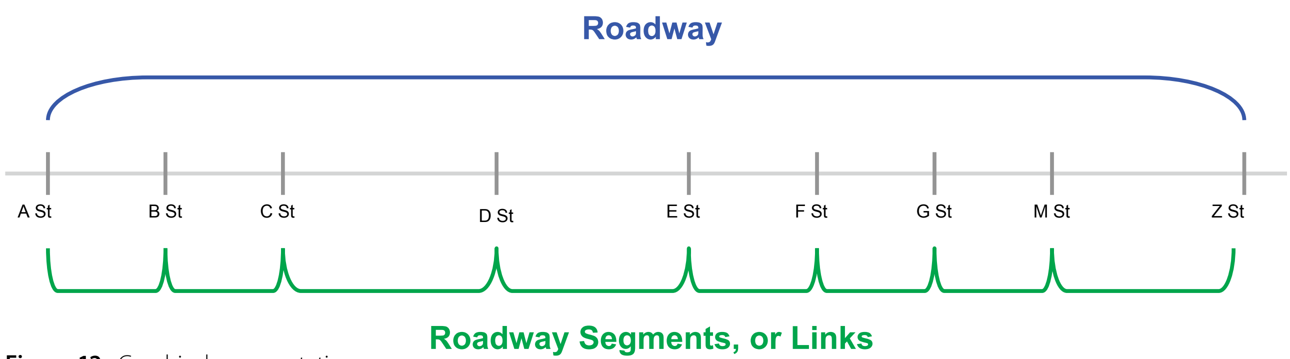


Figure 12. Graphical representation of relationship between the entire roadway and links.

A travel rate index of 1.0 means the rate of travel measured is the same as the free-flow condition. Each increase of 0.1 is equivalent to a 10 percent increase in travel rate. A travel rate index of 1.5 means that travel takes 50 percent longer than travel at the free-flow travel rate. This example is shown in Figure 13.

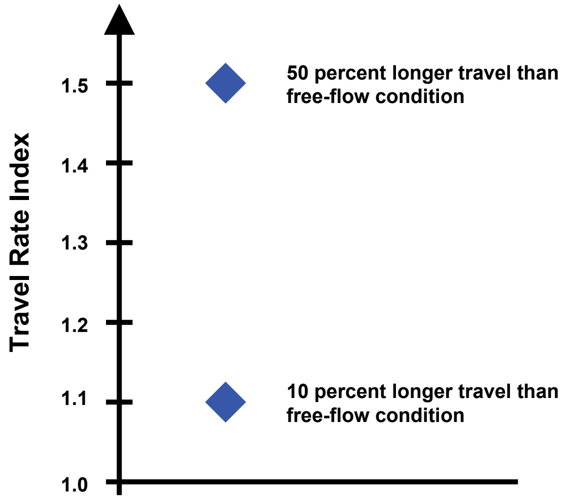


Figure 13. Interpretation of travel rate index.

How is free-flow travel rate calculated?

Begin calculating the travel rate index by first estimating the free-flow travel rate. The free-flow condition is calculated by summing the 15th percentile off-peak travel time data for each link in the roadway. Estimating this free-flow condition in this manner eliminates one or two (typically) of the fastest recorded times, mitigating any "speed racer" effect, and synthesizes better traffic flow conditions from all measurements, mitigating the effect of some congested links on the total run's travel time.

In the Table 9 example, data from six travel time runs from the off-peak period are shown. The 15th Pct column on the far right uses the MicroSoft (MS) Excel® PERCENTILE function, where the function requires an array (e.g., travel times to A St for Run 1 through Run 6) and the desired percentile in decimal form (0.15). The 15th percentile travel times for each link are then summed. In the example, the sum of these times is 315 seconds.

Table 9.
Example off-peak travel time run results.

	Observed Travel Time (seconds)						
Checkpoint	**Run 1**	**Run 2**	**Run 3**	**Run 4**	**Run 5**	**Run 6**	**15th Pct**
A St	82	50	81	100	89	108	73
B St	30	16	14	14	15	14	14
C St	48	109	45	47	140	39	44
D St	15	14	13	13	14	13	13
E St	17	16	17	15	17	16	16
F St	10	9	9	8	10	9	9
G St	19	19	17	15	16	16	16
H St	200	146	127	132	167	163	131
Total Time	421	379	323	344	468	378	315

The travel rate index for each run is the ratio of that run's total travel time to the 15th percentile total travel time. Because the roadway length is the same for each run and the 15th percentile travel time, it is not necessary to use roadway length in the calculation. The travel rate index results are shown in Table 10. The travel rate indices range from 1.03 to 1.49. The third travel time run (Run 3) was the fastest single run along the roadway (323 seconds). Run 3 was estimated to be 3 percent longer than the free-flow condition (1.03 travel rate index).

Table 10.
Example travel rate index results.

Travel Rate Index					
Run 1	Run 2	Run 3	Run 4	Run 5	Run 6
1.34	1.20	1.03	1.09	1.49	1.20

It is best to maintain the travel rate index to one or two decimal points. Additional decimal values are not appropriate because they infer greater accuracy in the data than is actually present.

For link travel rate indices, each checkpoint's time is set as a ratio to the link's 15th percentile travel time. The median and maximum link travel rate indices are recommended for reporting relative mobility on each link. The median represents the point where

50 percent of the number of travel time runs recorded were equally greater or less than the value. The median can be calculated using the MEDIAN function in MS-Excel.

The median travel rate index is an appropriate measure where half of the measurements were faster or slower than this rate. For statistical reasons, use of a median is more appropriate than an average because the travel rate index measurements are not normally distributed. Averages can easily be skewed when measurements are not normally distributed and extreme values are not removed from the dataset.

Because the 15th percentile travel time is used, it is possible to calculate a travel rate index less than 1.0. Travel rate indices should not be less than 1.0. To correct for this condition, you must set the minimum value as 1.0. This can be done in MS-Excel using an IF statement. The statement should be written so that if the travel rate index is less than 1.0, it will return a value of 1.0; otherwise it will return the calculated travel rate index.

Continuing the current example, the link travel rate indices are calculated and shown in Table 11. Notice on Table 9, for Run 2 at the A St checkpoint, when the link travel time (50 seconds) was below, or faster than, the 15th percentile link travel time (73 seconds), the travel rate index was forced to 1.0 in Table 11.

Table 11.
Example link travel rate index results.

	Link Travel Rate Index							
Checkpoint	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Median	Maximum
A St	1.12	1.00	1.11	1.37	1.22	1.47	1.17	1.47
B St	2.14	1.14	1.00	1.00	1.07	1.00	1.04	2.14
C St	1.10	2.51	1.03	1.08	3.22	1.00	1.09	3.22
D St	1.15	1.08	1.00	1.00	1.08	1.00	1.04	1.15
E St	1.08	1.02	1.08	1.00	1.08	1.02	1.05	1.08
F St	1.14	1.03	1.03	1.00	1.14	1.03	1.03	1.14
G St	1.21	1.21	1.08	1.00	1.02	1.02	1.05	1.21
H St	1.53	1.12	1.00	1.01	1.28	1.25	1.19	1.53

Figure 14 graphically conveys the results from the mobility monitoring example. The maximum measured link travel rate indices are also reported because these are measuring the extreme events occurring on the roadway. Drivers are perceptive and have a memory. For your monitoring process to have credibility with the general public, you need to acknowledge these extreme conditions. The extreme conditions may last only a short time each day, or they may occur infrequently such as when a special event is underway. Honesty in data will support your positions for future solutions. You may also be able to track the extreme conditions: are they worsening in intensity or becoming more frequent?

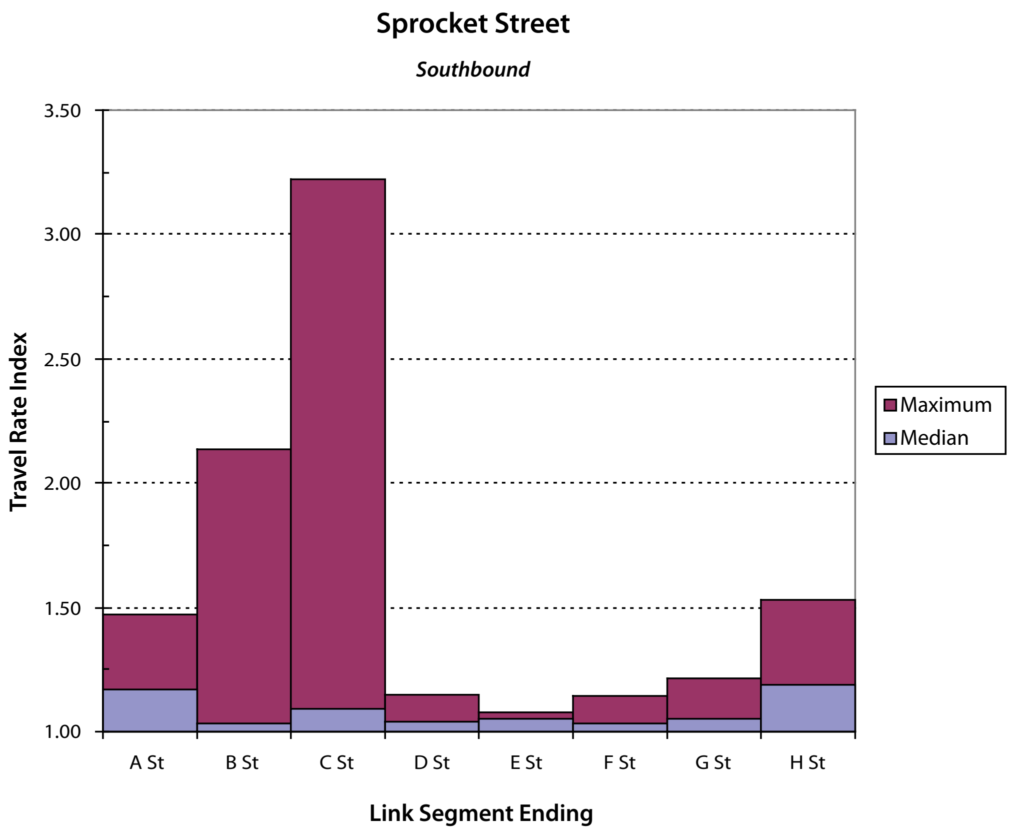


Figure 14. Graphical display of link travel rate indices.

Roadway travel rate indices can provide a relative comparison within the community. In the example shown in Table 12, Roadway D is the most congested in both morning and afternoon peaks but operates at a relatively similar level in the off-peak period. The mobility of Roadway D in the afternoon peak period is reduced by nearly half compared to the morning peak (1.75 versus 1.30).

A graphical example to relate better to the general public is shown in Figure 15, where a map of the community is used to convey problem areas. This example provides a means to highlight the negative congestion. If your purpose is to highlight your community's mobility, reversing the color scheme may be appropriate. The line thickness can also convey information to the reader. In this example it is used to support the color scheme of lower mobility values. Line thickness could also be used to relate roadway traffic volumes, giving the reader a sense of both vehicle demand and measured conditions.

Table 12.
Example travel rate indices by roadway and time period.

	Period		
Roadway	AM Peak	Off-Peak	PM Peak
A	1.10	1.03	1.10
B	1.10	1.05	1.10
C	1.15	1.02	1.14
D	1.30	1.05	1.75
E	1.09	1.04	1.10

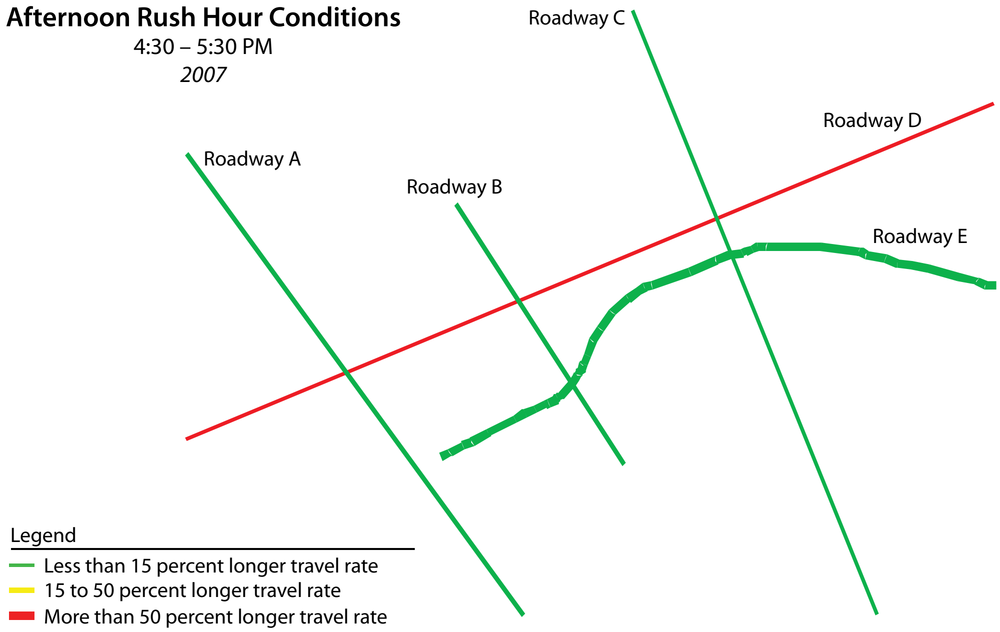


Figure 15. Example community representation of travel rate index results.

How do I estimate delay along the roadway?

Calculating roadway delay requires you to collect both traffic volume counts along the roadway and travel times within it. Combining the volume counts with your estimate of vehicle delay from travel time runs will provide you with roadway delay.

Most likely, it is not very practical to collect volume counts for each individual link within a roadway. Select groups of adjacent links that have similar cross-sections and total ADT. Breaks in the roadway should be made where either the cross-section changes or the ADT differs plus or minus 10 percent (*18*).

Using your travel time data, calculate to the nearest minute when your probe vehicle entered the link. This time entering the link will be used later when assigning recorded traffic volumes.

In the Table 13 example, the estimated free-flow travel time for the link is 21 seconds. You are interested in capturing the travel time delays greater than the 15th percentile travel time through the link. For each link, calculate the difference between the link travel time and the 15th percentile time in the off-peak period for the link. When the measured link travel time is faster than the 15th percentile travel time, a negative link delay will result. Manually set these link delays to 0 seconds. You should make a notation in your files for your documentation where data were adjusted. In the example, the 0 value is bolded.

