Traffic Congestion and Reliability: Linking Solutions to Problems

final report

prepared for

Federal Highway Administration

prepared by

Cambridge Systematics, Inc.

with

Texas Transportation Institute

July 19, 2004

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Executive Summary

The *Traffic Congestion and Reliability: Linking Solutions to Problems Report* provides a snapshot of congestion in the United States by summarizing recent trends in congestion, highlighting the role of unreliable travel times in the effects of congestion, and describing efforts to curb congestion. In particular, the *Report* develops a framework for understanding the various sources of congestion, the ways to address congestion by targeting these sources, and performance measures for monitoring trends in congestion.

Much of the *Report* is devoted to measuring recent trends in congestion. One of the key principles that the Federal Highway Administration (FHWA) has promoted is that the metrics used to track congestion should be based on the ***travel time experienced by users of the highway system.*** While the transportation profession has used many other types of metrics to measure congestion (such as "level of service"), travel time is a more direct measure of how congestion affects users. Travel time is understood by a wide variety of audiences – both technical and nontechnical – as a way to describe the performance of the highway system. All of the congestion metrics used in the *Report* are based on this concept.

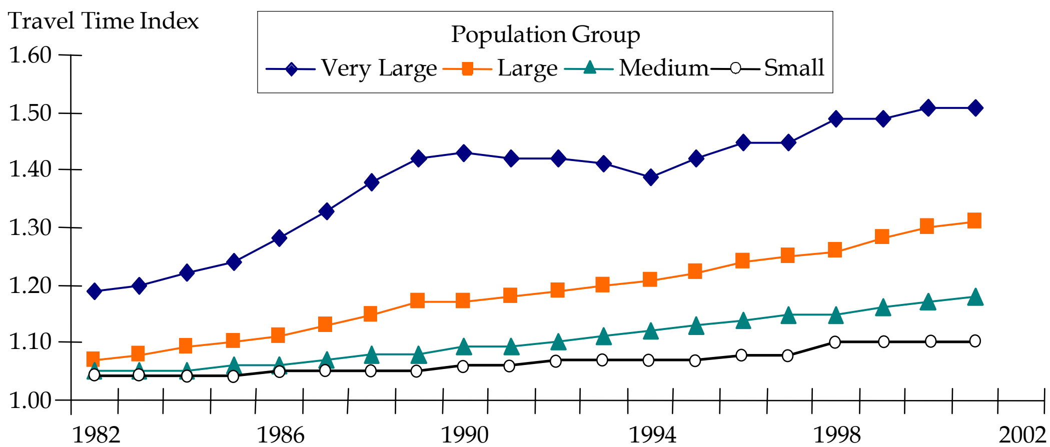
The different aspects of congestion are discussed using a variety of data sources, with perhaps the newest aspect being the role of reliability in the congestion problem. The variation in travel times is now understood as a separate component of public and business sector frustration with congestion problems. Average travel times have increased and the *Report* discusses ways to reduce them. But the day-to-day variations in travel conditions pose their own challenges and the problem requires a different set of solution strategies.

Trends in National Congestion

Is congestion getting worse? Yes. There are several statistics that point to worsening congestion levels. Congestion extends to more time of the day, more roads, affects more of the travel, and creates more extra travel time than in the past. And congestion levels have risen in cities of all sizes since 1982, indicating that even the smaller areas are not able to keep pace with rising demand.

Figure ES.1 illustrates trends for 75 major urban areas tracked in the Texas Transportation Institute's Annual Mobility Report.[1] Congestion levels have risen to levels experienced by the next largest population group every 10 years – in 2001, cities between 500,000 and one million people experienced the congestion of cities between one and three million in 1992.

Figure ES.1 Peak-Period Congestion (Travel Time Index) Trends by U.S. Population Group



Source: Reference (1). The Travel Time Index is a measure of the total amount of congestion. It is the ratio of the weekday peak-period travel time to the travel time under ideal conditions. A Travel Time Index value of 1.3 indicates that peak-period travel takes 30 percent longer than under ideal conditions. Population groups are: Very Large (greater than three million); Large (one to three million); Medium (500 thousand to one million); and Small (less than 500 thousand).

Congestion has clearly grown. Congestion used to mean it took longer to get to/from work in the "rush hour." But congestion now affects more trips, more hours of the day and more of the transportation system. Figure ES.2 shows the growth in several key dimensions of the congestion problem in cities of more than one million persons.

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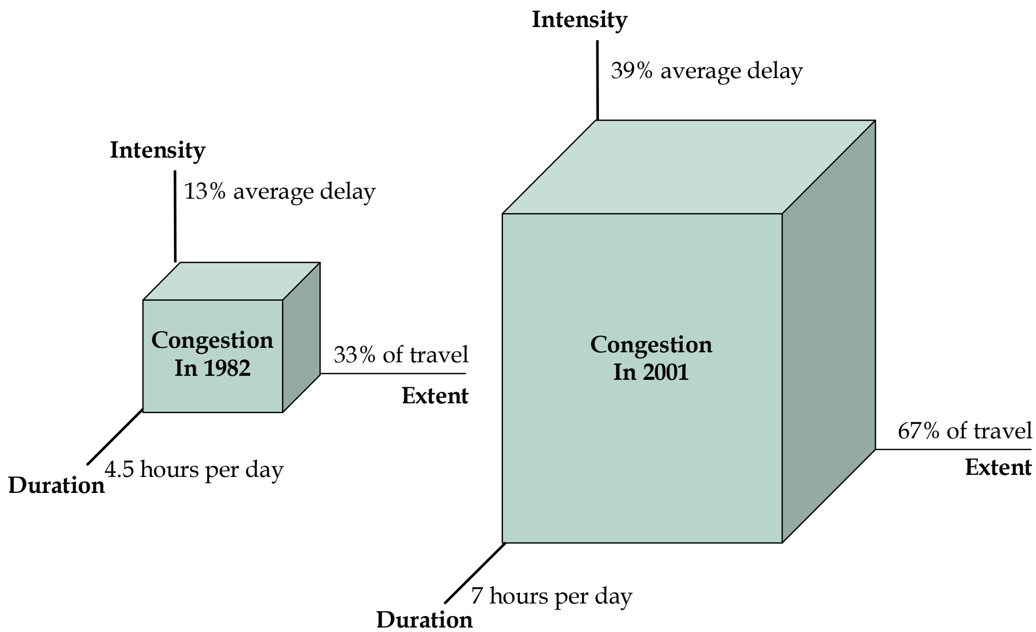
[1] Schrank, D. and Lomax, T., *2003 Annual Urban Mobility Report,* Texas Transportation Institute. This methodology measures congestion conditions on individual highway segments using roadway-based data. Alternate ways of measuring congestion exist, such as monitoring the travel times of entire trips with household surveys. One such survey, the National Household Travel Survey (NHTS) has been conducted periodically since 1969. Recent data from the NHTS suggest that commute times have not increased as fast compared to roadway-based congestion data, such as is used by the *Urban Mobility Report.* This may be due to people changing their residential and employment locations. The net result is that for individual travelers, congestion is probably not getting as worse as fast – highway segments may be more congested but the ability to move around the metropolitan landscape provides a "cushion" for some individuals.

- The average weekday peak-period trip takes almost 40 percent longer than the same trip in the middle of the day, compared to 13 percent longer in 1982.
- Sixty-seven percent of the peak-period travel is congested compared to 33 percent in 1982. Travelers in 75 urban areas spent 3.5 billion hours stuck in traffic in 2001, up from 0.72 billion in 1982.

Figure ES.2 Weekday Peak-Period Congestion Has Grown in Several Ways in the Past 20 Years in Our Largest Cities



Source: Analysis of data used in *2003 Annual Urban Mobility Report*, Texas Transportation Institute.

- Fifty-nine percent of the major road system is congested during peak hours compared to 34 percent in 1982.
- The number of hours of the day when weekday travelers might encounter congestion has grown from 4.5 hours to 7 hours.

These are just the average conditions. Many cities have a few places where any daylight hour might see "stop-and-go" traffic. Weekend traffic delays have become a problem in recreational areas, near major shopping centers or sports arenas, and on some constrained roadways (for example, bridges).

Travel time reliability is also a growing problem. The variation in travel time from day to day is a significant characteristic of the congestion problem (Figure ES.3). The extra travel time and amount of the day and system affected by travel delays is not the same every day. It affects not only commute trips, but any trip during the peak travel periods, and is a significant concern of large and small businesses in all parts of the economy. Very detailed data from some urban freeways allow agencies to identify the extra travel time that must be budgeted – or buffer time – above the average travel time. The time that shippers, carriers, business travelers, commuters, and households have to plan for is a real consequence of congestion.

As an example of how travel time reliability affects highway users, consider the following (Figure ES.3).

Figure ES.3 Travel Time Reliability Illustration

1982 Average | **2001 Average** | **2001 Planning**

In 1982, if your commute was 20 minutes at midday, it took 23 minutes in the peak and you would spend an extra 15 hours on the road each year.

By 2001, that 20 minute off-peak trip took 28 minutes in the peak.

And if you have an important meeting, the reliability problems mean that you should allow 40 minutes for the same trip.

Source: Reference (1).

- **1982 –** If your midday trip took 20 minutes, it would take you 23 minutes in the peak. Although no reliability statistics exist from that long ago, analysis of recent data suggest that you would have had to add an additional nine minutes to that trip to guarantee on-time arrival at your destination; a total of 32 minutes would be planned for that trip.
- **2001 –** By 2001, that 20-minute free-flow trip took 28 minutes.
- **2001 (Planning Time) –** And if on-time arrival was important you should allow 40 minutes for that trip.

The future holds more of the same. Population and employment growth in America's large cities are expected to continue rising by around two percent each year, resulting in longer periods of congestion on more of the transportation system. Forecasts of population and economic activity – strong determinants of transportation activity – along with forecasts of system-level transportation activity indicate that compared to year 2000[2]:

- By 2025, the U.S. population will grow by 26 percent;
- By 2025, the Gross National Product will double;

[2] Sources: (1) U.S. Department of Transportation, Bureau of Transportation Statistics, http://www.eia.doe.gov and (2) FHWA Freight Analysis Framework, http://www.ops.fhwa.dot.gov/freight/freight_news/FAF/talkingfreight_faf.htm.

- By 2025, passenger-miles (all modes, including highway, air, and transit) will grow by 72 percent; and
- By 2020, intercity truck tonnage will grow by 75 percent.