You are interested in the measured delay occurring at times when your probe vehicle entered the link. You will match the measured traffic volumes recorded for that link for specific time intervals. Do not use the time when the travel time run began. Using the run start time can result in improper delay calculations. Visually group the times entering the link by 15-minute intervals, beginning on the hour. The example in Table 13 uses orange to identify these 15-minute intervals.

Table 13.
Example link delay worksheet.

Node 13-14 : Rugby Road to State Avenue
Length (ft) **1150**
Direction **EB**

Run File	Date	Run Start Time	Time Entering Link	Travel Time (sec)	Average Speed (mph)	Link Delay (sec)
alteBEam1-1-EB-R001	4/15/07	7:00	7:07	19	42	**0**
alteJJam1-1-EB-R001	4/15/07	7:05	7:11	20	13	**0**
alteDWam1-1-R004	4/15/07	7:17	7:23	30	32	9
alteRSam1-1-R002	4/15/07	7:20	7:26	26	30	5
alteDSam1-1-R002	4/15/07	7:23	7:29	25	32	4
alteBEam1-1-R003	4/15/07	7:30	7:36	60	32	39
alteJJam1-1-R003	4/15/07	7:34	7:41	24	33	3
alteDWam1-1-R006	4/15/07	7:49	7:54	78	37	57
alteRSam1-1-R004	4/15/07	7:54	8:00	22	36	1
alteDSam1-1-R004	4/15/07	7:58	8:04	24	40	3
alteBEam1-1-R005	4/15/07	8:09	8:15	25	27	4
alteRSam1-1-R006	4/15/07	8:11	8:19	19	10	**0**
alteJJam1-1-R005	4/15/07	8:15	8:21	21	40	0
alteDWam1-1-R008	4/15/07	8:22	8:29	20	29	**0**
alteDSam1-1-R006	4/15/07	8:31	8:36	22	31	1
alteBEam1-1-R007	4/15/07	8:42	8:49	26	39	5
alteJJam1-1-R007	4/15/07	8:45	8:52	27	32	6
alteDWam1-1-R010	4/15/07	8:53	8:59	27	38	6
alteRSam1-1-R010	4/15/07	9:03	9:09	76	30	55
alteDSam1-1-R008	4/15/07	9:05	9:11	22	39	1
alteBEam1-1-R009	4/15/07	9:16	9:23	25	30	4
alteJJam1-1-R009	4/15/07	9:20	9:26	21	36	0
alteDWam1-1-R012	4/15/07	9:25	9:31	25	40	4
alteRSam1-1-R012	4/15/07	9:35	9:41	21	10	0
alteDSam1-1-R010	4/15/07	9:38	9:44	20	38	**0**
alteRSpm1-1-EB-R001	4/15/07	16:00	16:08	29	26	8
alteJJpm1-1-EB-R001	4/15/07	16:05	16:12	28	9	7
alteBEpm1-1-EB-R001	4/15/07	16:09	16:16	32	27	11
alteDWpm1-1-R002	4/15/07	16:18	16:25	26	33	5
alteDSpm2-1-R002	4/15/07	16:24	16:31	25	27	4
alteRSpm1-1-R003	4/15/07	16:30	16:38	26	28	5
alteJJpm1-1-R003	4/15/07	16:36	16:43	80	31	59
alteBEpm1-1-R004	4/15/07	16:49	16:55	90	30	69
alteDWpm1-1-R004	4/15/07	16:53	16:59	28	29	7
alteDSpm2-1-R004	4/15/07	16:55	17:02	31	30	10
alteRSpm1-1-R005	4/15/07	17:05	17:12	37	11	16
alteJJpm1-1-R005	4/15/07	17:08	17:15	44	19	23
alteBEpm1-1-R006	4/15/07	17:25	17:32	31	29	10
alteDWpm1-1-R006	4/15/07	17:35	17:42	29	32	8
alteDSpm2-1-R006	4/15/07	17:38	17:45	30	23	9
alteRSpm1-1-R007	4/15/07	17:40	17:47	28	29	7

Table 14 shows a 15-minute summary of the directional average link delays per vehicle, link volume, and expanded delay. The expanded delay is the product of the average link delay per vehicle and the link volume. The peak-period delay is the sum of the expanded delays in the peak period. Here the morning peak period is two hours, from 7:00 a.m. to 9:00 a.m.

Table 14.
Example link delay calculations.

Node 13-14 : Rugby Road to State Avenue
Length (ft) **1150**
Direction **EB**

Time Ending	Average Link Delay (sec)	Link Volume	Total Link Delay (veh-min)	Total Peak Period Delay (veh-min)
7:15	0	101	0	291
7:30	6	113	11	
7:45	21	139	49	
8:00	57	209	199	
8:15	2	232	8	
8:30	1	201	3	
8:45	1	183	3	
9:00	6	187	18	
9:15	28	202	94	
9:30	2	190	6	
9:45	1	217	5	
10:00		222		
16:15	8	424	53	1005
16:30	8	398	53	
16:45	23	385	145	
17:00	38	422	267	
17:15	13	470	102	
17:30	23	601	230	
17:45	9	572	86	
18:00	8	511	68	

The roadway delay is the sum of the directional links. Table 15 displays how the link delays within a roadway are summed (vehicle-minutes of delay) and converted to different unit measures (vehicle-hours, person-hours, vehicle-years, and person-years). AVO is used to translate vehicle delays into person delays. The annual day measure is equivalent to 50 standard work weeks, assuming people generally take two weeks of vacation each year. You can summarize these delays by direction, time period, or peak travel direction as examples.

Table 15.
Example roadway delay calculations.

	Delay (min)			
	Eastbound		Westbound	
	AM	PM	AM	PM
Route 4 to Eagle Creek Rd	147	101	52	442
Eagle Creek Rd to Bypass Rd	83	38	39	46
Bypass Rd to Invention Dr	96	74	67	92
Invention Dr to Fielder Rd	227	202	1,509	297
Fielder Rd to Wellington Rd	93	12	1,739	211
Wellington Rd to Old Main Dr	69	390	43	58
Old Main Dr to Taub St	21	38	55	46
Taub St to Britain St	41	278	54	72
Britain St to Pence St	318	1,014	37	93
Pence St to Normal Way	87	44	45	195
Normal Way to Rugby Rd	223	2,326	1,427	913
Rugby Rd to State Ave	291	1,005	115	124
State Ave to Terry St	459	485	108	0
Terry St to Terry St East	150	276	51	83
Terry St East to Winter Loop	636	1,383	752	500
Winter Loop to Grove Dr	122	1,765	499	989
Grove Dr to Glenhaven Dr	25	346	387	201
Glenhaven Dr to W Frontage Rd	5	106	699	1,582
W Frontage Rd to E Frontage Rd	139	584	44	35
E Frontage Rd to Goldplain Dr	108	277	479	641

Daily Total (veh-min)	3,340	10,744	8,201	6,620
	14,084		14,821	
	28,905			
Daily Total (veh-hr)	56	179	137	110
	235		247	
	482			
Daily Total (per-hr)	59	188	144	116
	247		260	
	507			
Annual Total (veh-yr)	2	8	6	5
	10		11	
	21			
Annual Total (per-yr)	3	8	6	5
	11		11	
	22			

Assumed AVO = 1.05
Annual days = 250

COMPARE PERFORMANCE TO COMMUNITY TARGETS

You defined your community's mobility targets in Step 1. Now that you have collected your data and calculated your performance measures, you can begin comparing those measured performance measures to your mobility targets.

What am I looking for relative to my community targets?

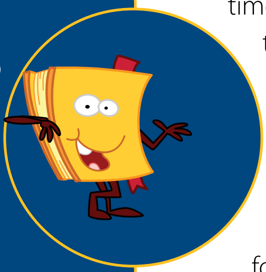
Comparing specific locations, roadway, or time periods to your community targets allows you to grade or classify mobility today relative to those targets. You can then begin to answer how much mobility there is relative to your community's targets — high, moderate, or low. These comparisons provide a snapshot of current conditions. Snapshots lack perspective on where mobility is headed. For that perspective, you must review trends within the data combined with your own knowledge of economic development activities.

COMPARE MOBILITY CHANGES FOR LOCATIONS AND TIME FRAMES IDENTIFIED IN THE PLAN

On your second and subsequent cycles of your mobility monitoring process, you can begin comparing performance measures over time — or trends. Trends can be developed by location, roadway, and time period.

Within the trends, you are looking for improvement or decline in your performance measures. If you applied mobility solutions, have performance measures improved in those areas? If you are seeking resources to improve mobility, a declining mobility trend will provide you with justification as it reaches or breaches key performance measure targets.

Defining what constitutes a significant change is unique to your community, but changes of 25 percent may be an adequate starting point for your monitoring process.



Attempt to identify new or recurring (if monitoring is conducted on a frequent basis) trends within the data. Specifically, examine the extent (geographic coverage) and duration (length of time) when mobility does not meet your community's targets. As more facilities or longer stretches of a particular facility fail to meet community targets, these changes can be reported. When the peak travel period spreads to an additional 10 or 15 minutes, this can be reported. Report locations or facilities where mobility changes significantly for your community. Defining what constitutes a significant change is unique to your community, but changes of 25 percent may be an adequate starting point for your monitoring process. Reporting these changes in system operations are an important tool for you in leveraging additional resources or assistance.

ENSURE PERFORMANCE MEASURES ARE CAPTURING KNOWN CONGESTION

Reasonableness, or common sense, checks are required throughout your data analysis. You will likely be monitoring facilities with known mobility problem areas. Review the results from a critical perspective. Are the mobility monitoring results showing your known congested intersection, or closely spaced series of intersections, in a congested state? Do the delays or traffic volumes seem reasonable? If not, you will need to check your analysis or confirm the data were collected correctly. Radar charts, like the one in Figure 16, enable you to confirm both intensity and duration of congested conditions from your travel time information. In this example, you are looking for data to radiate out from the center of the chart. These "spikes" represent large decreases in mobility. The largest spike in Figure 16 occurs in the 5:00 p.m. time frame, which matches with the local afternoon peak travel conditions.

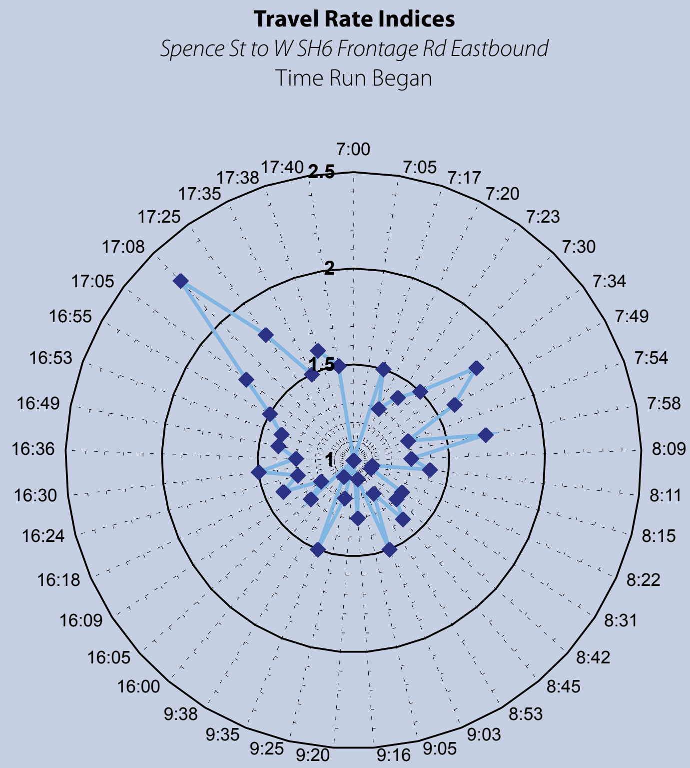


Figure 16. Use of radar charts to confirm mobility conditions with travel rate index values.

You may wish to check that the monitoring time periods include times when mobility is affected, and your system is operating at peak conditions. For many small and medium-sized communities, the peak periods when mobility is affected most are much narrower than for large urban cities. For this reason, exercise care so that measurements are taken before and after your peak demands are expected.

N.G. Neer
Director,
Public Works
Department

APPLICATION TO FENDER FALLS CASE STUDY

Within Fender Falls, the monitoring process measured traffic volumes and roadway travel times. The data were processed under the supervision the Public Works Director, N.G. Neer. When the community targets were established, they identified initial volume targets at 50 percent of the roadway capacity.

Figure 17 shows the directional volumes through the typical work day on Alternator Avenue west of the A Street intersection. The traffic demand is highest in the westbound direction in the morning period, reversing demand in the afternoon. Notice that the director included the amount of the workday that is at or exceeds the 50 percent working day capacity in the supplemental data area on the right side of the chart. N.G. Neer also reports how many locations exceed this target this year and expects to report changes from previous years in the future. Also reported are the durations this year and expectation to report changes from previous years in the future. These tools help the director identify if mobility is worsening throughout the community at more locations and if the demand is beginning to create longer peak demand periods.

At the same location, Fender Falls also overlays the measured speeds on the volume graph, shown in Figure 18. Because the general public may relate better to speeds, this graphic helps to convey the speed-flow-density relationship to a nontechnical audience.

Director Neer produces graphics to relate traffic volume measurements within the roadway. Current year daily traffic is shown in Figure 19. Traffic count locations are shown in relation to major cross streets on the roadway. The figure also separates out volumes by direction of travel. The graphic is kept relatively simple – no repeating axis values on each graph. Keeping the graphic simple directs the reader's attention to the data and is less distracting.

Fender Falls' historical traffic volumes along Alternator Avenue are displayed in Figure 20. N.G. Neer leverages data collected by the state department of transportation, and the historical traffic volumes shown in this figure use that leveraged data. The state performed annual counts on each end of Alternator Avenue. For the count locations between the ends, the state counts those locations every five years. It is acceptable to show gaps in your data, as Director Neer does here. You can still identify trends with data gaps; however trends are more evident and stronger conclusions are made when the data gaps are filled.

Because Fender Falls is a growing medium-sized community, Director Neer develops regional traffic flow diagrams to communicate the results of the mobility monitoring. An example of a diagram is shown in Figure 21. Community maps like these convey a larger geographical picture of data to the viewer than more detailed data can deliver.

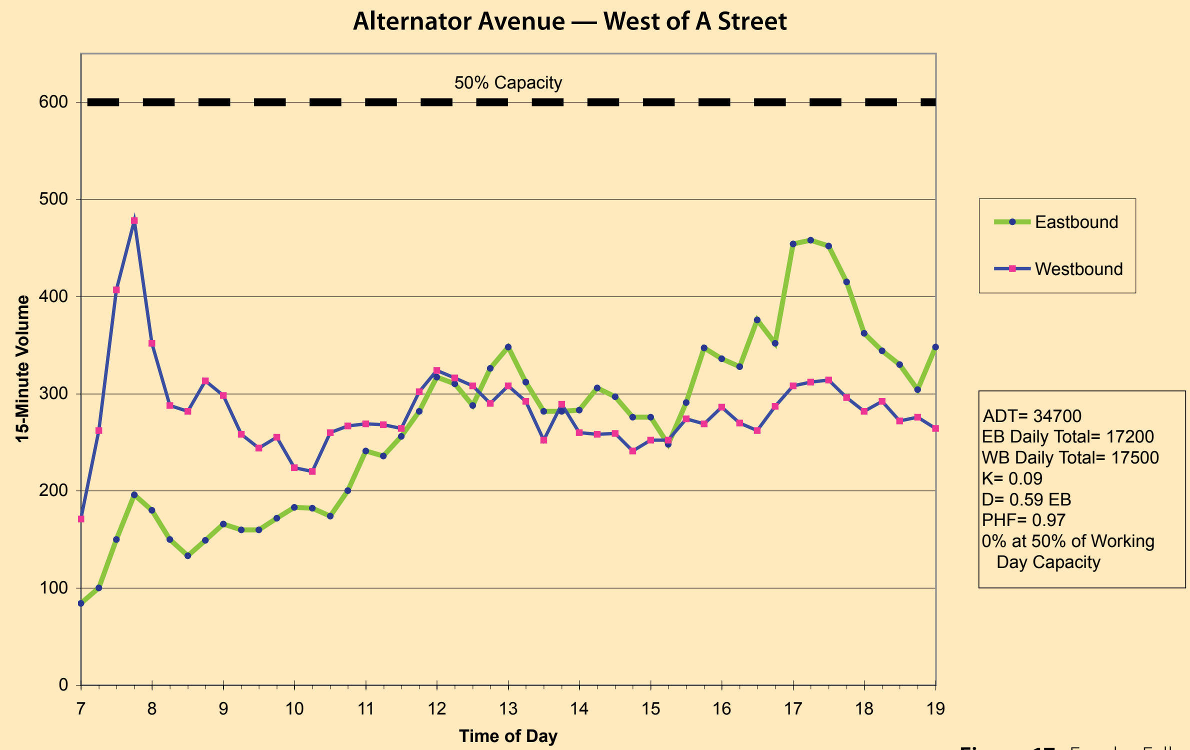


Figure 17. Fender Falls example for directional volume.

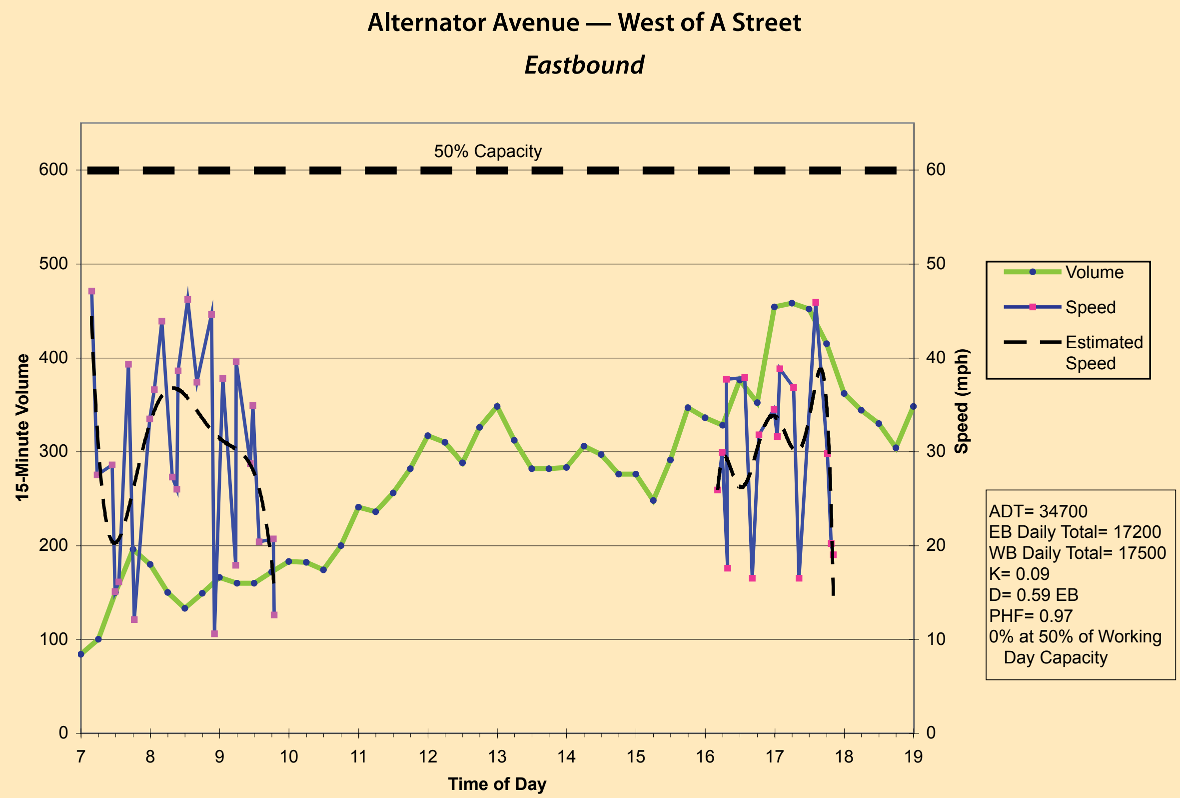


Figure 18. Fender Falls example for speed-volume reporting.

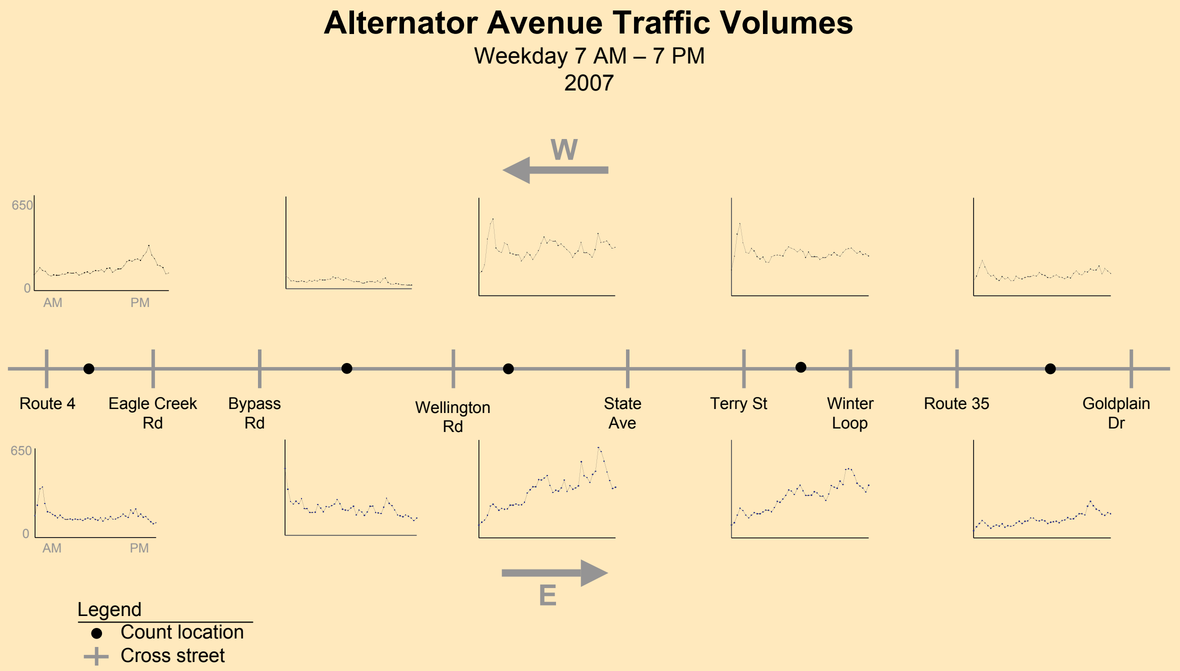


Figure 19. Fender Falls example for roadway current daily traffic volumes.

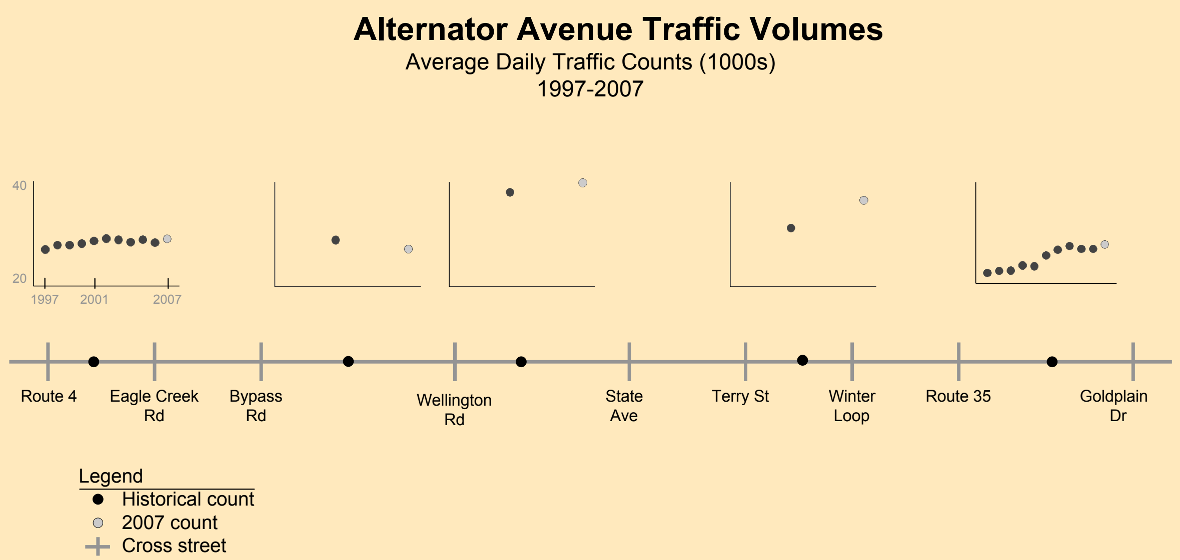
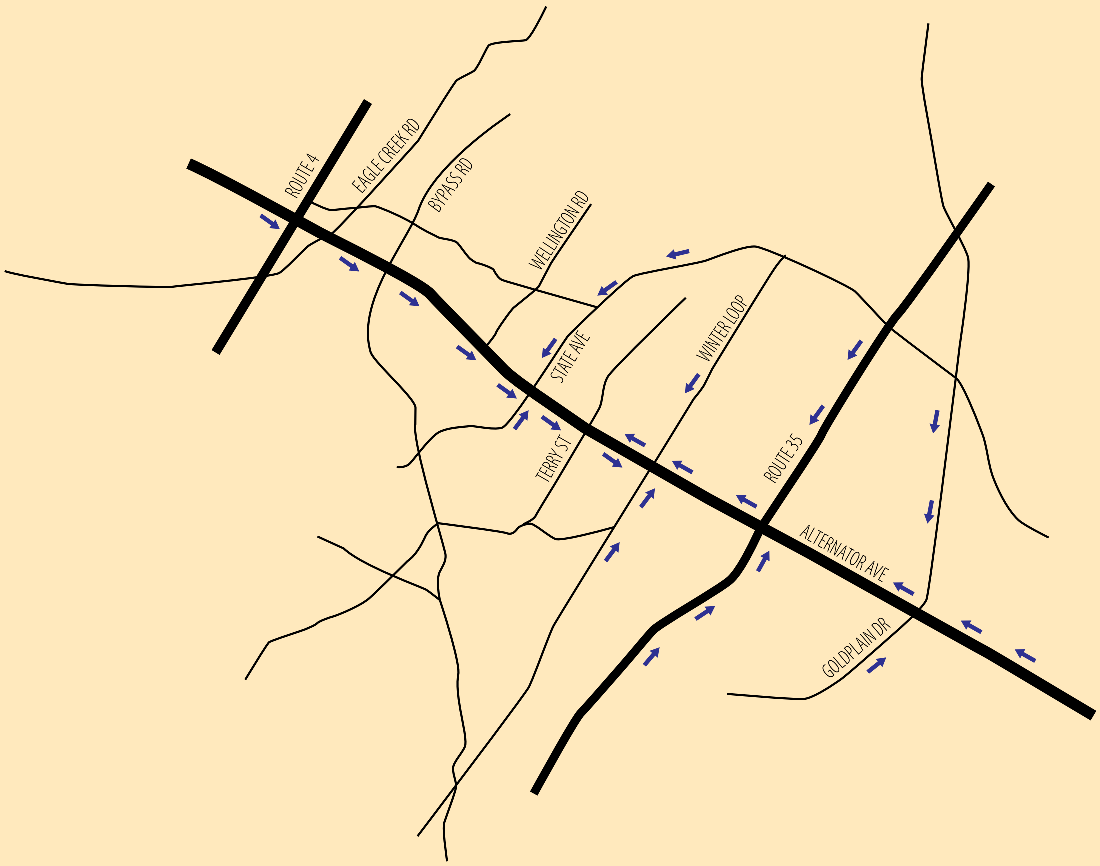


Figure 20. Fender Falls example for roadway volume trends.