THE SOURCES OF CONGESTION AND UNRELIABLE TRAVEL

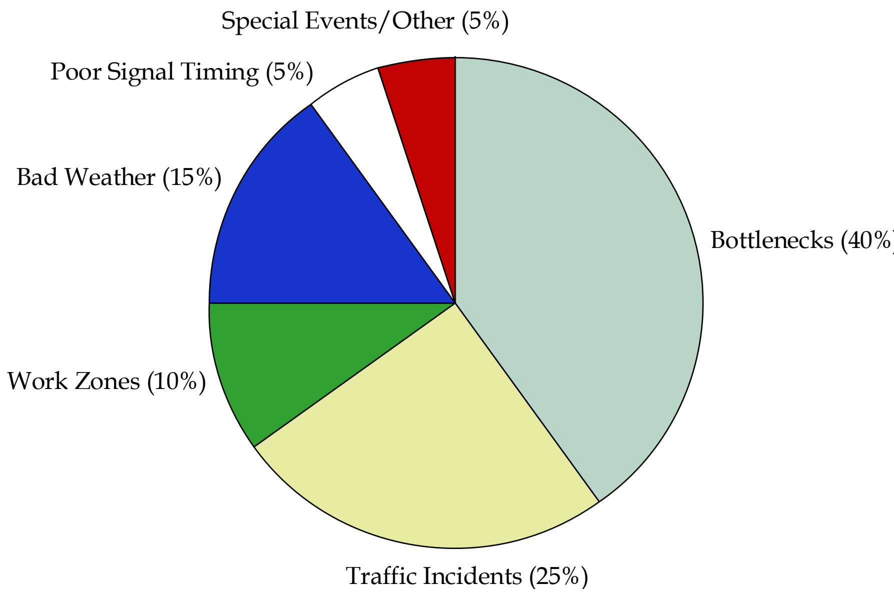
Congestion is a lot more complex than simply "too many vehicles trying to use the road at the same time," although that is certainly a major part of the problem. Congestion results from the interaction of many different factors – or sources of congestion. Congestion has several root causes that can be broken down into two main categories:

1. **Too much traffic for the available physical capacity to handle –** Just like a pipe carrying water supply or the electrical grid, there are only so many vehicles that can be moved on a roadway for a given time or so many transit patrons that can be accommodated in a given number of buses or trains. Transportation engineers refer to this as the physical capacity of the highway system. ***Physical bottlenecks are locations where the physical capacity is restricted, with flows from upstream sections (with higher capacities) being funneled into smaller downstream segments.*** This is roughly the same as a storm pipe that can carry only so much water – during heavy rains the excess water floods the streets and houses behind the pipe. However, the situation is even worse for traffic. Once traffic flow breaks down to stop-and-go conditions, capacity is actually reduced – fewer cars can get through the bottleneck because of the extra turbulence. Bottlenecks can be very specific chokepoints in the system, such as a poorly functioning freeway-to-freeway interchange, or an entire highway corridor where a "system" of bottlenecks exists, such as a closely spaced series of interchanges with local streets. Physical capacity can be reduced by the addition of "intentional" bottlenecks, such as traffic signals and toll booths. Bottlenecks can also exist on long upgrades and can be created by "surges" in traffic, as experienced around resort areas.
2. **Traffic-influencing events –** In addition to the physical capacity, external events can have a major effect on traffic flow. These include traffic incidents such as crashes and vehicle breakdowns; work zones; bad weather; special events; and poorly timed traffic signals. When these events occur, their main impact is to "steal" physical capacity from the roadway. Events also may cause changes in traffic demand by causing travelers to rethink their trips (e.g., snow and other types of severe weather).

The level of congestion on a roadway is determined by the interaction of physical capacity with events that are taking place at a given time. For example, the effect of a traffic incident depends on how much physical capacity is present. Consider a traffic crash that blocks a single lane on a freeway. That incident has a much greater impact on traffic flow if only two normal lanes of travel are present than if three lanes are present. ***Therefore, strategies that improve the physical capacity of bottlenecks also lessen the impacts of roadway events such as traffic incidents, weather, and work zones.***

Only recently has the transportation profession started to think of congestion in these terms. Yet it is critical to do so because strategies must be tailored to address each of the sources of congestion, and they can vary significantly from one highway to another. Nationally, a composite estimate of how much each of these sources contribute to total congestion is depicted in Figure ES.4.[3]

Figure ES.4 The Sources of Congestion
National Summary



What Causes Travel Times to be Unreliable? ***The interaction of all the sources of congestion produce unreliable travel times.*** Travel time reliability can be defined in terms of how travel times vary over time (e.g., hour-to-hour, day-to-day). The event-related sources (e.g., traffic incidents, weather, and work zones) that contribute to total congestion also conspire to produce unreliable travel times, since events and demand volumes vary day to day. The problem is worse when events are added on top of existing capacity-related congestion. When traffic flow has already broken down to stop-and-go conditions, any additional disturbance causes a large increase in congestion.

What Are the Benefits of Making Travel Times More Reliable? If it is possible to reduce the impact of these events on travel, a double benefit is realized: not

[3] http://www.ops.fhwa.dot.gov/aboutus/opstory.htm; these estimates are a composite of many past and ongoing congestion research studies and are rough approximations.

only are conditions made more "reliable" (that is, less variable), but overall delay is reduced as well. This is because extreme events, especially in combination, lead to high congestion. Making improvements in both the congestion level and reliability is significant for a number of reasons:

- Reducing total congestion saves time and fuel, and leads to decreased vehicle emissions;
- Reducing congestion at international border crossings leads to lower transportation costs and benefits the national economy as a whole. Further, reducing congestion on U.S. highways for freight moving between Canada and Mexico fosters international trade. In essence, ***congestion on U.S. highways can be thought of as an international problem as well as a national one;***
- Improving reliability leads to more predictable and consistent travel, something that all travelers seek: they do not have to budget as much extra time in order to arrive on time at their destinations. This is particularly important for truckers and shippers because many activities (e.g., manufacturing, sales) are now closely timed to the arrival of shipments. Many types of personal travel – such as getting to business appointments and child care pickup on time – are also sensitive to unreliable travel times; and
- Treating three major components of unreliable travel – traffic incidents, bad weather, and work zones – also leads to safer highways. By reducing the duration of these events, we are reducing how long travelers are exposed to less safe conditions.

What Value Does Providing Reliable Travel Times Have? Commuters as well as freight carriers and shippers are all concerned with travel time reliability. Variations in travel time can be highly frustrating and are valued highly by both groups. Previous research[4] indicates that commuters value the variable component of their travel time between one and six times as much as average travel time. Adoption of just-in-time (JIT) manufacturing processes has made a reliable travel time almost as important as an uncongested trip. Significant variations in travel time will decrease the benefits that come from lower inventory space and the use of efficient transportation networks as "the new warehouse." ***Therefore, in both the passenger and freight realms, evidence suggests that travel time reliability is valued at a significant "premium" by users.***

What is Freight's Role in Congestion? Demand for freight transportation in the United States, which is expected to grow substantially over the next 15 years (Figure ES.5), is a major contributing factor to congestion. The expected growth

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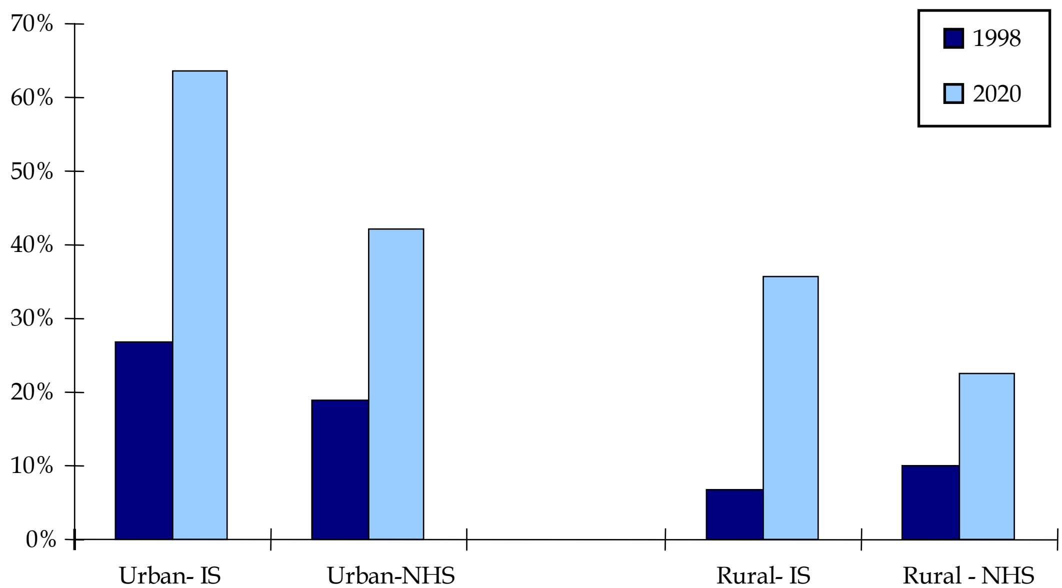
[4] Cohen, Harry, and Southworth, Frank, *On the Measurement and Valuation of Travel Time Variability Due to Incidents on Freeways*, Journal of Transportation Statistics, Volume 2, Number 2, December 1999, http://www.bts.gov/jts/V2N2/vol2_n2_toc.html.

in truck travel is being driven by economic and population growth. The most striking growth is expected to be on rural Interstate highways, indicating the potential for congestion to spread outside of metropolitan areas. Since 1992, traffic has grown substantially on rural highways and at a faster pace than on metropolitan highways. National data shows that between 1992 and 2002, traffic on rural Interstates increased 36 percent compared with an increase of 25 percent on urban Interstates. Further analysis shows that traffic volume per lane (a measure of traffic density) increased by 35 percent on rural Interstates compared with 21 percent on urban Interstates.

Figure ES.5 Percentage of Highway Segments with over 10,000 Trucks Per Day
Comparison of 1998 to 2020



Source: Analysis of data from FHWA's Freight Analysis Framework.

What Are the Costs of Congestion? Congestion has real costs for all travelers, including truckers (both long-haul and local pickup and delivery), household and business service providers (such as plumbers, computer technicians, police, and ambulance services), and personal travel (such as commuters, vacationers, and shoppers). Congestion causes more fuel to be used and more emissions to be produced. The extra time spent in congestion causes service providers to make fewer calls per day, leading to higher prices for consumers; this is particularly important for emergency medical, fire, and police services which may be unnecessarily delayed from attending to medical, crime, and disaster situations. Companies with production schedules timed to take advantage of trucks delivering components to an assembly line as they are needed must instead plan for items to arrive early. This consumes space and inventory, expending resources that could otherwise be spent on productive activity. For personal travelers, congestion "steals" time that could be put to better use in the workplace or for social or recreational purposes.

The congestion costs to freight interests are significant. Freight transportation has gone through many changes over the past 20 years as it has adapted to changes in business practices. Within this new operating environment, freight operations and productivity have been optimized to work closely with other aspects of business activity. Deregulation has resulted in excess capacity being eliminated from the highway and rail freight systems. Intermodal services and facilities have revolutionized international trade. Ports and airports have seen services and demand grow rapidly. Freight services are now more efficient and in many cases lower in cost (in constant dollars) than in previous decades. But the elimination of excess capacity has resulted in systems with less redundancy and less ability to withstand shocks or disruptions. Congestion is growing on many key freight segments of the transportation system, and congestion can drastically reduce the productivity of the overall freight network. The delay caused by congestion could vastly increase the costs of those freight movements that are today managed to exacting schedules.

Time is literally money for shippers and trucking interests. A direct linkage exists between transportation investment, travel conditions (congestion and reliability) and economic productivity. For trucking, two key trends identified above will have a substantial impact on the total cost of moving freight:

1. As congestion spreads into the midday period, which is the peak travel period for trucks, more direct costs will be incurred; and
2. Reliability – For trucks, the ability to hit delivery windows predictably will decrease and will add even more costs as firms struggle to optimize delivery schedules. This is especially a problem for truckers who must meet "just-in-time" delivery schedules set by shippers, manufacturers, and retailers.

All of this adds up to a staggering amount of costs imposed on travelers by congestion. The Texas Transportation Institute estimates that in 75 of the largest U.S. cities in 2001, $69.5 billion dollars are wasted in time and fuel costs.[5] (The costs are a composite of automobile and truck travel costs in urban areas.) The time value costs for trucks are conservative – they include only the cost of truck operating time, primarily the cost of drivers' wages and equipment. The value of the cargo and the response of firms to transportation costs is not included, yet recent work suggests these costs can be significant. These costs include:

[5] Schrank, D. and Lomax, T., 2003 Annual Urban Mobility Report, Texas Transportation Institute.