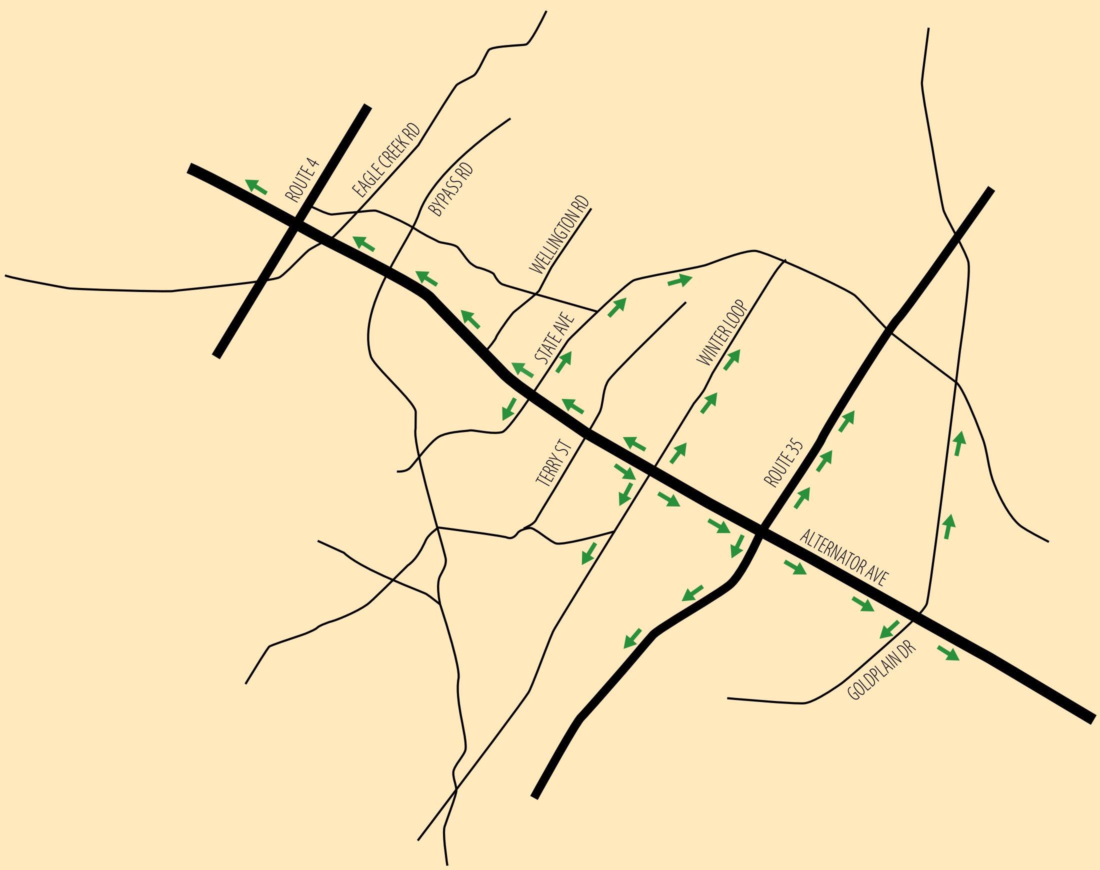
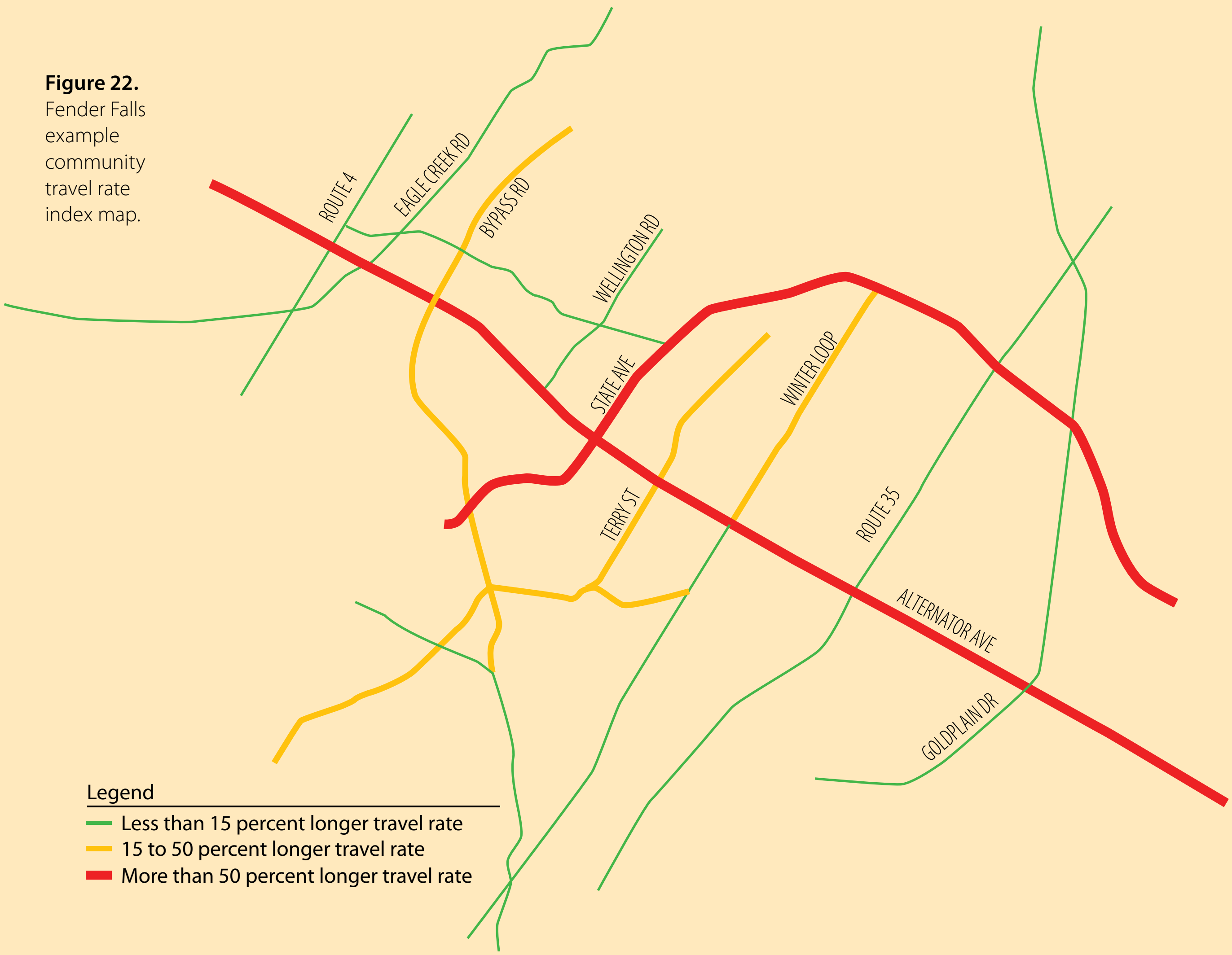


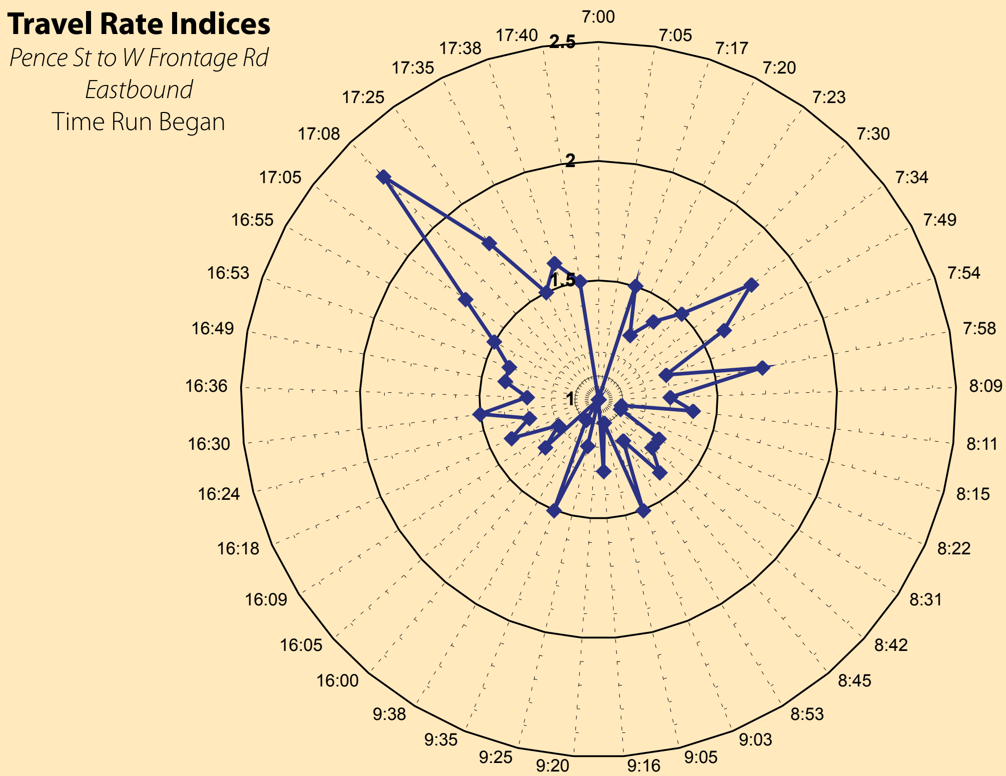
Figure 21. Fender Falls example AM (top) and PM traffic flow.

Figure 22. Fender Falls example community travel rate index map.



Fender Falls produces a community map for travel rates measured on its major roadways. The map is shown in Figure 22. The use of color and line weight help to direct the viewer's attention to problem areas within the community. The green roadways were measured with acceptable mobility. Mobility measured in the red roadways exceeded the community targets defined in Step 1.

Director Neer uses radar charts, as shown in Figure 23, with travel rate index results to direct focus to measurements that appear extreme. Using local knowledge of congestion conditions, the director verifies when and where congestion is occurring, thereby validating that the data collection results are reasonable. The director's assessment is that the data were collected and analyzed properly.



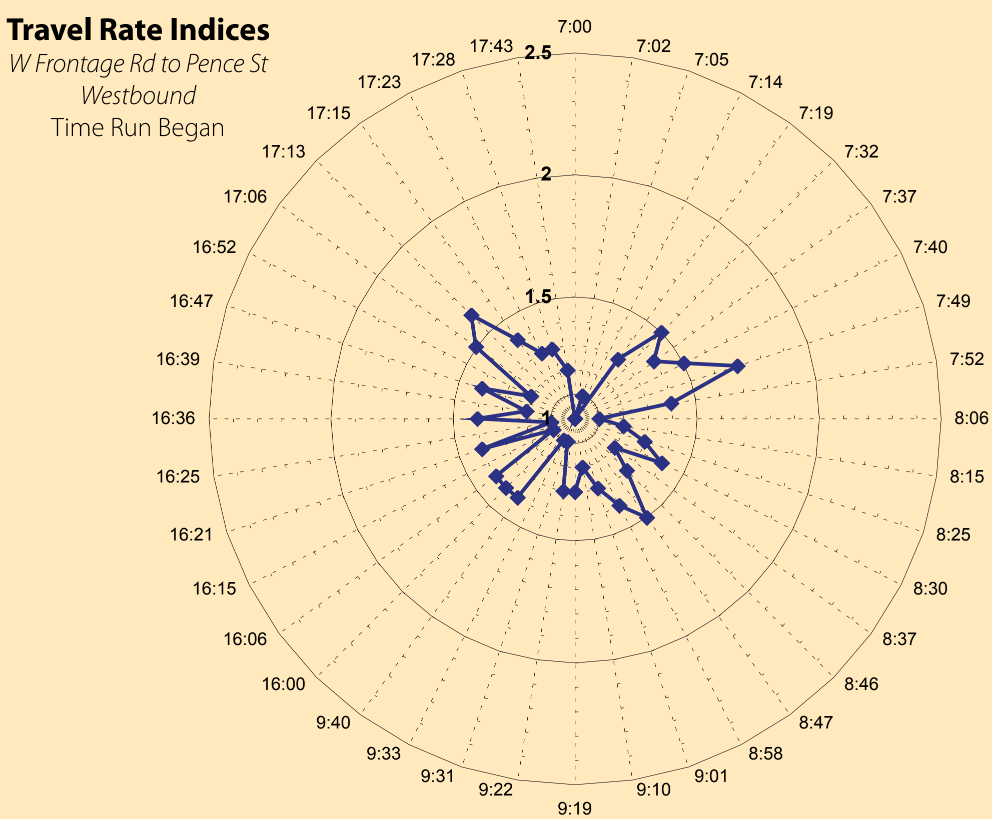


Figure 23. Fender Falls example travel rate index radar charts used for quality control.

Step 5: Package and Distribute the Results

STEP OBJECTIVE: To present the results of the mobility monitoring program in a manner that speaks to several audiences – technical, elected officials, and the general public.

DEVELOP EFFECTIVE GRAPHICS DISPLAYING PERFORMANCE

You've heard the saying "A picture is worth a thousand words." Well, the rest of that should include that a picture can tell a better story to relate intensity, distance, and time relationships than an intimidating table full of values.

It takes a great deal of time, and trial and error, to develop a meaningful graphic that conveys just the right amount of information in a manner that is easy to understand. As a technical professional, you may not be in tune with the creative half of your brain. So this work can be frustrating and cumbersome.

But with some patience and strength to draw on your creative side, you will be able to develop graphics that convey the power of your data. Several examples of graphics are presented here. These are starting points for you and are not meant to be the one-and-only graphic format for conveying your results to your stakeholders. Always keep your audience in mind when preparing any supporting graphic. Consider what they want to know, how they want to see it, and to whom they may pass it.

Maps

Use map-type graphics when possible. Stakeholders relate easily to their physical environments. Choose an appropriate scale where the area and its context are large enough to orient the reader, while balanced against the need to show enough detail.

Consider the needs of the viewer when preparing your maps. Consider what you want viewers to see and what visual information you need to provide so they can orient themselves. Avoid extraneous information on the map. Include only the information that is meaningful to the purpose of the data.

Tables

Data tables serve a valuable purpose. Tables should be able to stand alone, be concise, and use simple but clear labels and titles. You should use graphic aids like lines, shading, or spacing to separate data groups. These graphic aids should be used both horizontally and vertically in the table. Separating data groups helps the reader understand where data categories change.

Use consistent table formats in your documents with a font that differs from document text. The best fonts for document text are those that have serifs (the embellishments to the letters that lead the eyes to the next letter or word). Examples are Times New Roman or Garamond. Data tables are best displayed in a sans serif font (a font that has no embellishments). Examples are Arial or Helvetica. Use a leading zero for data between zero and one (0.97 vs. .97). Use decimal alignment in columns to clearly convey magnitudes to the reader.