- **Foregone Investment Opportunities –** Higher transportation costs due to congestion reduce a firm's ability to invest in making more products, improve product quality, and introduce new products; and
- **Decreases in Regional Employment or Decreases in the Rate of Growth of Regional Income –** Higher transportation costs are passed onto other sectors of the economy and hinder general economic efficiency.[6]

WHAT CAN WE DO ABOUT TRAFFIC CONGESTION?

Transportation engineers and planners have developed a variety of strategies to deal with congestion – a toolbox for managing congestion. The strategies can be grouped as follows:

1. Adding more capacity for highway, transit and railroads;
2. Operating existing capacity more efficiently; and
3. Encouraging travelers to use the system in less congestion-producing ways.

Each of these congestion reducing strategies has a role in major cities. More accurately, they all have a role in some locations and corridors within major cities. Implementing the strategies involves consideration of the size and type of problem, funding, and public approval, environmental and social consequences. The decisions resulting from all these factors will be different, diverse and reflect local, state, and national priorities. When used in combination, however, the strategies can have a powerful impact on congestion growth. Also, when applying these strategies, agencies ***need to think and act regionally about solutions to congestion problems.*** In fact, FHWA is promoting the concept of regional partnerships as a means to implementing effective operations. These partnerships provide a platform for interagency coordination and joint delivery of operations-based services.

Specifically, each of the three major categories of congestion management strategies entails the following:

1. **Adding More Capacity – Increasing the Number and Size of Highways and Providing More Transit and Freight Rail Service.** Adding more lanes to existing highways and building new ones has been the traditional response to congestion. In some metropolitan areas, however, it has become difficult to undertake major highway expansions because of funding constraints, increased right-of-way and construction costs, social effects and environmental constraints and opposition from local and national groups. However, it is clear that adding new physical capacity to highways, transit systems, and

[6] ICF Consulting, HLB Decision Economics, and Louis Berger Group, *Freight Benefit/Cost Study: Capturing the Full Benefits of Freight Transportation Improvements: A Non-Technical Review of Linkages and the Benefit/Cost Analysis Framework*, May 11, 2001.

railroads is an important strategy for alleviating congestion. This often means that highway designers must find creative ways to incorporate new designs that accommodate all stakeholders' concerns. Since the worst highway bottlenecks tend to be major freeway interchanges, advanced design treatments that spread out turning movements and remove traffic volumes from key merge areas have been developed, often by using multilevel structures that minimize the footprint of the improvement on the surrounding landscape.

Key Strategies to Address Congestion

- Adding travel lanes on major freeways and streets (including truck climbing lanes on grades);
- Adding capacity to the transit system (buses, urban rail or commuter rail systems);
- Closing gaps in the street network;
- Removing bottlenecks;
- Overpasses or underpasses at congested intersections;
- High-occupancy vehicle (HOV) lanes; and
- Increasing intercity freight rail capacity to reduce truck use of highways.

2. **Operating Existing Capacity More Efficiently – Getting More Out of What We Have.** In recent years, transportation agencies have embraced strategies that deal with the *operation* of existing highways, transit systems, and freight services, rather than just building new infrastructure. Collectively referred to as Intelligent Transportation Systems (ITS), real-time control of transportation operations involves making changes from minute to minute and take many forms. In addition to ITS, other Transportation System Management and Operations (TSM&O) strategies that improve the efficiency of the existing road system include minor widening projects, changing the operating methods or the policies that govern the use of the roadway, and monitoring transit vehicles in real-time. There are numerous operations-based congestion mitigation strategies that are enhanced by the use of advanced technologies or ITS.

Key Strategies to Address Congestion

- Metering traffic onto freeways;
- Optimizing the timing of traffic signals;
- Faster and anticipatory responses to traffic incidents;
- Providing travelers with information on travel conditions as well as alternative routes and modes;
- Improved management of work zones;

- Identifying weather and road surface problems and rapidly targeting responses;
- Providing real-time information on transit schedules and arrivals;
- Monitoring the security of transit patrons, stations, and vehicles;
- Anticipating and addressing special events that cause surges in traffic;
- Better freight management, especially reducing delays at border crossings;
- Reversible commuter lanes;
- Movable median barriers to add capacity during peak periods;
- Restricting turns at key intersections;
- Geometric improvements to roads and intersections;
- Converting streets to one-way operations; and
- Access management.

3. **Encouraging Travel and Land Use Patterns that Use the System in Less Congestion Producing Ways – Travel Demand Management (TDM), Non-Automotive Travel Modes, and Land Use Management.** Another key approach to the problem of congestion involves managing the demand for highway travel. These strategies include providing a variety of options that result in more people traveling in fewer vehicles, trips made during less congested times, or trips not made (at least in a physical sense). A major barrier to the success of demand management strategies is that they may require changes in traditional decisions about where, when and how to travel, live and work. Flexible scheduling, for example, is not possible for a large number of American shift schedule workers. Still, when considered as part of an overall program of transportation investments, demand management and non-automotive modes of travel can contribute substantially to a metropolitan area's transportation system.

   The historical cycle of suburban growth has led to an ever increasing demand for travel. Suburban growth was originally fueled by downtown workers who moved from city centers to the urban fringe to take advantage of lower land prices and greater social amenities. In the past 20 years, businesses also have moved to the suburbs to be closer to their employees. This in turn allows workers to live even further away from city centers, thereby perpetuating suburban expansion. Strategies that attempt to manage and direct urban growth to influence these processes have been used in several metropolitan areas. The main problem with many of these strategies is that they can be contrary to market trends, burdening consumers with extra costs and dampening economic efficiency, at least in the short term. Unless a truly regional approach is followed – with cooperation of all jurisdictions within the region – and the policies are considered as part of a package of development options, sprawl may simply be attracted into areas not conforming to growth policies.

Key Strategies to Address Congestion

- Programs that encourage transit use and ridesharing;
- Curbside and parking management;
- Flexible work hours;
- Telecommuting programs;
- Bikeways and other strategies that promote non-motorized travel;
- Pricing fees for the use of travel lanes by the number of persons in the vehicle and the time of day;
- Pricing fees for parking spaces by the number of persons in the vehicle, the time of day or location;
- Land use controls or zoning;
- Growth management restrictions such as urban growth boundaries;
- Development policies that support transit-oriented designs for homes, jobsites, and shops; and
- Incentives for high-density development, such as tax incentives.

NEXT STEPS

Is Success Possible Against Congestion? Yes, but past successes tends to be localized. Multiple and systematic strategies for addressing congestion are required, given that demand is increasing on an already stressed highway and transit system. All of the strategies covered in this *Report* have been successfully implemented – the key to future progress is deploying and using them in a more comprehensive and aggressive manner. It also requires cooperation between transportation agencies, businesses, elected officials, and the public. Since we are all affected by congestion, it is important that we all work together to address the congestion problem. Here are some ways that transportation agencies, businesses, elected officials, and the public can collaborate to mitigate congestion.

1. **Take Ownership –** The first step is for all parties to recognize they have a stake in the congestion problem. Public agencies are in the business of serving customers the same way that any private firm is – except that the customers (the public and businesses) are buying efficient and safe travel. The public, elected officials, and businesses are more than just consumers – they are shareholders too. These consumers also should examine their own decisions and policies to identify changes that can improve their quality of life while recognizing that the agencies cannot solve the problem by themselves. The ongoing transportation planning process, which has been successfully used in major metropolitan areas for the past 40 years to address

transportation problems, provides an excellent framework for promoting ownership of congestion problems. A major part of the transportation planning process is establishing a Vision that outlines what the future transportation system should look like. The Vision leads to more specific statements of desired actions to achieve these states or characteristics. The Vision is also an opportunity to educate all stakeholders on the nature of congestion in your area and the importance of mitigating it.

2. **Identify the Congestion Problems and Opportunities –** Both technical analyses and anecdotal information from the public are useful in identifying where the major congestion problems are, where they will be, and what causes them. The existing transportation planning process in metropolitan areas can be tapped as a resource for this purpose. Thoroughly analyze and provide realistic assessments on what can reasonably be done in each case, and what the expected improvements might be. FHWA supports a wealth of information on expected improvements from operational strategies, such as the ITS Benefits and Cost Database.[7] The process should include considerations of:

   – **Strategies –** What types of treatments should be considered?

   – **Coverage –** How much area does the treatment cover?

   – **Density –** How well is congestion treated?

   – **Congestion Target –** What aspect of congestion is treated?

   – **Effect –** What is the delay reduction effect? Are there secondary effects, such as on safety? What are the spillover effects on other facilities and neighborhoods?

3. **Develop Plans, Programs, Policies, and Projects –** Congestion solutions can take a variety of forms. Think broadly – no single tool will be highly effective against the congestion problem. But when used in combination – and tailored to specific circumstances – packages of congestion mitigation strategies can be successful. The strategies should include action elements – things we can accomplish in a short timeframe and at low cost. But longer-term actions also should be developed – consider all types pf strategies including adding new highway and rail capacity, improved operations, and better land use planning. Recognize that many transportation and community plans already exist and should be tapped as mechanisms for carrying out the Vision. In fact, acting on a list of "things we can do now" should help galvanize support for congestion mitigation over the long term.

4. **Plan, Manage, and Operate the Transportation System Proactively and Regionally.** Focus on addressing system reliability by targeting capital and

[7] http://www.mitretek.org/its/benecost/BC_Update_2003/index.html.

operations strategies to specific conditions. Anticipate problems and take corrective actions early. Also, regional and multimodal cooperation is key to the success of deploying effective operations – many different agencies have a stake in the congestion problem. Therefore, a broad perspective should be taken in applying capital and operations strategies – avoid a narrow, facility-oriented view.

5. **Use Performance Measures to Track Progress –** One of the main actions that transportation agencies can contribute is the tracking of congestion trends and the effect of improvements over time. Trends provide a basis for determining how well your actions are working and can identify changes in the underlying congestion problem (e.g., traffic crashes may become more important in your area). Use of performance measures also brings an element of **accountability** to the process – what we are really getting for our investments – just as businesses do.

DETAILED DEFINITIONS

Travel Time Index (TTI) is a comparison between the travel conditions in the peak period to free-flow conditions. It uses the units of travel rate (the inverse of speed) due to the ease of mathematical calculation and availability of data elements in both traffic surveillance and roadway inventory databases. The equation below presents the calculation of the travel time index for areawide applications.

$$\text{Travel Time Index} = \frac{\left(\dfrac{\text{Freeway Travel Rate}}{\text{Freeway Free-flow Rate}} \times \text{Freeway Peak Period VMT}\right) + \left(\dfrac{\text{Principal Arterial Street Travel Rate}}{\text{Principal Arterial Street Free-flow Rate}} \times \text{Principal Arterial Street Peak Period VMT}\right)}{\left(\text{Freeway Peak Period VMT} + \text{Principal Arterial Street Peak Period VMT}\right)}$$

The index can be applied to various system elements with different free-flow speeds. The travel time index compares measured travel rates to free-flow conditions for any combination of freeways and streets. Index values can be related to the general public as an indicator of the length of extra time spent in the transportation system during a trip.

The **Buffer Time Index (BTI)** expresses the amount of extra "buffer" time needed to be on-time 95 percent of the time (late 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. The index is calculated for each road segment and a weighted average is calculated using vehicle-miles of travel as the weighting factor.

$$\text{Buffer Time Index} = \begin{matrix}\text{Weighted}\\ \text{Average of}\\ \text{All Sections}\\ \text{(Using VMT)}\end{matrix} \left[\frac{\begin{matrix}\text{95th Percentile Travel Rate}\\ \text{(in minutes per mile)}\end{matrix} - \begin{matrix}\text{Average Travel Rate}\\ \text{(in minutes per mile)}\end{matrix}}{\begin{matrix}\text{Average Travel Rate}\\ \text{(in minutes per mile)}\end{matrix}} \times 100\%\right]$$

The **Planning Time Index (PTI)** is simply the 95^{th} percentile travel time index. It is used as a supplemental measure for reliability. Because reliability is related to the distribution of travel rates, the 95^{th} percentile indicates an excessively high travel rate, one that only five percent of all travel rates exceed for the time period under consideration.

Delay is the amount of extra time spent in congestion compared to the time it would take under ideal or free-flow conditions. For example, if a trip takes 10 minutes under ideal conditions, and during the peak it takes 15 minutes, the total amount of delay is five minutes.

To Access the Full Report on Traffic Congestion and Reliability – To gain access to the full report and detailed appendices, go to the FHWA Office of Operations web site at: http://www.ops.fhwa.dot.gov/.

1.0 Introduction

Mitigating congestion is a high priority for the Federal Highway Administration (FHWA), which has established congestion as a key focus area.[8] The *Traffic Congestion and Reliability: Linking Solutions to Problems Report* supports this effort by providing a review of congestion in the United States. The emphasis of the *Report* is on measuring trends in travel time reliability and making travel more reliable through initiatives in Transportation System Management and Operations (TSM&O). The topic of congestion is clearly much broader than this focus. While the broader context of congestion is discussed, the *Report* spends most its effort on defining and measuring travel time reliability, and highlighting TSM&O strategies to address it. Among the important features of this report are:

- **Focus on travel time reliability.** The *Report* extends the total delay-based statistics in the Texas Transportation Institute's *Urban Mobility Report*[9] with statistics on travel time reliability, a topic of increasing interest in the transportation community.
- **Investigate the root causes (sources) of congestion.** Understanding the causes of congestion leads to more effective strategies for dealing with it.
- **Explore the impact of congestion on freight and the economy.** Congestion not only affects individual travelers (primarily commuters) but also truck travel and costs as well as the economy as a whole.
- **Present performance measurement as a process for making things better.** How the transportation system performs is significant not just at the global level presented in the *Report* – it also can be used to make changes in day-to-day activities like traffic incident management and to develop more effective transportation investments.
- **Highlight the effects that both operational improvements and physical capacity expansion can have on congestion.** As we present later, operations versus capacity expansion is not an "either/or" proposition. Rather, these activities are complementary and each has an important role to play in alleviating congestion. This is especially true given that recent history has taught us that no single strategy can effectively address congestion – only through a combination of strategies can congestion be controlled.

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[8] Federal Highway Administration, FY 2003 Performance and Accountability Report, http://www.fhwa.dot.gov/reports/2003performance/index.htm.

[9] Schrank, D. and Lomax, T., *2003 Annual Urban Mobility Report,* Texas Transportation Institute, http://mobility.tamu.edu.

- **Identify how congestion affects everyday life in the U.S.** The *Report* develops a series of "vignettes" showcasing the effects of congestion on the daily activities of the public.

Much of the *Report* is devoted to measuring recent trends in congestion. One of the key principles that the Federal Highway Administration (FHWA) has promoted in congestion measurement is that the metrics used to track congestion should be based on the ***travel time experienced by users of the highway system.*** While the transportation profession has used many other types of metrics to measure congestion (such as "level of service"), travel time is a more direct measure of how congestion affects users. Travel time is understood by a wide variety of audiences – both technical and nontechnical – as a way to describe the performance of the highway system. All of the congestion metrics used in the *Report* are based on this concept.

2.0 Background to the Congestion Problem

2.1 The Sources of Congestion

Congestion results from the interaction of many different factors – or sources of congestion. Congestion has several root causes that can be broken down into two main categories:

1. **Too much traffic for the available physical capacity to handle.** Just like a pipe carrying water supply or the electrical grid, there are only so many vehicles that can be moved on a roadway for a given time. Transportation engineers refer to this as the physical capacity of the highway system. Physical capacity is determined by such things as: how many lanes are available to carry traffic, the curvature of the highway, side clearance, and interchange and intersection design (for example, length and position of on-ramps and exclusive turning lanes at intersections). ***Physical bottlenecks are locations where the physical capacity is restricted, with flows from upstream sections (with higher capacities) being funneled into them.*** This is roughly the same as a storm pipe that can carry only so much water – during floods the excess water just backs up behind it, much the same as traffic at bottleneck locations. However, the situation is even worse for traffic. Once traffic flow breaks down to stop-and-go conditions, capacity is actually reduced – fewer cars can get through the bottleneck because of the extra turbulence. Bottlenecks can be very specific chokepoints in the system, such as a poorly functioning freeway-to-freeway interchange, or an entire highway corridor where a system of bottlenecks exists, such as a closely spaced series of interchanges with local streets.[10] Physical capacity can be reduced by the addition of "intentional" bottlenecks, such as traffic signals and toll booths. Opportunities to improve the operation of "intentional" bottlenecks can have the effect of boosting physical capacity.

2. **Traffic-influencing events.** In addition to the physical capacity, external events can have a major effect on traffic flow. These include traffic incidents such as crashes and vehicle breakdowns; work zones; bad weather; special

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[10] In rural areas, physical bottlenecks take a different form. Highway grades can be a significant problem for large trucks in rural areas. Also, surges in travel to resorts during the "peak" season and travel around holidays can overwhelm physical capacity for some time. However, since traffic is lower in these cases or only lasts for a short periods of time, the total amount of delay on a yearly basis is far less than in major urban areas, where just about every weekday of the year is congested.

events; and poorly timed traffic signals. When these events occur, their main impact is to "steal" physical capacity from the roadway. Events may also cause changes in traffic demand by causing travelers to rethink their trips (e.g., snow and other types of severe weather).

Physical bottlenecks have been the focus of transportation improvements – and of travelers' concerns – for many years. On much of the urban highway system, there are specific points that are notorious for causing congestion on a daily basis. These locations – which can be a single interchange (usually freeway-to-freeway), a series of closely spaced interchanges, or lane-drops – are focal points for congestion in corridors; major bottlenecks tend to dominate congestion in corridors where they exist. Many acquire nicknames from local motorists such as:

- "Spaghetti Bowl" in Las Vegas;
- "Hillside Strangler" in Chicago; and
- "Mixmaster" in Dallas.

How bad congestion becomes at a bottleneck is related to its physical design. Some bottlenecks were originally constructed many years ago using designs that are now considered to be antiquated. Others have been built to extremely high design specifications and are simply overwhelmed by traffic. A recent examination of national bottlenecks identified the worst physical bottlenecks in the country and examined the positive effects that improving them could have on travel times, safety, emissions, and fuel consumption. Table 2.1 provides a ranking of these bottlenecks.

Table 2.1 The Worst Physical Bottlenecks in the United States
2002

Rank	City	Location	Annual Hours of Delay (Hours in Thousands)
1	Los Angeles	U.S. 101 (Ventura Freeway) at I-405 Interchange	27,144
2	Houston	I-610 at I-10 Interchange (West)	25,181
3	Chicago	I-90/94 at I-290 Interchange ("Circle Interchange")	25,068
4	Phoenix	I-10 at SR 51/SR 202 Interchange ("Mini-Stack")	22,805
5	Los Angeles	I-405 (San Diego Freeway) at I-10 Interchange	22,792
6	Atlanta	I-75 south of the I-85 Interchange	21,045
7	Washington (D.C.-Maryland-Virginia)	I-495 at I-270 Interchange	19,429
8	Los Angeles	I-10 (Santa Monica Freeway) at I-5 Interchange	18,606
9	Los Angeles	I-405 (San Diego Freeway) at I-605 Interchange	18,606
10	Atlanta	I-285 at I-85 Interchange ("Spaghetti Junction")	17,072
11	Chicago	I-94 (Dan Ryan Expressway) at I-90 Skyway Split (Southside)	16,713

Rank	City	Location	Annual Hours of Delay (Hours in Thousands)
12	Phoenix	I-17 (Black Canyon Freeway) at I-10 Interchange (the "Stack") to Cactus Road	16,310
13	Los Angeles	I-5 (Santa Ana Freeway) at SR 22/SR 57 Interchange ("Orange Crush")	16,304
14	Providence	I-95 at I-195 Interchange	15,340
15	Washington (D.C.-Maryland-Virginia)	I-495 at I-95 Interchange	15,035
16	Tampa	I-275 at I-4 Interchange ("Malfunction Junction")	14,371
17	Atlanta	I-285 at I-75 Interchange	14,333
18	Seattle	I-5 at I-90 Interchange	14,306
19	Chicago	I-290 (Eisenhower Expressway) between Exits 17b and 23a	14,009
20	Houston	I-45 (Gulf Freeway) at U.S. 59 Interchange	13,944
21	San Jose	U.S. 101 at I-880 Interchange	12,249
22	Las Vegas	U.S. 95 west of the I-15 Interchange ("Spaghetti Bowl")	11,152
23	San Diego	I-805 at I-15 Interchange	10,992
24	Cincinnati	I-75, from Ohio River Bridge to I-71 Interchange	10,088

Source: *Unclogging America's Arteries: Effective Relief for Highway Bottlenecks*, American Highway Users Alliance, February 2004. Delay is the extra time it would take to travel through the bottlenecks compared to completely uncongested conditions. The report did not consider many severe bottlenecks from the New York City area. As most travelers know, congestion in and around the boroughs of New York can be significant. However, a very large amount of delay in the New York area is related to bridge and tunnel crossings into Manhattan, most of which are toll facilities. Also, while the New York metropolitan area is laced with Interstates, parkways, and expressways, they seldom reach the proportions seen in other major areas, except where multiple highways converge on bridge of tunnel crossings. (A typical lane configuration for a New York area freeway is six lanes, three in each direction. But there are many of these.) Toll facilities were excluded from the study because toll facilities are fundamentally different from other physical bottlenecks (such as freeway-to-freeway interchanges) that are prevalent around the country. Delay comparisons between toll facilities and other types of bottlenecks might not be consistent since different modeling techniques would be used. If objective field measurements of delay could be made at all locations around the country, several river crossings into Manhattan would no doubt be included in a list of the nation's worst bottlenecks.

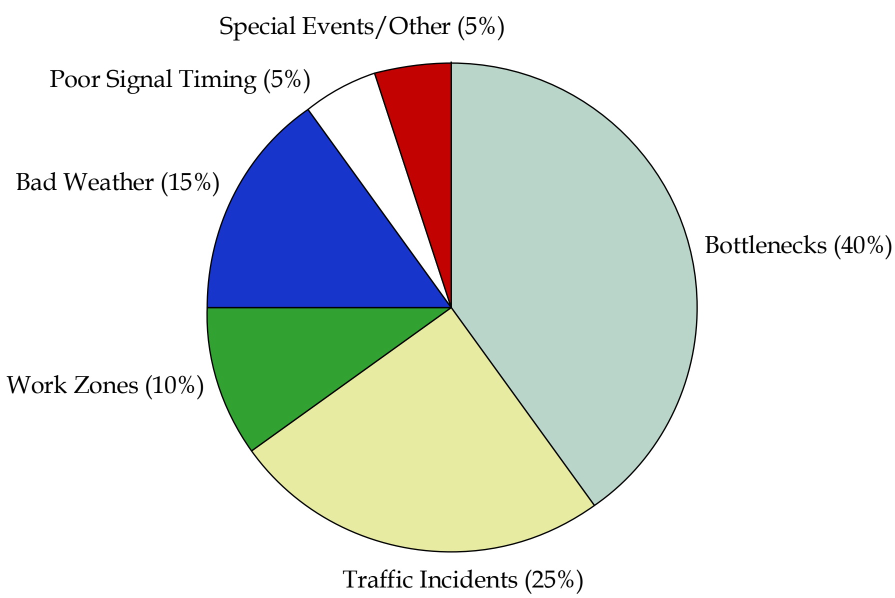
Most of the worst bottlenecks identified in Table 2.1 are specific chokepoints: freeway-to-freeway interchanges where both freeways carry extremely high traffic volumes. However, several of them were identified as "bottleneck systems." In such areas, a single dominant bottleneck does not exist. Rather, traffic flow is influenced by several smaller bottlenecks.