Finally, you should include only the appropriate number of significant digits in the data. Currently available tools are capable of reporting calculated data results out to many decimal places. Your calculated results are only as precise as your least accurate input parameter. Reporting with more significant digits than your least accurate data input is a misstatement of the data.

Density Plots

The density plots shown in Figure 24 through Figure 26 provide readers with a sense of congestion intensity along the roadway and through time. Figure 24 is a basic representation. This density plot compresses all of the data together so that each observation (ending cross-street run time) is weighted equally in terms of plot area. Time is read from left to right in accordance with natural reading tendencies. Likewise, movement along the roadway is conveyed as the reader scans down the graphic. Note that the direction of travel is also indicated to confirm the reader's sense of movement along the roadway. Increasing congestion, or higher travel rate index values, is color coded through the use of either more intense color saturation or more intense color choices. In this example, decreased mobility can be seen to become more common through time over the afternoon peak period and geographically from midway through to the end of the roadway.

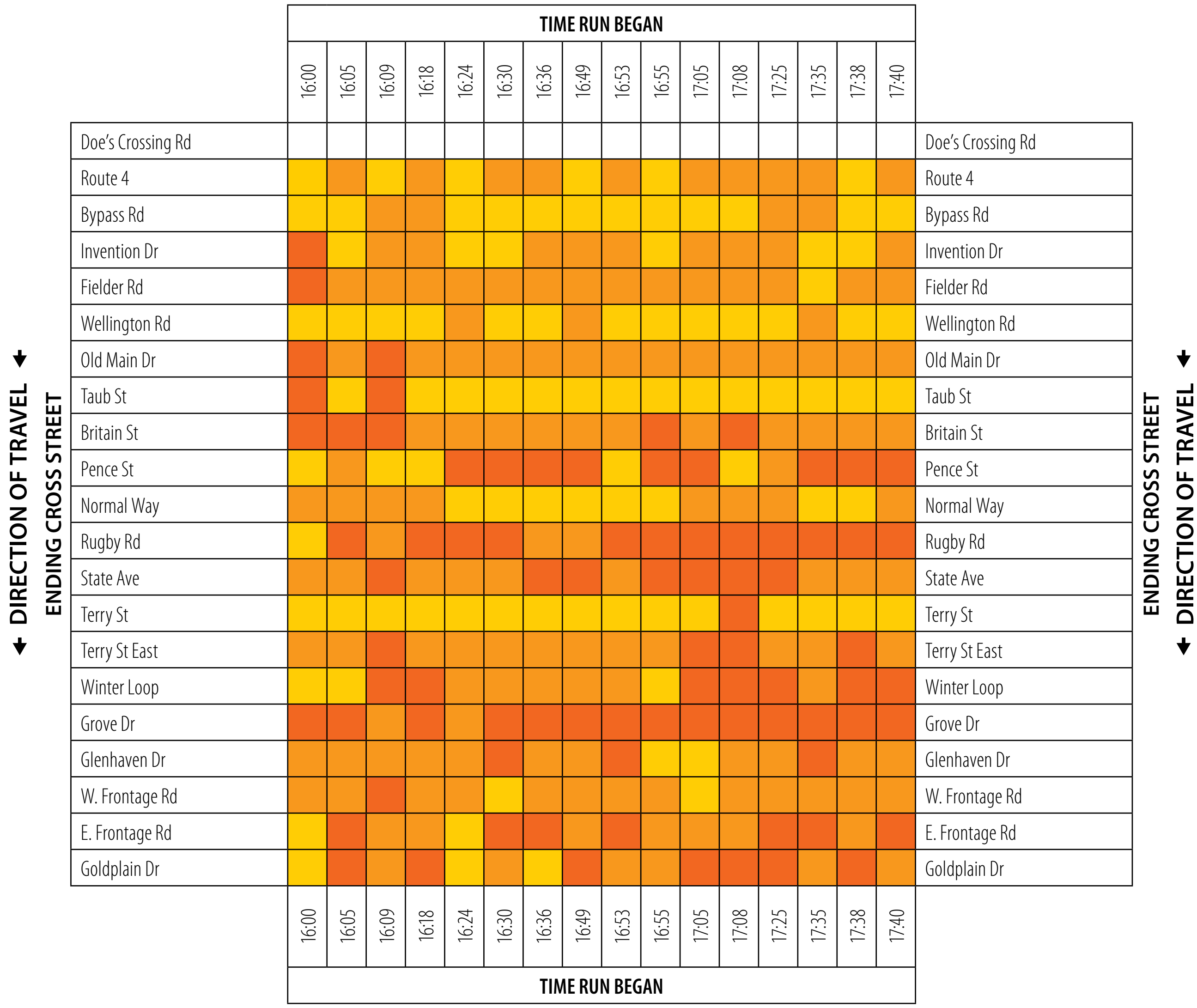


Figure 24. Color density plot of travel rate index measurements.

A second density plot, shown in Figure 25, provides the reader more information by adding blank rows for times (in this case at 5-minute intervals) where data were not collected. This graphic switches column and row headers to show movement along the roadway in a left-to-right configuration. Time is shown as an upward movement, forcing the reader to begin at the bottom of the graphic and work up through the visual data.

Finally, Figure 26 displays the last density plot in this progressive series. This figure builds upon the previous figure by relating the length of the individual roadway segments. This graphic succeeds relating congestion intensity and duration over a spatial representation. For instance, travel rate index values near the center of the roadway are intense over short links.

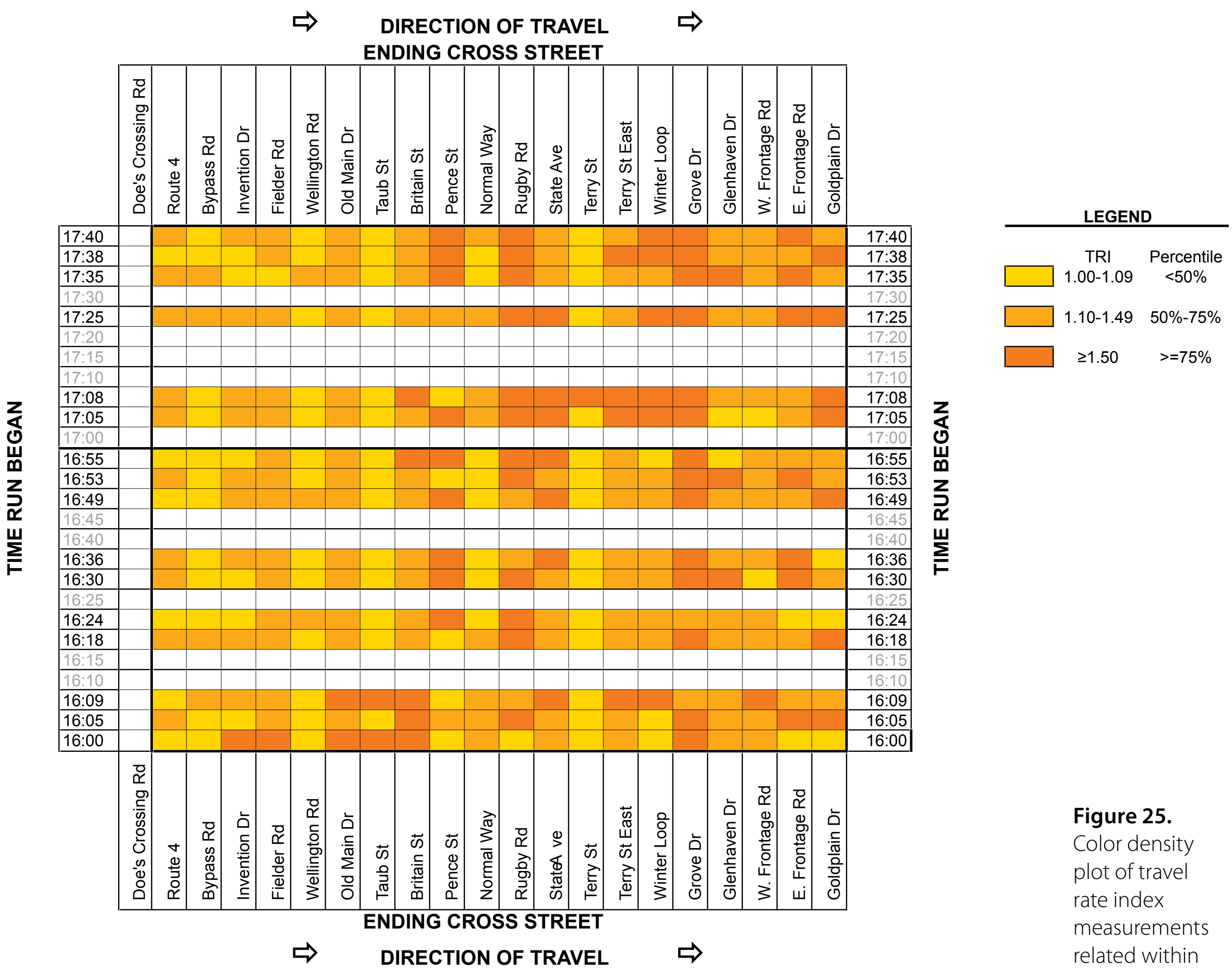


Figure 25. Color density plot of travel rate index measurements related within the time period.

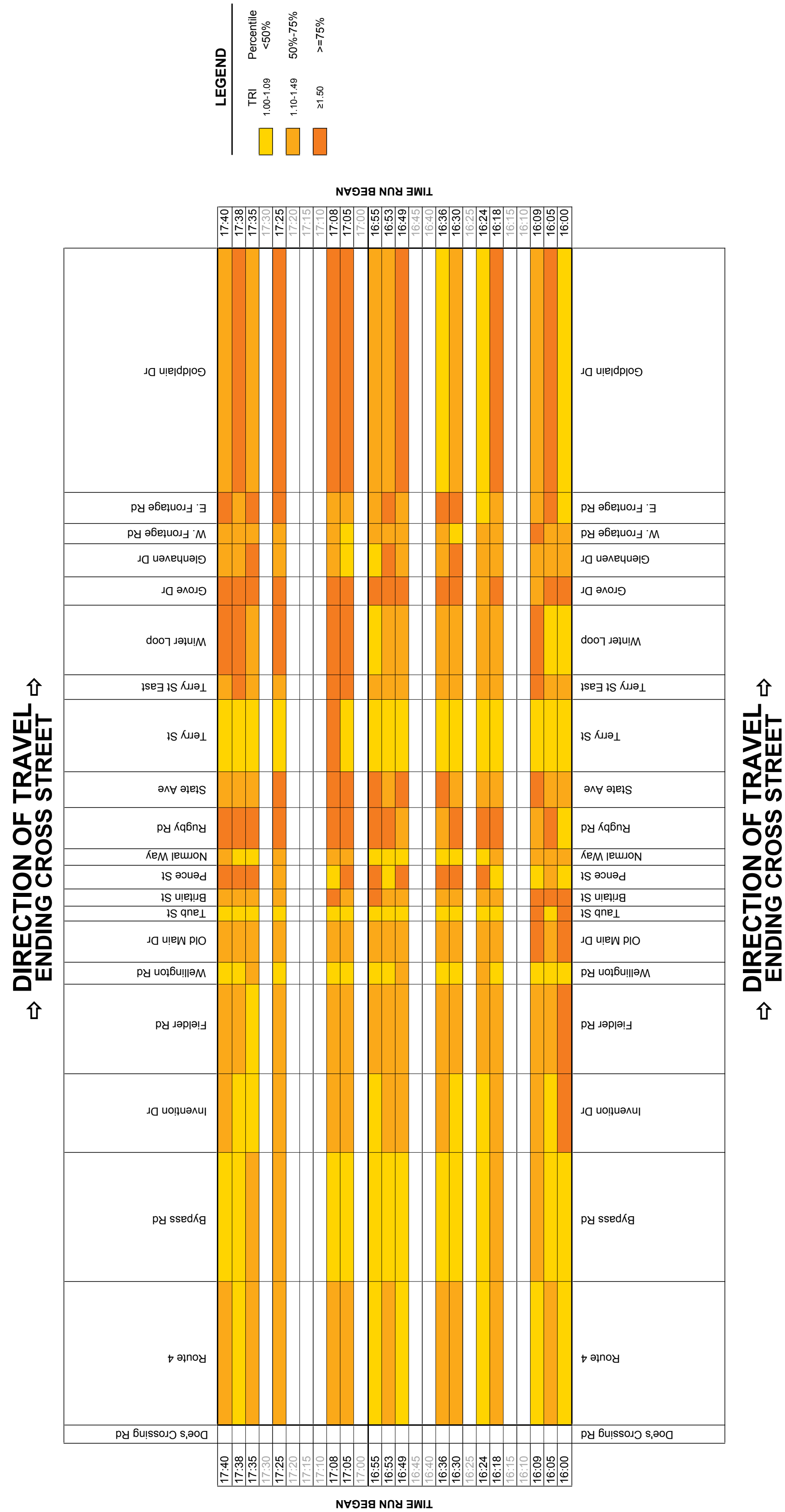


Figure 26. Color density plot of travel rate index measurements relating to time and roadway length.

Visualization Techniques

Visualization techniques are effective means to convey information to the public. Figure 27 is an interesting graphic developed to relate vehicle density in a 3-dimensional context (grass, shoulder and pavement, white dots for vehicles, sky) with the density functions hovering above. The technical professional would be able to interpret the standalone density function, but the general public may have a difficult time. The example is able to relate a technical issue in a nontechnical manner. Bringing the physical "sense" of the roadway operation can make an immediate connection with the viewer, allowing them to relate to the information easily.

Scale Plots

The traveling public easily relates to how long it takes for them to travel between two points. They use these times to base their decisions of when to travel for a reliable arrival time. Where travel times are not reliable, travelers add extra time, or buffer time, to their trips so that they will arrive at their destination on time.

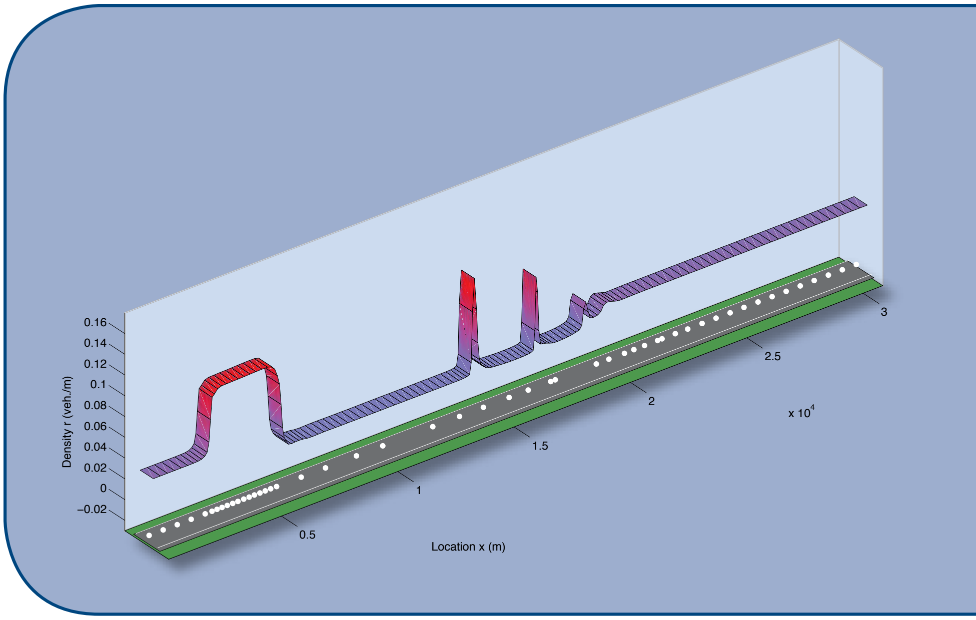


Figure 27. TraFlow$_{PACK}$ macroscopic traffic flow simulation software output. (See Interactive CD "Other Resources," Page 2 to see Figure 27 animated.)

Adapted from Reference 19

Where Figure 26 related congestion intensity through color changes, a scale plot of this same route relates to the viewer the actual distance traveled on the route over a fixed increment of time, or time interval. In Figure 28, the time interval is two minutes. The alternating color bands (white or blue) for each "Time Run Began" relate where on the route the driver was located in every 2-minute interval. The figure shows that travelers in the 5 PM rush hour have difficulties progressing through the Terry St East and Winter Loop link taking about 2 minutes to traverse this distance. Outside of the highest peak demand, travelers at Terry St East can typically cover greater distance to reach either W Frontage Rd or E Frontage Rd in the same 2 minutes.

Use of Color and Scale

Use of color in your graphics makes them more visually appealing to readers. You likely were trained to develop your graphics for black-and-white reproduction. This is important when you know your results will be shown in a grayscale format. However, many applications you will create these graphics for — workshops, presentations, brochures — are more likely to use color.

Carefully select your scale. Time-based scales can either highlight acute, short-duration events or can dampen them so that they appear less severe. Distance-based scales should be used to relate spatial concepts.

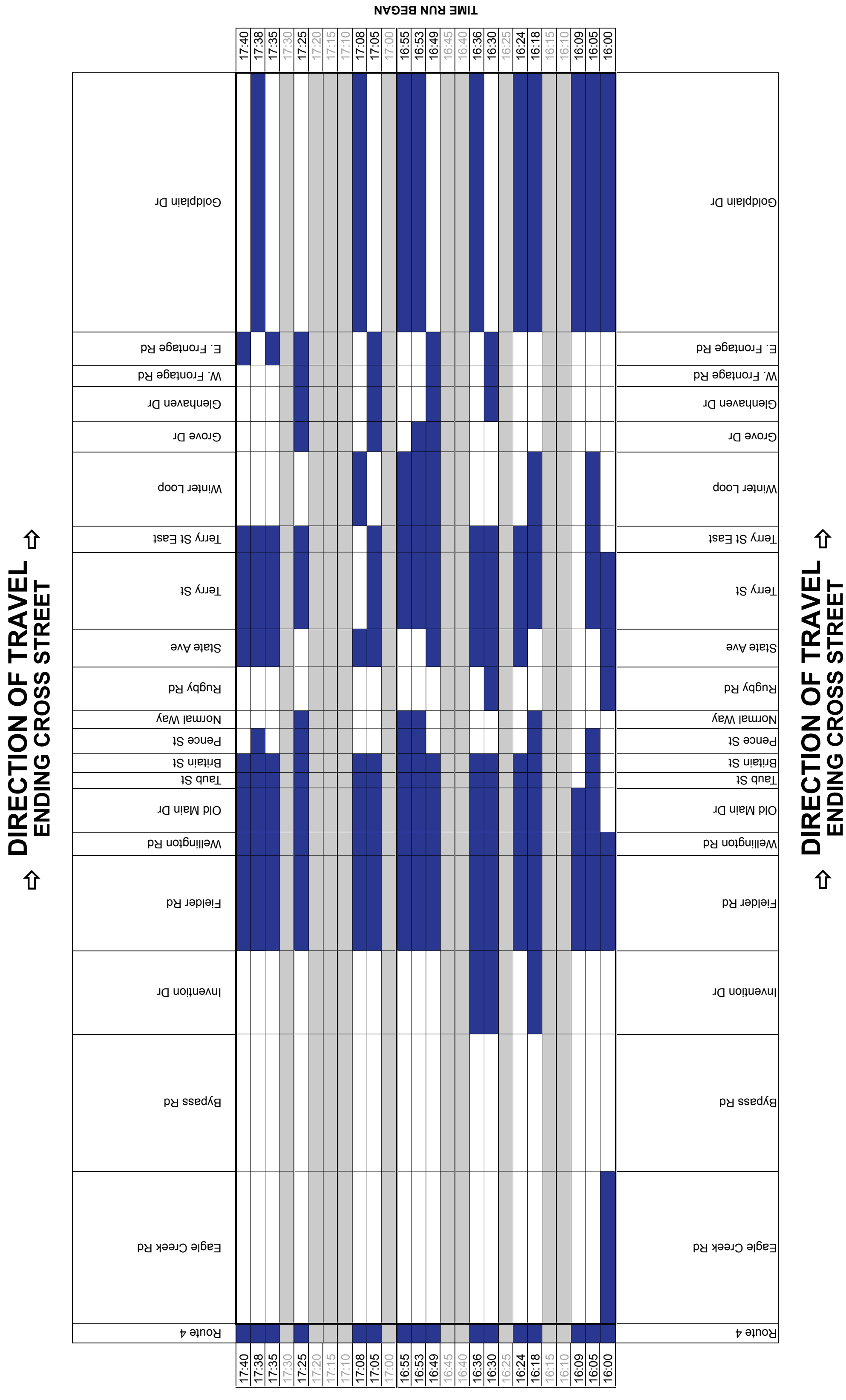
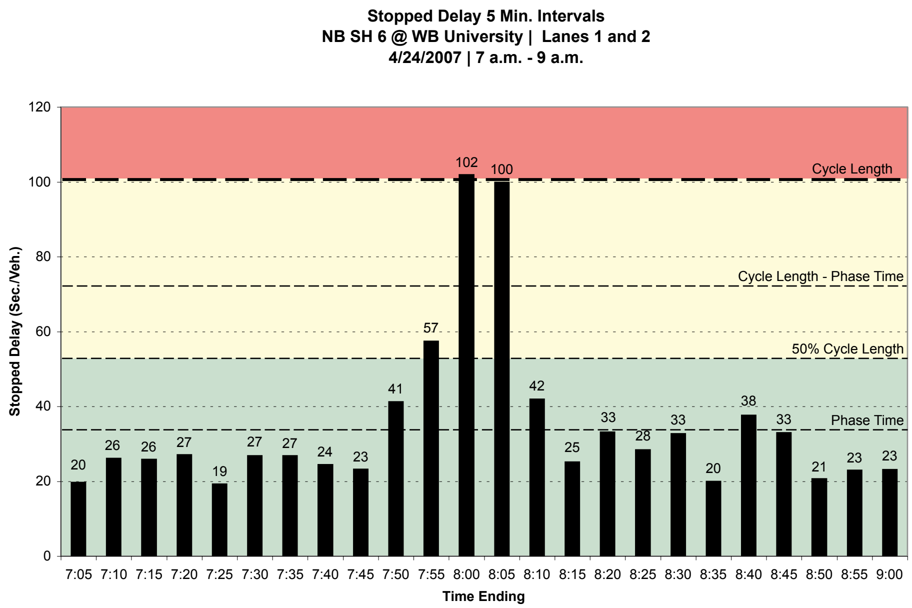
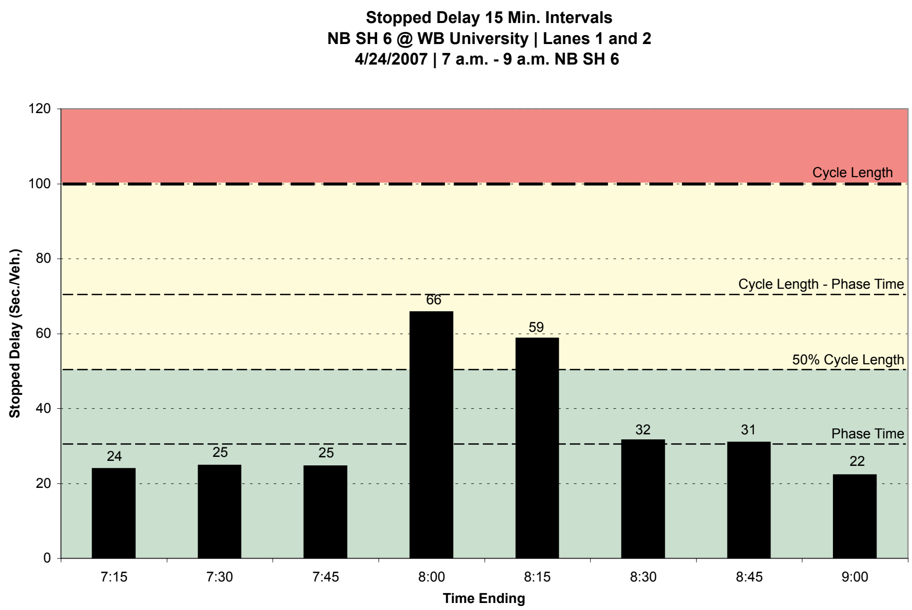


Figure 28.
Scale plot of travel rates.

In conveying stopped delay at intersections, Figure 29 uses color to relate delay intensity and contrast time scales. Use of color here relates the measured delay to the signal cycle length, which is a tangible quantity for the reader or driver. The green section of the graph indicates acceptable operation. The yellow area begins at the first target value, defined here as half of the cycle length. Finally, the critical area shown in red indicates when the average stopped delay exceeds the cycle length. This means that a vehicle must wait to be processed through the intersection on the second cycle after its arrival in the queue.

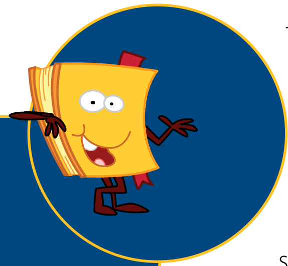


a) 5-minute intervals



b) 15-minute intervals

Figure 29. Use of color and scale for stopped delay study results.



Now that your data are analyzed and you are packaging the results, you will identify problem areas that either do not meet your community's mobility targets or are nearing or crossing some performance thresholds that may need your attention in the near future.

The 5-minute interval time scale provides the reader with a sense of quickly rising and falling intensity (5 minutes each) and the short duration (10 minutes). In contrast, the 15-minute interval time scale does not convey the same loss of mobility as shown in the 5-minute interval. It shows instead a low or moderate loss of mobility over a 30-minute period.

Link-based Measurements

Figure 30 is an example of a link-based travel rate index for a roadway that provides several packets of information. First, along the bottom or x-axis, the reader understands the physical aspects of the roadway — its width, distance between cross streets, traffic signal density, and land uses that may impact travel along the roadway. The blue and red lines relate the travel rates. The thick red line conveys the worst mobility conditions measured. The thinner blue line indicates the median observation, where half of the data experienced higher or lower travel rates. Finally, the summary box on the right side provides the reader with travel rate index values for a few long segments along the roadway. The y-axis scale is relatively larger than the data within the chart. The scale was lengthened to provide a level comparison for data in other time periods that approached an index level of 12.0.

Some specialty, commercially available software is able to translate data, like that collected from travel time runs, into several pre-formatted chart types. Figure 31 displays chart output generated from PC-Travel. The speed profile is the average speed traced through this example roadway beginning and ending at the roadway end points (page 72). The chart is able to relate accelerations and decelerations along the roadway. The time-space diagram is able to display the trajectory for each individual travel time run (page 73). Grouping of trajectories indicates very consistent operations. The reader is able to understand the variability in the data following trajectories down the page to the endpoint of the roadway.

Figure 32 shows another common method for presenting average link speed and travel time data along the same x-axis for a roadway. The thick red line presents average speed between links. The thin blue line with symbols indicates the average cumulative travel time along the roadway. Similar to Figure 30, the x-axis presents the number of lanes, cross streets, and signal locations.