The study noted that many of the bottlenecks are either under reconstruction or will be shortly. It also noted that the improvement "packages" undertaken by transportation agencies commonly combine reconstruction with other strategies such as operational improvements, high-occupancy vehicle lanes, transit service, and toll lanes.

However, just focusing on physical bottlenecks only tells a fraction of the congestion story. The transportation profession has come to recognize that the level of congestion on a roadway is determined by the interaction of physical capacity with events that are taking place at a given time. For example, the effect of a traffic incident depends on how much physical capacity is present. Consider a traffic crash that blocks a single lane on a freeway. That incident has a much greater impact on traffic flow if only two normal lanes of travel are present than if three lanes are present. ***Therefore, strategies that improve the physical capacity of bottlenecks also lessen the impacts of roadway events such as traffic incidents, weather, and work zones.***

Only recently has the transportation profession started to think of congestion in these terms. Yet it is critical to do so because strategies must be tailored to address each of the sources of congestion, and they can vary significantly from one highway to another. Nationally, an estimate of how much each of these sources contribute to total congestion is as follows and depicted graphically in Figure 2.1.[11] These estimates are a composite of many past and ongoing research studies and are rough approximations.

Figure 2.1 The Sources of Congestion
National Summary



It is important to note that these global estimates of congestion sources do not necessarily hold for specific highway corridors. For example, some highways may have high crash rates, leading to a greater proportion of congestion due to

[11] http://www.ops.fhwa.dot.gov/aboutus/opstory.htm; estimates of the effects of variable traffic demand are not available.

traffic incidents. Others may be dominated by a physical bottleneck, such as a narrow bridge, leading to a higher proportion of bottleneck-related congestion. Differences in congestion sources between rural and urban are particularly striking. In rural areas, just about any delay that occurs will be event-related rather than caused by bottlenecks (insufficient capacity). In fact, in rural areas, preliminary estimates suggest that traffic incidents and work zones alone cause 80 to 90 percent of what delay that does occur. Of course, the total amount of delay in rural areas (about 400 *million* vehicle-hours of delay annually) is but a fraction of what occurs in urban areas (about 5.1 *billion* vehicle-hours of delay).[12] These distinctions are extremely important because they indicate what specific strategies should be implemented at any given location.

2.2 THE GROWING IMPORTANCE OF TRAVEL TIME RELIABILITY

A Definition of Travel Time Reliability. The traveling public experiences large swings in congestion level, and their expectation or fear of unreliable traffic conditions affects both their view of roadway performance, and how and when they choose to travel. For example, if a road is known to have highly variable traffic conditions, a traveler using that road to catch an airplane routinely leaves lots of "extra" time to get to the airport. In other words, the "reliability" of this traveler's trip is directly related to the variability in the performance of the route she or he takes.

Reliability and variability in transportation are being discussed for a variety of reasons. The two terms are closely related, but are slightly different in their focus, how they are measured, and how they are communicated:

- **Reliability** is commonly used in reference to the level of consistency in *transportation service*; and
- **Variability** might be thought of as the amount of inconsistency in *operating conditions*.

Measures can be developed to relate the reliability/variability concept to "average measures" of mobility (i.e., measures that capture average conditions such as average delay, average speed, etc.) and to identify differences in performance by time of day, assessing the methods to measure reliability for long and short trips, different trip purposes, trip locations, etc.

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[12] Preliminary estimates from the *Temporary Loss of Capacity* project underway at Oak Ridge National Laboratory. Estimates of rural delay include traffic incidents, weather, work zones, and traffic signals. Rural delay also includes that due to highway grades and high demand in recreational areas, but these have not been addressed.

With this discussion in mind, from a practical standpoint, ***travel time reliability can be defined in terms of how travel times vary over time*** (e.g., hour-to-hour, day-to-day). This concept of variability can be extended to any other travel time-based metrics such as average speeds and delay. For the purpose of this report, the terms travel time variability and reliability are used interchangeably.

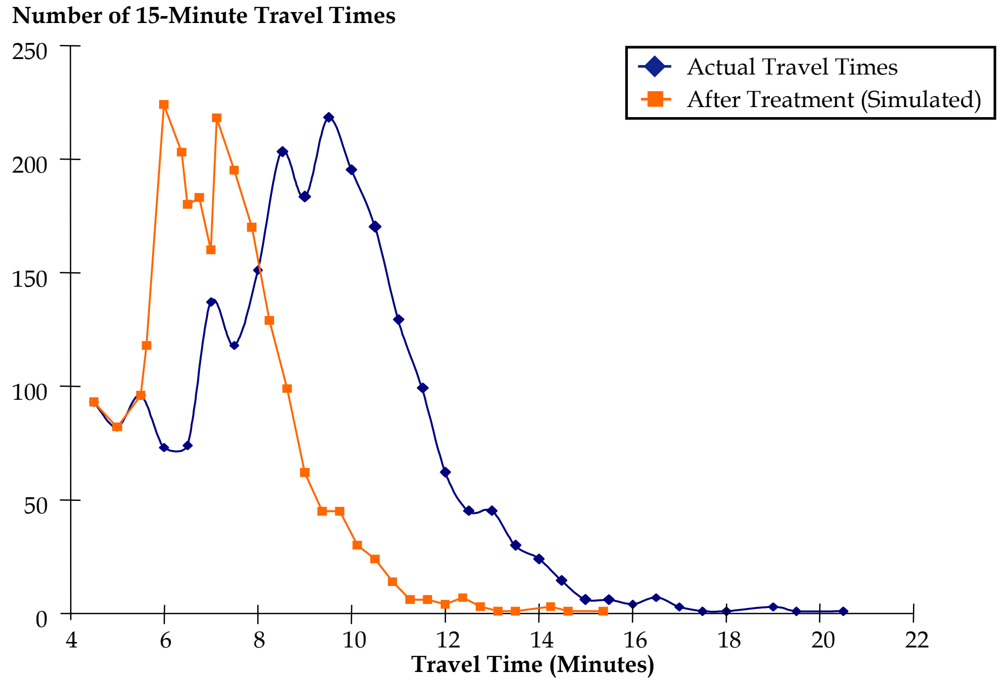
What Causes Travel Times to Be Unreliable? The sources previously identified (e.g., traffic incidents, weather, and work zones) that contribute to total congestion also conspire to produce unreliable travel times, since events and demand volumes vary day-to-day. To illustrate how travel times vary, we observed travel times on a 4.05-mile stretch of I-75 in central Atlanta, from the I-20 junction to the I-85 split (Figure 2.2). To develop this figure, we calculated travel times of trips made at 15-minute intervals for the three-hour period from 4:00 to 7:00 p.m. (Data were taken from the NaviGAtor traffic surveillance system for 2002). This corridor is extremely heavily traveled: one location on this stretch carries more than 320,000 vehicles per day. The variability in travel times is caused by the interaction of the physical capacity, traffic demand, and all the events that occurred on this roadway section in 2002. That is, ***the interaction of all the sources of congestion produce unreliable travel times, as shown in the distribution of existing travel times.***

What Are the Benefits of Making Travel Times More Reliable? If it is possible to reduce the impact of these events on travel, a double benefit is realized: not only are conditions made more "reliable" (that is, less variable), but overall delay is reduced as well. This is because extreme events, especially in combination, lead to high congestion. As a proof of principle, we examined what effect this would have on the Atlanta travel times. We reduced all of the abnormally high travel times (those greater than seven minutes for the 4.05-mile corridor) by an across-the-board 25 percent. As shown in Figure 2.2, the effect is to reduce delay ***and*** improve reliability. Making improvements in both the average congestion level and reliability is significant for a number of reasons:

- Reducing total congestion saves time and fuel, and leads to decreased vehicle emissions.
- Reducing congestion at international border crossings leads to lower transportation costs and benefits the national economy as a whole. Further, reducing congestion on U.S. highways for freight moving between Canada and Mexico fosters international trade. Therefore, ***congestion on U.S. highways has a large influence on the efficiency of international trade.***

Figure 2.2 Actual and Improved Peak-Period Travel Times on I-75 Southbound

Central Atlanta, 2002



Source: The data plotted above for "Actual Travel Times" came from the NaviGAtor system in Atlanta, Georgia. The highway segment covered by these data is 4.05 miles long. Average travel times for vehicles moving along this segment were computed at 15-minute intervals for the three-hour period from 4:00 to 7:00 p.m. on weekdays for 2002. (This time slice is usually called the "afternoon peak period.") A total of 12 15-minute intervals are therefore present each weekday. If trips were able to be made at 55 mph, they would take 4.4 minutes to complete.

However, the average travel time for the 4:00 to 7:00 p.m. period is about nine minutes, indicating that (on average) peak-period trips are made at 27 mph on this segment. Many trips take much longer – a few took as long as 20 minutes (an average travel speed of about 12 mph). Others were made in shorter amounts of time. ***This large variability in observed travel times is due to traffic-influencing events occurring on different days,*** added on top of an already congested system. (The I-20 interchange at the south end of this stretch is a known bottleneck.) Traffic incidents may happen on some days but not on others. Bad weather and temporary work zones may compound the effect of traffic incidents or may happen by themselves.

The "After Treatment" travel times show the effect of reducing all travel times above seven minutes by 25 percent (hypothetically). This was done to simulate the effect of reducing the impacts of traffic-influencing events on travel. The "tighter" (less spread-out) distribution for the "After Treatment" case indicates that reliability (variability) has been improved. Also, since the majority of trips now have lower travel times, total delay also is reduced. This is indicated by the "After Treatment" curve's shift to the left. More specifically, the average travel time is now about seven minutes in the "After Treatment" case, reduced from nine minutes.

- Improving reliability leads to more predictable and consistent travel in the corridor, something that all travelers seek: they do not have to budget as much extra time in order to arrive on time at their destinations. This is particularly important for truckers and shippers. Many activities (e.g., manufacturing, sales) are now closely timed to the arrival of shipments. Businesses depend on shipments to show up at precise times rather than holding onto inventories. Many types of personal travel – such as getting to business appointments and child care pickup on time – are also sensitive to unreliable travel times.

- Treating three major components of unreliable travel – traffic incidents, bad weather, and work zones – also leads to safer highways. By reducing the duration of these events, we are reducing how long travelers are exposed to less safe conditions.

What Value Does Providing Reliable Travel Times Have? Commuters as well as freight carriers and shippers are all concerned with travel time reliability. Variations in travel time can be highly frustrating and are valued highly by both groups. Previous research[13] indicates that commuters value the variable component of their travel time between one and six times as much as average travel time. And the increase in just-in-time (JIT) manufacturing processes has made a reliable travel time almost more important than an uncongested trip. Significant variations in travel time will decrease the benefits that come from lower inventory space and the use of efficient transportation networks as "the new warehouse." ***Therefore, in both the passenger and freight realms, evidence suggests that travel time reliability is valued at a significant "premium" by users.***

How Do We Measure Travel Time Reliability? Formal measures of how "unreliable" travel times are can be derived from describing the size and shape of the distributions, such as those shown for Atlanta in Figure 2.2. A complete description of the different measures can be found in Appendix C, but all of these relate directly to describing the distribution of travel times as they occur throughout the year. Returning to the Atlanta example, reliability statistics can be computed from these data, for both actual conditions and the hypothetical case of reducing abnormally high travel times (Table 2.2). These statistics verify what we observed in Figure 2.2 – that both delay and reliability are improved by treating "extreme" events. ***Operational strategies – which treat these extreme events – therefore have the effect of not only improving reliability but reducing total congestion as well.***

[13] Cohen, Harry, and Southworth, Frank, *On the Measurement and Valuation of Travel Time Variability Due to Incidents on Freeways*, Journal of Transportation Statistics, Volume 2, Number 2, December 1999, http://www.bts.gov/jts/V2N2/vol2_n2_toc.html.

Table 2.2 Effect of Treating Unreliable Travel Times on I-75 in Central Atlanta
Hypothetical

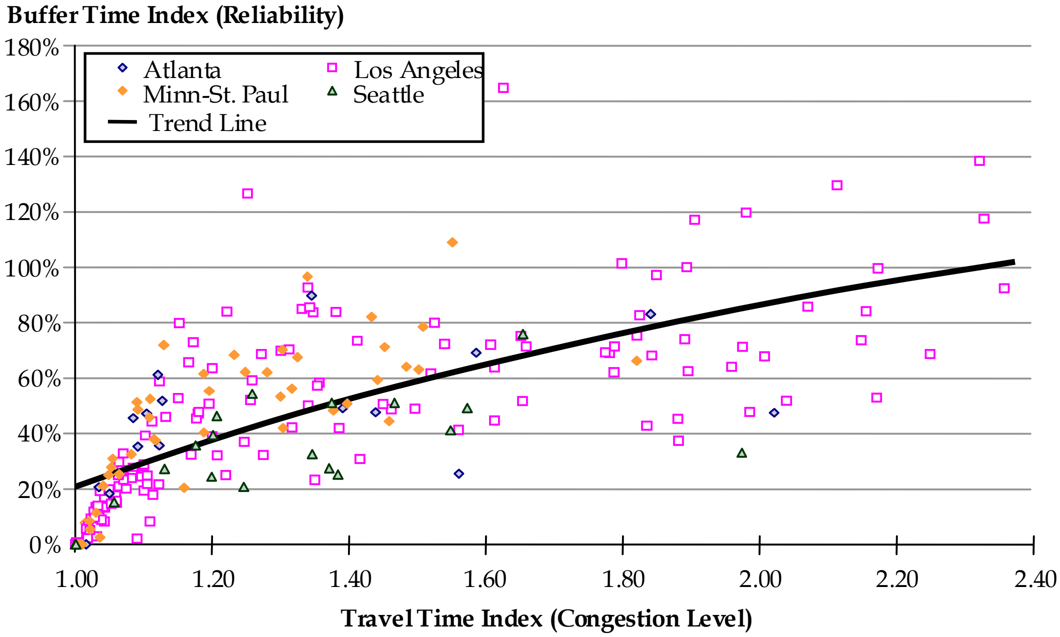
		Southbound, 4:00 to 7:00 p.m.
Travel Time Measure	**Observed Travel Times**	**Abnormally High Travel Times Reduced by 25 Percent**
Average Travel Time (minutes)	9.0	7.1
95th Percentile[a] (minutes)	13.1	9.8
Buffer Time Index[a]	46%	39%

[a] Reliability measures used by FHWA for performance monitoring. See Appendix C for definitions and discussion. The 95th percentile travel time is referred to as the "Planning Time Index" elsewhere in this report. The Buffer Time Index is the 95th percentile travel time normalized to the average travel time (see Appendix C). For both the 95th percentile travel time and the Buffer Time Index, high values indicate unreliable travel times.

Does Congestion Level Influence Travel Time Reliability? In other words, if travelers on average can expect high congestion, are their travel times also more variable? In general, the answer is "Yes." Figure 2.3 shows the Buffer Time Index plotted against the Travel Time Index for highway corridors in four cities. The plot reveals that as the average congestion level (Travel Time Index) increases, travel times become less reliable (as indicated by an increasing Buffer Time Index).[14] Why does this occur? As congestion builds (i.e., the Travel Time Index increases above 1.0), the highway becomes more "vulnerable" to disruptions caused by events such as bad weather, work zones, and traffic incidents. That is, once traffic has broken down to stop-and-go conditions, throwing an additional event on top causes even greater problems. In other words, ***"congested highways also are unreliable highways."***

[14] A brief explanation of these terms appears in Figure 2.3. Appendix C has a more thorough discussion.

Figure 2.3 Relationship Between Congestion Level and Reliability



Source: Analysis of data from FHWA's *Mobility Monitoring Program* (see Appendix A for a description of this data source). Each point on the graph came from individual freeway corridors in Atlanta, Minneapolis, Los Angeles, and Seattle.

The **Travel Time Index** is a measure of the total amount of congestion. It is the ratio of the peak-period travel time to the travel time under ideal conditions. A Travel Time Index value of 1.3 indicates that peak-period travel takes 30 percent longer than under ideal conditions. Another way to think of this measure is as a "multiplier." That is, the value of the Travel Time Index is the amount you would multiply the "ideal" travel time by to get the actual travel time you experienced. Thus, "Travel Time Multiplier" would be an alternate name for this term.

The **Buffer Time Index** is a measure of reliability, or more appropriately, *un*reliability. As it increases, travel times become more unreliable. Although conditions vary from highway-to-highway and city-to-city, a general relationship between congestion level and reliability is present in these data – as congestion increases, so does unreliable travel.

Many more performance measures can used to monitor congestion besides these. Appendix B has a discussion of performance measures.

3.0 National State of Congestion: Congestion by the Numbers and Why It Matters

3.1 TRENDS IN NATIONAL CONGESTION

Is congestion getting worse? Yes. The best single source for monitoring congestion trends is produced annually by the Texas Transportation Institute (TTI).[15] In their 2003 report, TTI's researchers found that congestion levels in 75 of the largest metropolitan areas have grown continuously in almost every year in all population groups from 1982 to 2001, as exemplified by the following trends.

Eleven-Year Average Trends (Urban Travel, 1990 to 2001)

- Peak-period[16] trips take an average of about 10 percent longer.
- Travelers spend 51 extra hours per year in travel compared to 42 hours in 1990.
- The percent of freeway mileage that is congested has grown from 49 percent to 60 percent.

Nineteen-Year Trends (Urban Travel, 1982 to 2001)

- "Congestion extends to more time of the day, more roads, affects more of the travel, and creates more extra travel time than in the past. And congestion levels have risen in all size categories, indicating that even the smaller areas are not able to keep pace with rising demand."
- Twenty-seven urban areas have a Travel Time Index[17] above 1.30 compared with one such area in 1982.

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[15]Schrank, D. and Lomax, T., *2003 Annual Urban Mobility Report,* Texas Transportation Institute.

[16]In most metropolitan areas, the idea of "rush hour" is obsolete – congestion happens for multiple hours on both morning and evening weekdays.

[17]Travel Time index is the ratio of actual travel time for a trip compared to the "ideal" travel time for a trip. Thus, a Travel Time Index of 1.3 indicates that the trip takes 30 percent longer than it would under "ideal" or uncongested conditions.

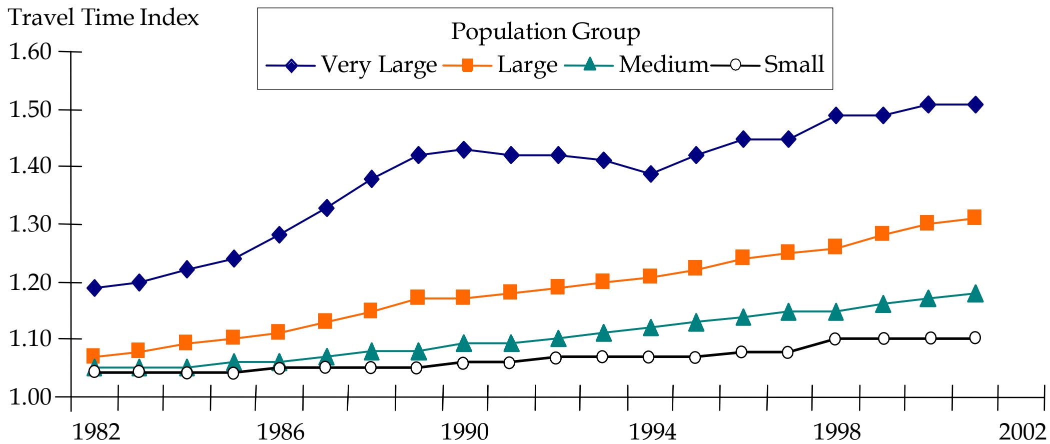
- Sixty-seven percent of the peak-period travel is congested compared to 33 percent in 1982. Each traveler in the top 75 urban areas spent an average of 51 hours per year stuck in traffic in 2001, up from 17 hours in 1982.
- Sixty percent of the major road system is congested compared to 34 percent in 1982.
- The number of hours of the day when travelers might encounter congestion has grown from 4.5 hours to 7 hours.

Why Is This a Problem?

- Congestion isolates people from other activities, such as business, recreation, and family time.
- Congestion results in a less productive work force. Except for the distracted drivers chatting on their cell phones, drivers are not very productive while commuting. And too often they are tense and frustrated when they get to work.
- Service workers do not make as many calls per day if they spend extra time in stop-and-go traffic. This is particularly important for emergency medical, fire, and police services which may be unnecessarily delayed from attending to medical, crime, and disaster situations.
- Congestion leads to increased fuel consumption and automobile emissions (because vehicles are operating less efficiently).
- Congestion caused by unexpected events leads to increased vehicle crashes. When traffic incidents occur, congestion often appears in places where motorists are not expecting it. Rubbernecking and conflicts with emergency vehicles just make the problem worse. Work zones present unexpected changes in highway alignment and other features. By reducing how long traffic incidents and work zones last, we are not only reducing congestion and improving reliability, but making it safer for travelers as well.
- Companies with production schedules timed to take advantage of trucks delivering components to an assembly line as they are needed must instead plan for items to arrive early. This consumes space and inventory, expending resources that could otherwise be spent on productive activity.

Congestion has clearly grown. Congestion used to mean it took longer to get to/from work in the "rush hour." It used to be thought of as a big city issue or an item to plan for while traveling to special large events (Figure 3.1). Sure there was slower traffic in small cities, but it was not much more than a minor inconvenience. The problems that smaller cities faced were about connections to and between cities, manufacturing plants, and markets.

Figure 3.1 Peak-Period Congestion (Travel Time Index) Trends by U.S. Population Group



Source: Reference (1). The Travel Time Index is a measure of the total amount of congestion. It is the ratio of the weekday peak-period travel time to the travel time under ideal conditions. A Travel Time Index value of 1.3 indicates that peak-period travel takes 30 percent longer than under ideal conditions. Population groups are: Very Large (greater than three million); Large (one to three million); Medium (500 thousand to one million); Small (less than 500 thousand).