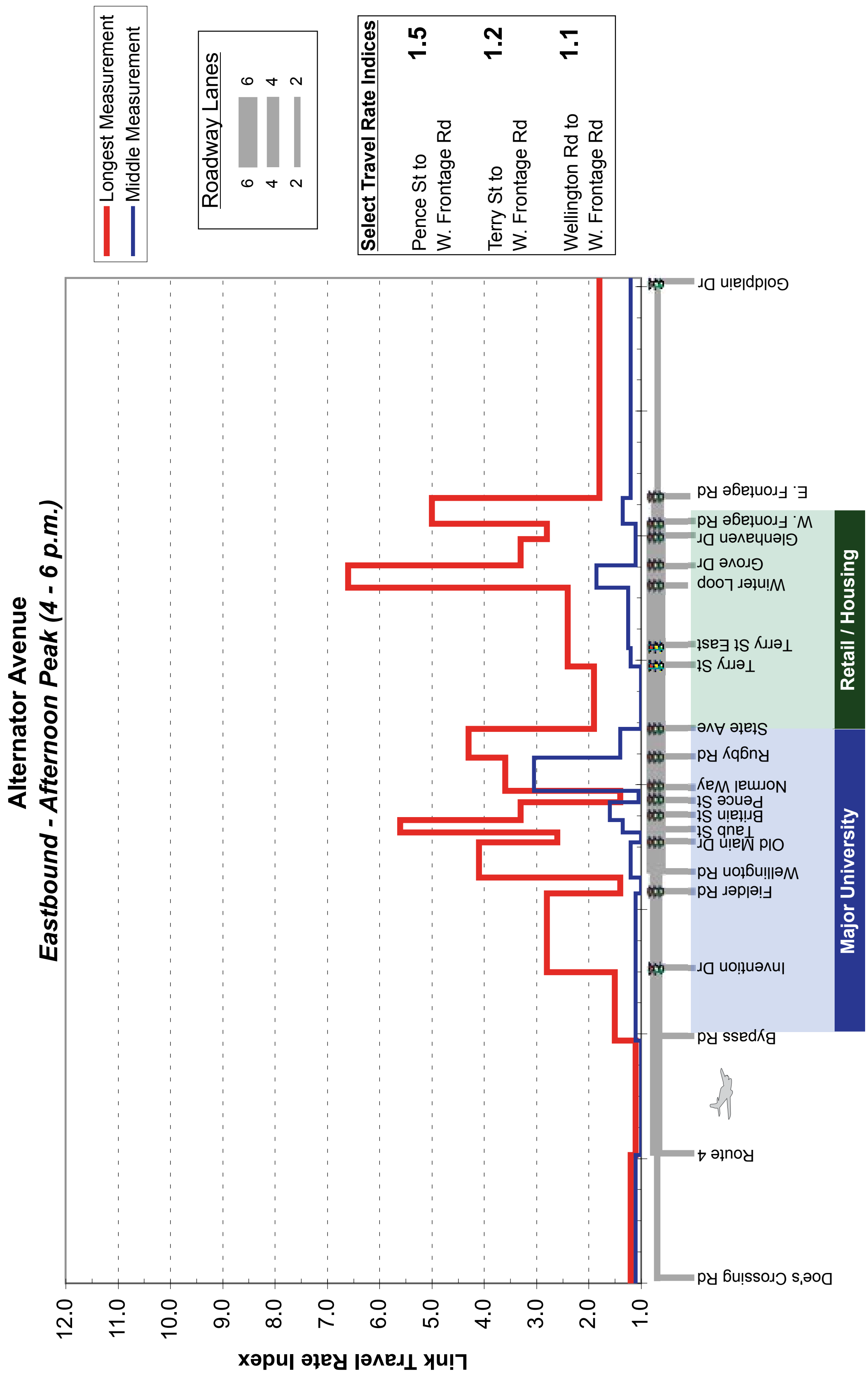


Figure 30. Chart of measurements on roadway links.

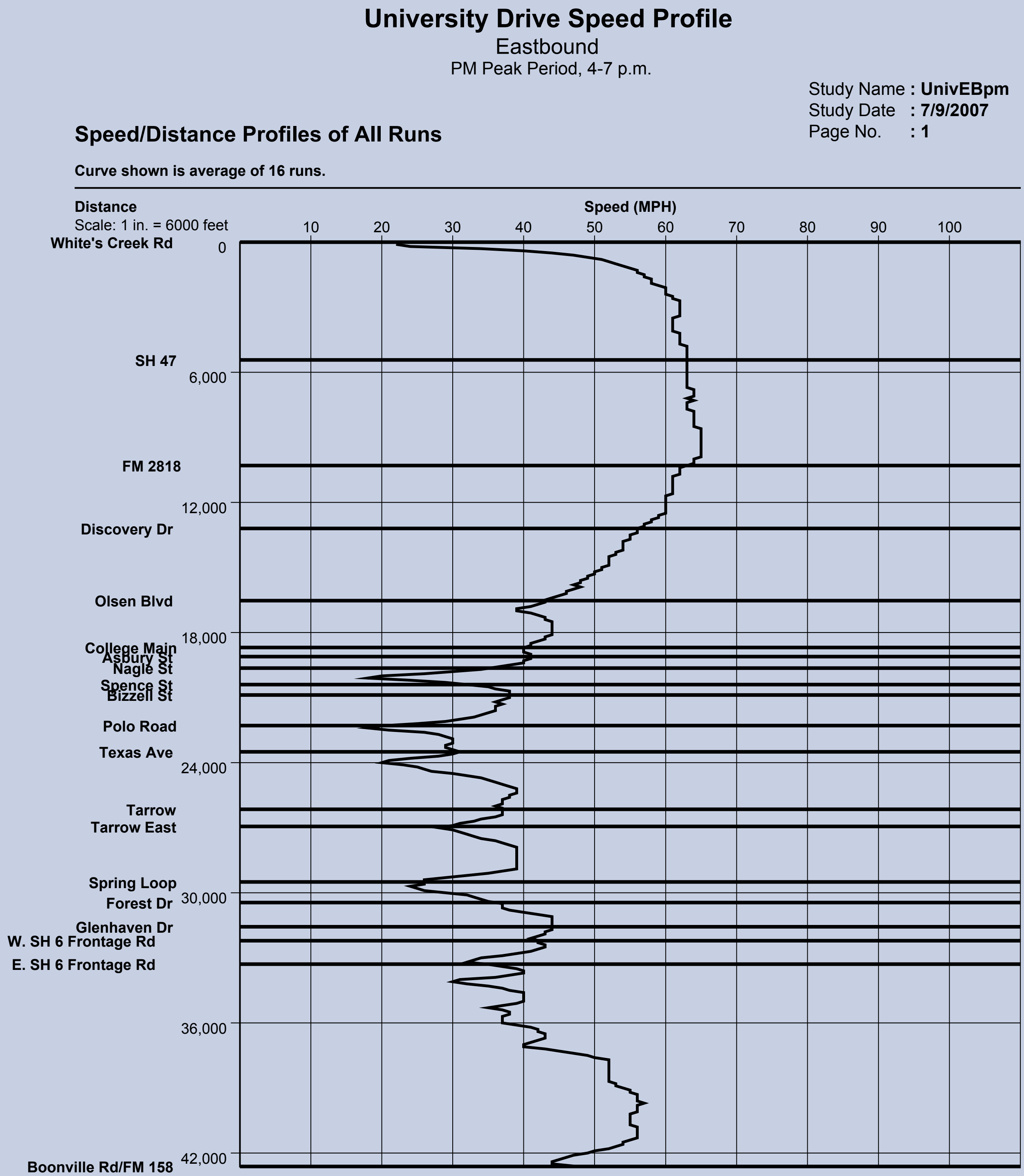


Figure 31.
Examples of two chart outputs available from PC-Travel.

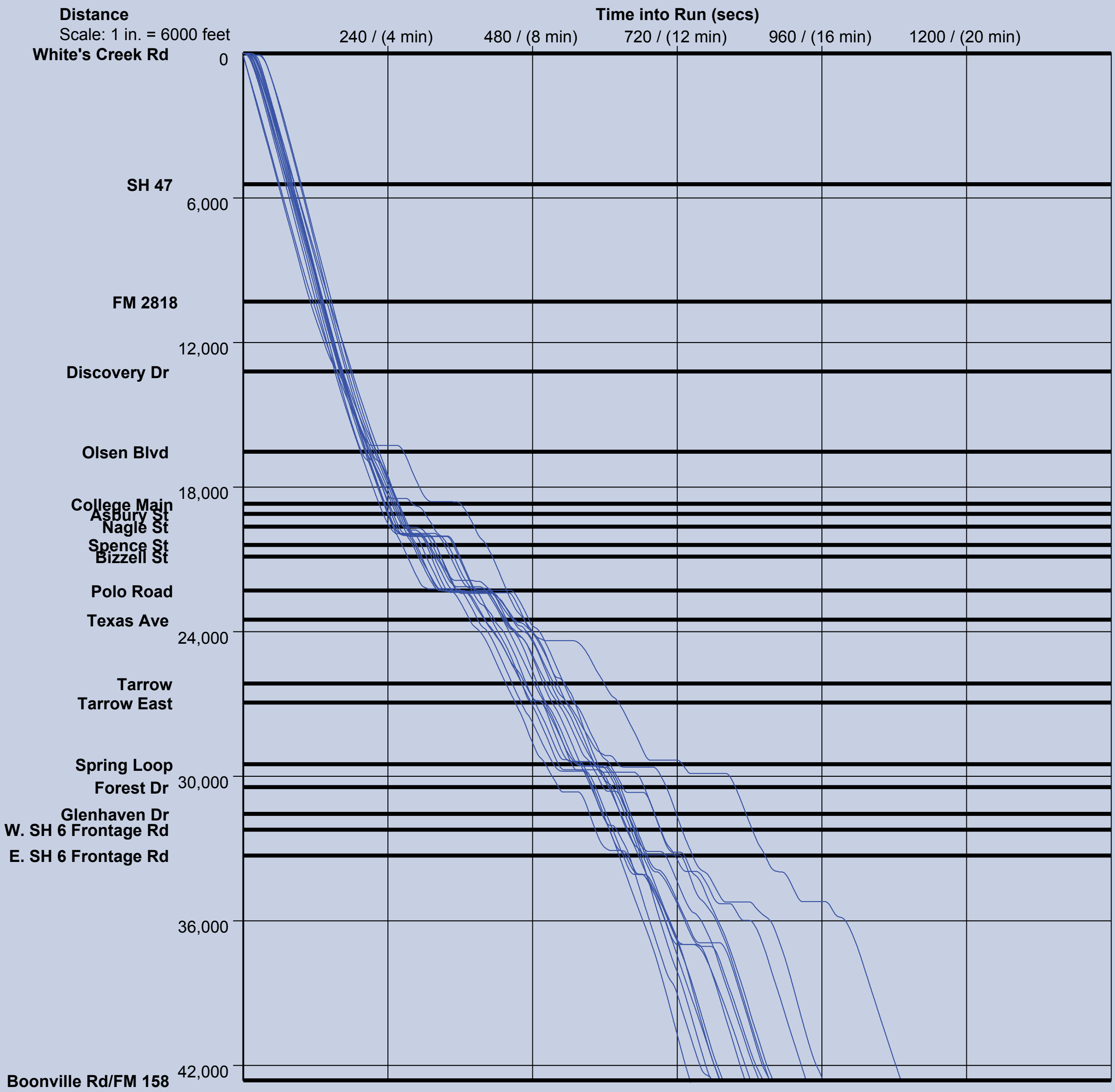
University Drive Time/Space Diagram

Eastbound

PM Peak Period, 4-7 p.m.

Study Name : **UnivEBpm**
Study Date : **7/9/2007**
Page No. : **1**

Time/Space Trajectories of All Runs



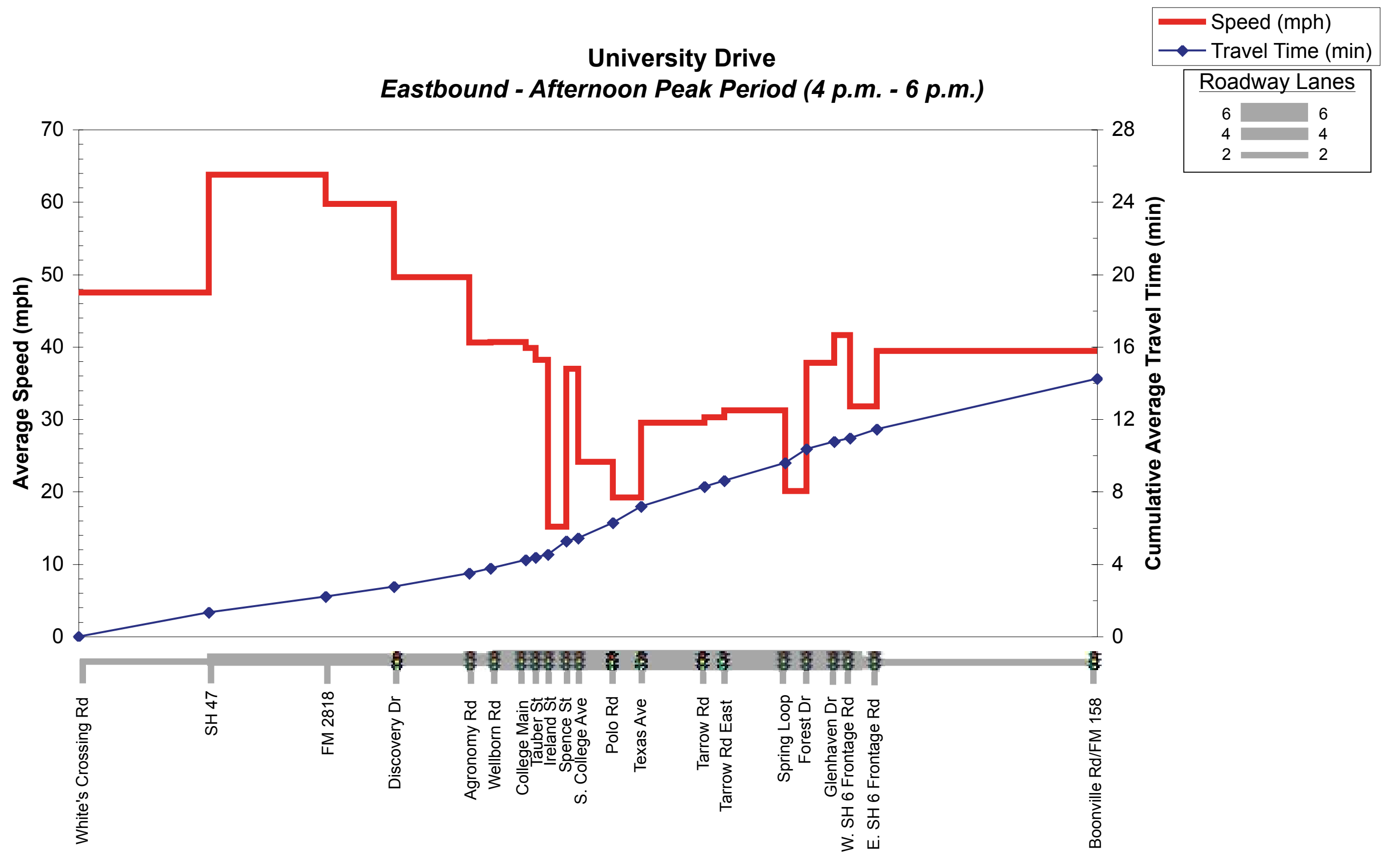


Figure 32. Illustration of average speed and cumulative average travel time.

DEVELOP MOBILITY IMPROVEMENT STRATEGIES AND ACTION PLAN

You identified potential improvement strategies in Step 1 that were agreeable to the community. Now that your data are analyzed and you are packaging the results, you will identify problem areas that either do not meet your community's mobility targets or are nearing or crossing some performance targets that may need your attention in the near future.