As the economy and lifestyles have changed over the past two decades, congestion is an element that is more often thought of during the planning stages. Maybe that is the measure of the age we live in, with more meetings and child activities to arrange. Congestion effects also are reflected in decisions about business location and expansion, home and job sites, school, doctor visits, recreation, and social events and even who you date.[18] But it also is due to the fact that congestion affects more trips, more hours of the day and more of the transportation system (Figure 3.2). Congestion is affecting not only weekday commuter travel but several other types of travel: weekend travel in suburban shopping areas, travel near major recreational areas, and travel related to special events (such as sporting events).

Consider the following characteristics of congestion trends:

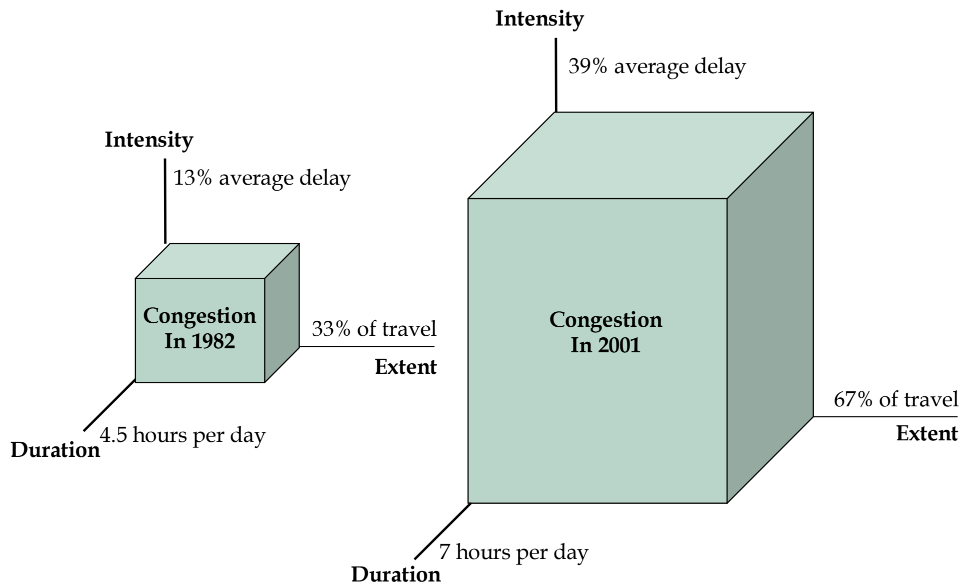
- **Congestion affects more of the system**. You might encounter stop-and-go traffic on any major street or freeway. Congestion effects have spread to neighborhoods, where cities and residents have developed elaborate plans and innovative techniques to make it harder for commuters to use the streets where kids play as bypass routes for gridlocked intersections.
- **Congestion affects more time of the day**. We are not just seeing these problems in the "rush hour." Peak periods typically stretch for two or three hours

[18] Caitlin Liu. Los Angeles Times. "SigAlert on the Roadway to Love; Traffic Sometimes Dictates the Route of Romance in Los Angeles." February 13, 2004.

in the morning and evening in metro areas around one million people (Figure 3.3). Larger areas can see three or four hours of peak conditions.

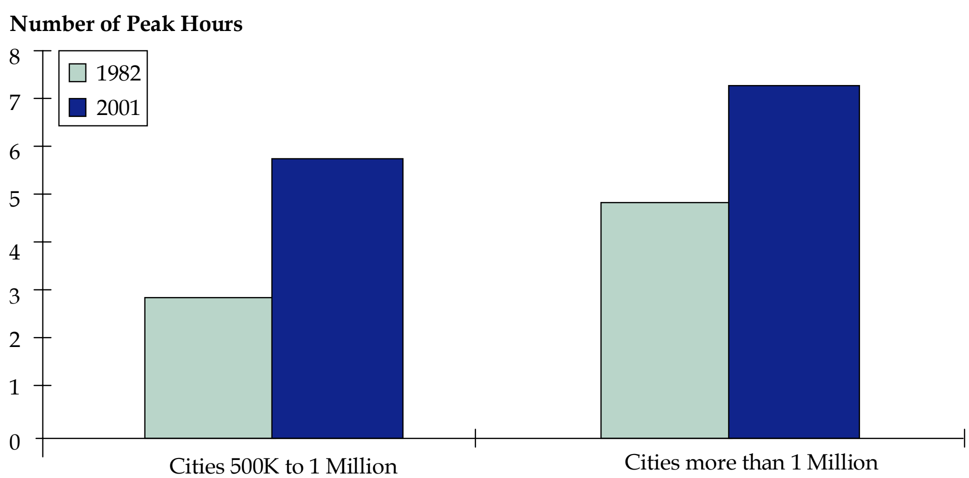
These are just the average conditions. Many cities have a few places where any daylight hour might see stop-and-go traffic. Weekend traffic delays have become a problem in recreational areas, near major shopping centers or sports arenas and in some constrained roadways.

Figure 3.2 Weekday Peak-Period Congestion Has Grown in Several Ways in the Past 20 Years in Our Largest Cities



Source: Analysis of data used in *2003 Annual Urban Mobility Report*, Texas Transportation Institute.

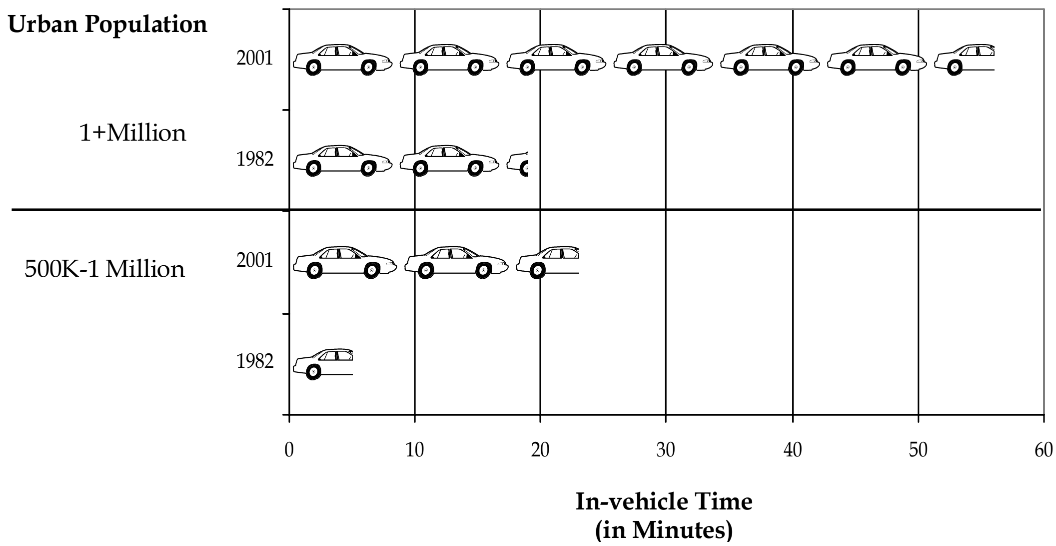
Figure 3.3 How Many Rush Hours in a Day?



Source: Analysis of data used in 2003 Annual Urban Mobility Report, Texas Transportation Institute.

- **The extra travel time penalty has grown**. It just takes longer to get to your destination (Figure 3.4). Not just work or school, but shopping trips, doctor visits and family outings are planned around the questions "How long do I want to spend in the car, bus or train?" and "Is it worth it?" Peak-period trips required 39 percent more travel time in 2001 than a free flow trip at midday, up from 28 percent 10 years earlier.

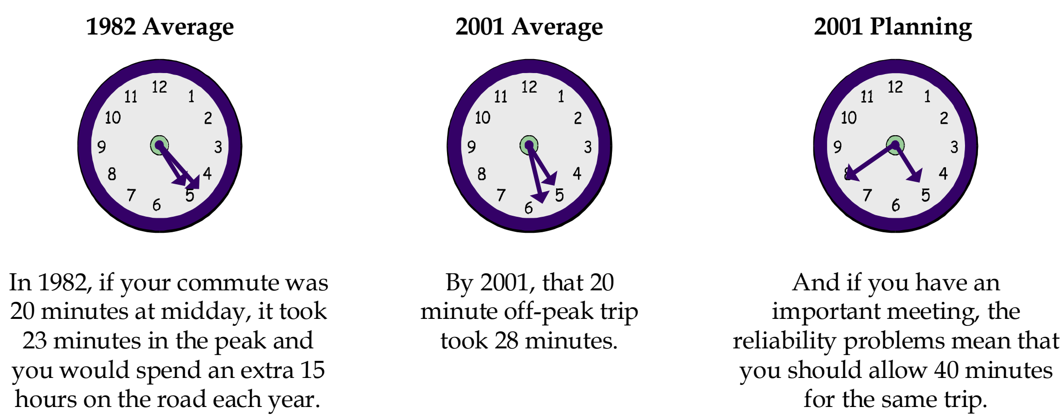
Figure 3.4 In-Vehicle Travel Times for Peak-Hour Trips Have Grown Substantially in Large Cities



Source: Analysis of data used in *2003 Annual Urban Mobility Report*, Texas Transportation Institute.

Travel Reliability is getting worse. There really is a fourth characteristic to the congestion problem – Reliability. The extra travel time and amount of the day and system affected by travel delays is not the same every day. It may not even be as it was predicted 10 minutes ago (Figure 3.5).

Figure 3.5 Travel Time Reliability Illustration



Source: Analysis of data used in *2003 Annual Urban Mobility Report*, Texas Transportation Institute.

- **1982 –** If your midday trip took 20 minutes, it would take you 23 minutes in the peak. Although no reliability statistics exist from that long ago, analysis of recent data suggest that you would have to add an additional nine minutes to that trip to guarantee on-time arrival at your destination; a total of 32 minutes would be planned for that trip.
- **2001 –** By 2001, that 20-minute free-flow trip took 28 minutes.
- **2001 (Planning Time) –** And if on-time arrival was important you should allow 40 minutes for that trip.

Why is Congestion Getting Worse and Where Is It Headed? Highway travel in the United States has been increasing at about two to three percent per year for the past decade; barring serious upheavals in the economy, growth is expected to continue but perhaps at a slower pace. This growth comes on top of a highway system which in many cities already is congested. To understand how congestion grows, consider the following. As traffic volumes rise, speeds stay near the speed limit. It may feel more crowded, but drivers do not slow down. Capacity on a freeway lane is between 2,050 and 2,200 vehicles in an hour (allowing for some trucks); only the last few hundred cars result in any speed decline. As vehicles in an hour reach the upper limit of capacity, speeds drop to a stop-and-go condition. As if that was not enough of a problem, the number of cars carried on the road also drops. So, fewer cars and trucks can use each lane, and once they do begin traveling, it is at a slower speed. This is one of the reasons the economic price of congestion is so high. Congestion robs part of the value of highway investment by causing the highway's capacity to be diminished below the capacity it is capable of conveying. Congestion, in other words, creates massive social and investment inefficiency by actually diminishing the performance capacity of an existing infrastructure asset.

The future holds more of the same. Population and employment growth in America's large cities are expected to continue rising by around two percent each year, resulting in longer periods of congestion on more of the transportation system. Tables 3.1 and 3.2 present forecasts of population and economic activity – strong drivers of transportation activity – along with forecasts of system-level transportation activity. The tables show that compared to year 2000:

- By 2025, the U.S. population will grow by 26 percent;
- By 2025, the Gross National Product will double;
- By 2025, passenger-miles (all modes, including highway, air, and transit) will grow by 72 percent; and
- By 2020, intercity truck tonnage will grow by 75 percent.