The public and elected officials will be most interested in mobility solutions after the problems are noted. Match the potential improvement strategies to the locations, problems, and time periods that require mobility solutions.

Supplement the solution set with your expectations through an action plan and discussion of potential funding sources. You should address questions like:

- How long will your solution take to implement once funding is secured?
- Does the solution require any construction and design preparation time?
- Does the solution require coordination with other government agencies like the state department of transportation?

- Are state or federal funds available to the project?
- What type of support is needed from your locally elected officials?

DOCUMENT AND DISTRIBUTE RESULTS

What are some tips for developing effective documentation?

The documents you produce initially to document your findings will likely be written for professional audiences, not for elected officials or the general public. To better connect with elected officials and the general public, craft your results into a story about the community where your readers live, work, and play. Here are some points to consider for more effective communication (adapted from *20*):

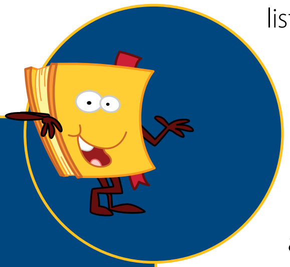
- **Tell a story:**
  - Use an outline for an organized document.
  - Explain the problem and why people should care.
  - Write in clear, simple language that your neighbor can understand.
  - Highlight the benefits of the monitoring process.
- **Engage the reader:**
  - Ask questions in document headings to better engage your readers.
  - Define key terms and avoid use of acronyms; spell out acronyms often to remind the reader what the acronym means.
  - Choose easy-to-read layouts that don't overwhelm the audience.
- **Make it visual:**
  - Invest time early in creating powerful graphic designs of your results.
  - Refrain from overusing tables of numbers when visual methods to convey the data would be more effective.
  - Use maps to explain the data and show physical relationships.
- **Make it brief:**
  - Keep the document brief by summarizing and referencing technical details.
  - Provide only relevant information.

After you've documented the results from your monitoring program, you are now ready to announce the results to the community.

How do I get the word out about my results?

Use a variety of tools to distribute your results. These tools can include summary reports directed to your elected officials or the general public. Summary reports should be very brief and use powerful graphics that are easy to interpret. In the summary reports, refer to the technical report for additional detail.

Consider making a presentation at a town hall meeting or local community service meeting. It is important that these presentations be developed for a nontechnical audience. Developing your presentation for a wide audience will better engage the listener and will allow you to better connect with them so your message is clearly received. Using a lot of technical language can easily shut down the listener's attention. For listeners that approach you after the presentation and seek more information, gauge the conversation for appropriateness of technical language.



Community workshops are another method for distributing your results. They can also be used as a tool to strengthen community support and help you identify potential improvements to your monitoring process. Usually, workshop participants are made up of active and interested community members. These participants are not likely to hold back opinions, so when responding, realize that their suggestions and statements may well lead you to a better process.

Take the time to report on what possible solutions may be used to make mobility improvements and when those improvements might be completed.

PRODUCE PRESS RELEASE OF FINDINGS

At the beginning of this mobility monitoring process, you defined measurable outcomes or performance measures. Now is the time to push your message out to your community.

This is where you and your public information officer will work together as a team. You don't have to be the expert on how press releases are formatted or where and how they are sent out. You should be focused on:

- why the monitoring was performed;
- when it was conducted;
- what the results are;
- when monitoring will be conducted again; and
- what improvements are being pursued and where.

Report to your community how their mobility measures up to their established targets. You can report on how many locations or miles of roadways failed to meet community mobility targets. Take the time to report on what possible solutions may be used to make mobility improvements and when those improvements might be completed. If mobility enhancements were completed, report if they improved mobility and by how much.

In developing your press release, use principles similar to the recommendations given earlier in this guidebook for documenting your results. Again, these principles are:

- Tell a story (make your news compelling to the press).
- Engage the reader (everyone is an expert and has opinions; write simply and clearly).
- Make it visual (be prepared to provide graphics for print or broadcast media).
- Make it brief (this is an understatement for a press release).

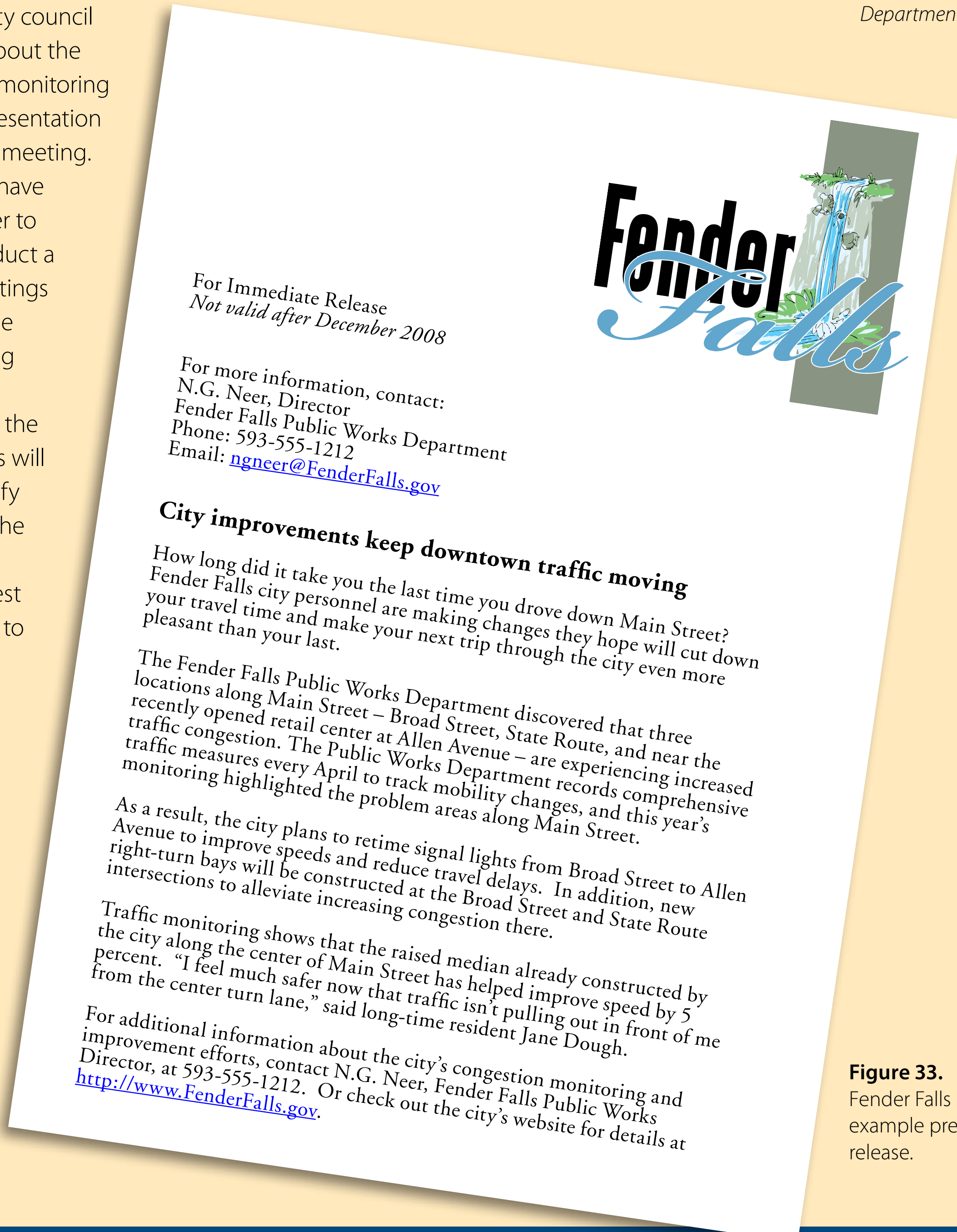
APPLICATION TO FENDER FALLS CASE STUDY

Director N.G. Neer has a productive working relationship with the city's public information officer, N. Pho. At the conclusion of the first mobility monitoring program, Neer and Pho worked to issue their press release to the hometown newspaper, the Fender Falls Record. The press release is shown in Figure 33.

Director Neer also coordinates with several local service organizations to speak at their monthly meetings. The director prepared a brief visual presentation to help accentuate results from the monitoring program and the city's proposed solutions.

N.G. Neer
Director, Public Works Department

The Fender Falls city council was enthusiastic about the success of its new monitoring program after a presentation at a recent council meeting. Council members have asked Director Neer to schedule and conduct a few town hall meetings on the results of the mobility monitoring program. The city council hopes that the town hall meetings will help the city identify improvements to the process and ways information can best be communicated to the public.



Fender Falls

For Immediate Release
Not valid after December 2008

For more information, contact:
N.G. Neer, Director
Fender Falls Public Works Department
Phone: 593-555-1212
Email: ngneer@FenderFalls.gov

City improvements keep downtown traffic moving

How long did it take you the last time you drove down Main Street? Fender Falls city personnel are making changes they hope will cut down your travel time and make your next trip through the city even more pleasant than your last.

The Fender Falls Public Works Department discovered that three locations along Main Street – Broad Street, State Route, and near the recently opened retail center at Allen Avenue – are experiencing increased traffic congestion. The Public Works Department records comprehensive traffic measures every April to track mobility changes, and this year's monitoring highlighted the problem areas along Main Street.

As a result, the city plans to retime signal lights from Broad Street to Allen Avenue to improve speeds and reduce travel delays. In addition, new right-turn bays will be constructed at the Broad Street and State Route intersections to alleviate increasing congestion there.

Traffic monitoring shows that the raised median already constructed by the city along the center of Main Street has helped improve speed by 5 percent. "I feel much safer now that traffic isn't pulling out in front of me from the center turn lane," said long-time resident Jane Dough.

For additional information about the city's congestion monitoring and improvement efforts, contact N.G. Neer, Fender Falls Public Works Director, at 593-555-1212. Or check out the city's website for details at http://www.FenderFalls.gov.

Figure 33.
Fender Falls example press release.

Step 6: Move Forward with Improvements and Continue Monitoring

STEP OBJECTIVE: To ensure that funding and other resources remain available for continued mobility monitoring to meet community needs.

PERFORM MONITORING ON A REGULAR BASIS

A successful mobility monitoring program requires continued measurement. One-time measurements will provide only a snapshot in time of the mobility conditions in your community. Mobility changes annually, with day of week and season of year. Depending on your community's needs, you may plan to monitor regionally each year, but conduct more frequent monitoring on your one or two most critical roadways.

Why is regular monitoring important?

The motivation for continued monitoring should be recorded in the monitoring plans outcomes/desires/objectives. Monitor your community's mobility at the frequency you identified in Step 2. For programs beginning a mobility monitoring process, an annual or bi-annual cycle with some limited, more frequent monitoring, like traffic volumes, may be an adequate starting point. As support for your mobility monitoring program grows from municipal or county leaders and the general community, you may seek to increase the monitoring frequency for greater feedback to these stakeholders.

How often should I monitor?

Monitoring frequencies greater than five years may not provide your community enough clarity regarding mobility changes. Lengthy frequencies may not assist you in detecting smaller changes in mobility resulting from population growth and economic development activities within your community. Such long gaps in monitoring may also reduce your ability to detect early warnings of decreasing mobility and, therefore, implement corrective actions.

Keep the question "What do we want the press release to say this year, next year, etc.?" in mind. If you desire to report your progress in improving mobility or to strengthen your case for needed resources to halt or turn back worsening mobility, continued monitoring is needed.

INCORPORATE IMPROVEMENTS TO THE MOBILITY MONITORING PROCESS

As you complete a monitoring cycle, reflect on the process to identify where improvements can be made. Identifying improvements as you work through the monitoring process may be more helpful so that time will not fade your thoughts. Seeking improvement is a method to provide feedback into the monitoring process.

The planning steps you took at the beginning of your monitoring process enabled you to establish a monitoring process flexible enough to include new locations, roadways, or time periods as they become important to your community. New economic development will spur increased vehicle activity where it occurs. During development review, seek to make roadway improvements that will lessen a development's impact on the transportation system. After construction, consider if any surrounding locations should be included in your monitoring process.

You may need to periodically extend the monitoring length on a roadway as new development begins to push toward your existing limits.

The monitoring process should support and interact with other planning and engineering efforts in your community. Adapt the monitoring process as your community's vision and goals change. When you make updates to your comprehensive plan, adapt your monitoring process to support measurement.

Changing leadership, professional staff, or elected officials is also a reason the monitoring process may change. New leadership may project performance measures in new or different perspectives.

Do I document improvements?

In all cases, you should document changes and improvements to your monitoring process. As you make comparisons to previous monitoring efforts, you will have to interpret the results – the processes may not be an exact "apples to apples" comparison. Process documentation is your key aid for interpreting your results. Was a change in monitoring methods a contributing factor to change? Did you add new locations or roadways to your monitoring network? Did you change the resolution (in terms of time increments) of your data collection? Did you select a new method for estimating your free-flow speeds? Answers to questions like these will certainly help you better understand your results.

N.G. Neer
Director,
Public Works
Department

APPLICATION TO FENDER FALLS CASE STUDY

Perform monitoring on a regular basis

Fender Falls had a very positive experience implementing its mobility monitoring process and was pleased with the results obtained from it. Director Neer received praise from the city council and Fender Falls citizens. As a result, Fender Falls, the county, state DOT, and MPO will continue to support the monitoring program on an annual basis. The financial stakeholders all agree that this frequent monitoring will allow them to detect and track changes to their mobility.

Incorporate improvements to the mobility monitoring process

Director Neer maintained notes throughout the first cycle of the Fender Falls monitoring process. The director shared these notes and other observations, recorded after some reflection, with the other transportation agencies. At a later meeting, the group collectively decided to make minor improvements to the monitoring plan:

- Lengthen the monitoring of two roadways beyond new retail development.
- Conduct stop delay studies at two or three major intersections each year on a three-year rotating basis.
- Coordinate with the local university to draw more data collection labor.
- Use the first mobility monitoring cycle spreadsheet structure as templates for the next cycle.
- Hold additional public workshops during both the planning and results phases.

Director Neer sees the results from the Fender Falls mobility monitoring supporting the Planning Department's update to the Comprehensive Plan within the next five years. Director Neer sought input from the planning director for the first monitoring cycle.

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