Table 3.1 Forecasts of Passenger Transportation System Activity

Activity	2000	2010	2025
Population (millions)	276	309	347
GDP ($2,000 billion)	9,834	13,043	19,816
Vehicle-Miles (billions)	2,424	3,041	4,173
Licensed Drivers (millions)	213	244	274
Vehicles (millions)	215	262	326

Source: U.S. Department of Transportation, Bureau of Transportation Statistics, http://www.eia.doe.gov.

Table 3.2 Forecasts of Freight Transportation System Activity

	Tons (Millions)		
Mode of Travel	**1998**	**2010**	**2020**
Total	15,271	21,376	25,848
Domestic			
Air	9	18	26
Highway	10,439	14,930	18,130
Rail	1,954	2,528	2,894
Water	1,082	1,345	1,487
Total, Domestic	13,484	18,820	22,537
International			
Air	9	16	24
Highway	419	733	1,069
Rail	358	518	699
Water	136	199	260
Other (including pipeline)	864	1,090	1,259
Total, International	1,787	2,556	3,311

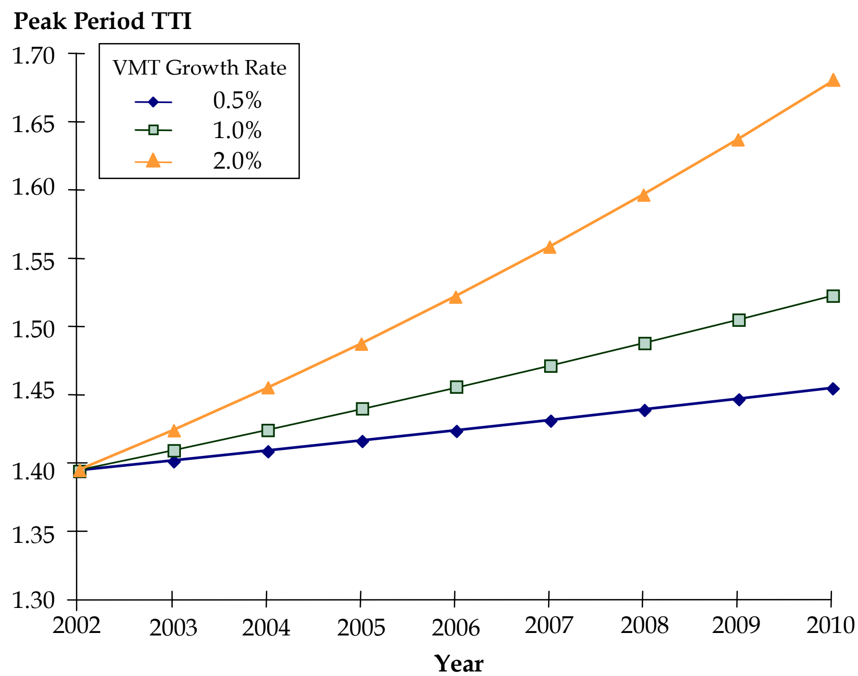
Source: FHWA Freight Analysis Framework, http://www.ops.fhwa.dot.gov/freight/freight_news/FAF/talkingfreight_faf.htm.

Keeping up with this increased demand for transportation services will be extremely challenging, and will require new ways of thinking about the problem. For highway travel alone, addressing the growth in demand will be particularly tricky. Figure 3.6 shows the effect of different growth rates for travel (as measured by vehicle-miles of travel) on congestion (as measured by the Travel Time Index, or TTI). The effect of adding increased demand on top of an already congested peak-period highway system can be easily seen – note the steep growth in congestion for the two percent per year growth compared to the 0.5 percent growth. These forecasts assume that no improvements to the transportation system will be made over the 2002 to 2010 period, which is clearly not the case.

However, they can be used to illustrate two significant points about congestion growth:

1. The effect of "doing nothing" to the transportation system is probably intolerable. Under the two percent VMT growth rate – roughly a continuation of recent trends – peak-period congestion will worsen substantially.
2. The effect of strategies aimed at controlling VMT growth – and controlling congestion in general – can have a dramatic impact on controlling congestion growth. Strategies that reduce VMT directly (such as demand management controls discussed in the next section) can lead to a substantial slowdown in congestion growth. Likewise, congestion mitigation strategies can have the same effect by increasing physical capacity, shifting demand, and improving roadway operations. ***In other words, congestion mitigation strategies can produce the same effect as reduced VMT growth. When used in combination, demand management and mitigation strategies can have a powerful impact on congestion growth.***

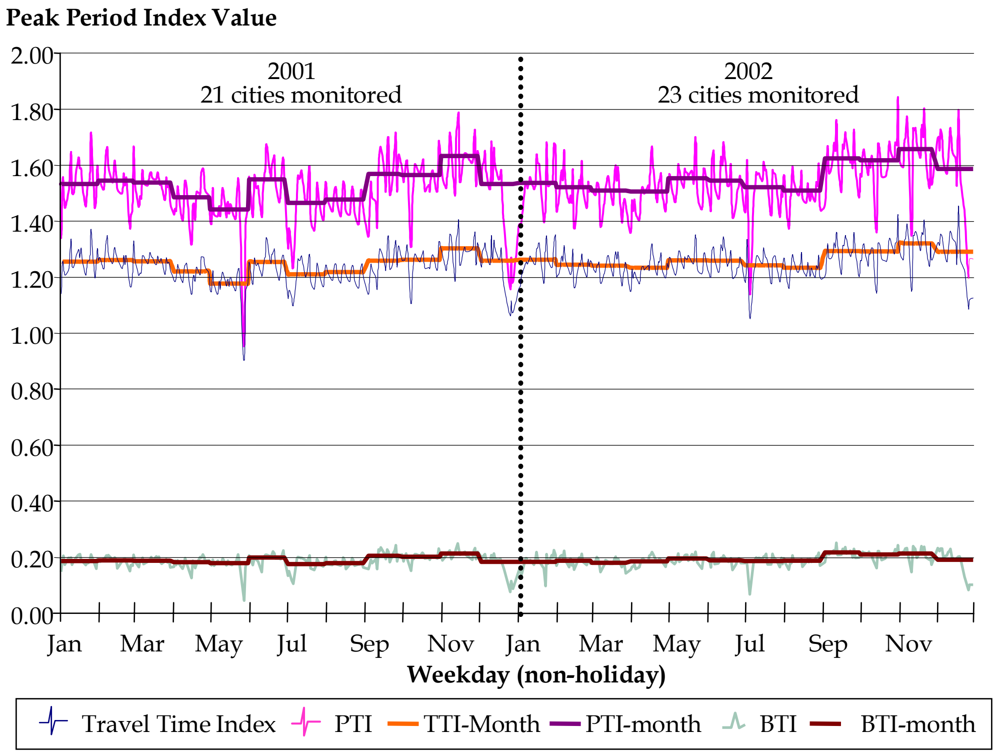
Figure 3.6 Projected Growth in Urban Freeway Congestion
(Bottleneck-Related) under Different VMT Growth Rates, 2002-2010 (Top 78 Metro Areas)



Source: Analysis of 2002 HPMS data using the Surface Transportation Efficiency Analysis Model (STEAM) delay relationships (http://www.fhwa.dot.gov/steam/). The analysis assumes that no additional highway improvements are made. The Travel Time Index (TTI) is a measure of total congestion. It is the ratio of the peak-period travel time to the travel time under ideal conditions. A TTI value of 1.4 indicates that peak-period travel takes 40 percent longer than under ideal conditions.

What Are the Trends in Reliability at the Metropolitan Level? Only recently have we defined reliability and started to measure it. Part of the problem is related to the availability of data. Because reliability is defined by how travel times vary, a continuous history of travel times is needed to measure it. Archived data from traffic management centers are starting to be used for this purpose. Figure 3.7 shows travel time and reliability statistics from 2001 and 2002. Although it is difficult to note trends with only two years of data, this is just the beginning of our monitoring of reliability. As we begin to track more cities for more years, we will be able to observe long-term changes in reliability.

Figure 3.7 Travel Time and Reliability Trends
2001-2002

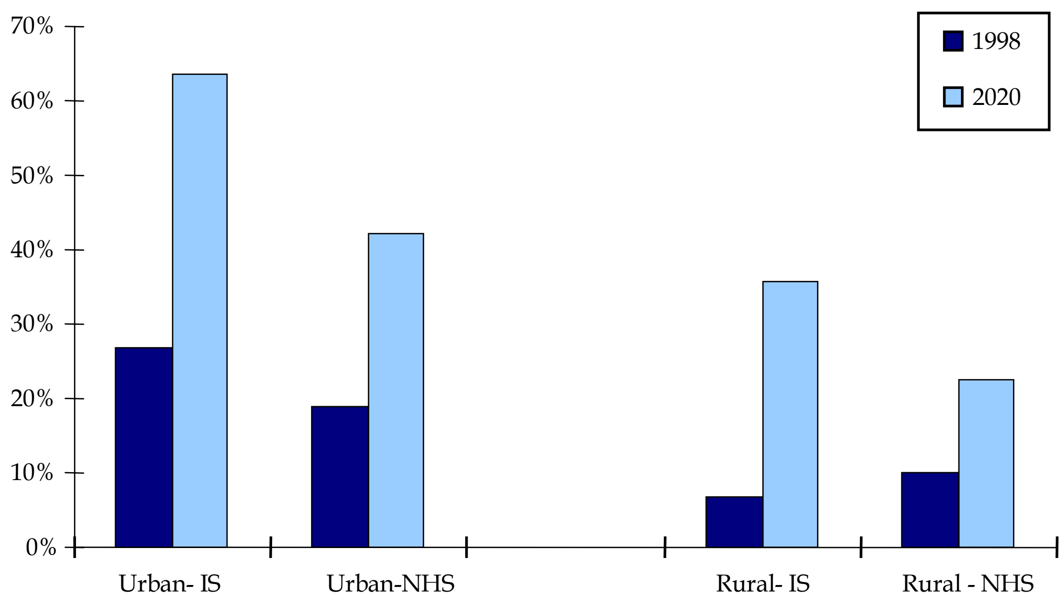


Source: Analysis of data from FHWA's *Mobility Monitoring Program*. The Travel Time Index (TTI) is a measure of total congestion. It is the ratio of the peak period travel time to the travel time under ideal conditions. A TTI value of 1.2 indicates that peak period travel takes 20 percent longer than under ideal conditions. PTI is the Planning Time Index, the 95th percentile of the Travel Time Index. BTI is the Buffer Time Index. (See Appendix for definitions.) All are shown for individual days. The "-Month" indices are monthly averages and are shown to smooth out the trends. Although weekends and holidays are excluded, days next to holidays show light peak-period traffic characteristics (e.g., July 5). Note the upturn in peak period delay and unreliability in the Autumn months as vacationing travelers return to work and school. Note also that as the Travel Time Index increases, so does unreliable travel.

Is Congestion Growing in Medium and Small Cities as well as Rural Areas? For the time being, most of the congestion outside of cities is related to work zones, poor weather, and traffic incidents. This rural congestion is very small compared to that experienced in metropolitan areas. However, there are indications that this could change considerably.

Demand for freight transportation in the United States is expected to grow substantially over the next 15 years. Figure 3.8 displays this dramatic expected growth. The most striking growth is expected to be on rural Interstate highways, indicating the potential for congestion to spread outside of metropolitan areas. The potential for non-metropolitan congestion is further indicated by the growth in total traffic on rural Interstates over the past decade. Since 1992, traffic has grown substantially on rural highways and at a faster pace than on metropolitan highways. Table 3.3 shows that between 1992 and 2002, traffic on rural Interstates increased 36 percent compared with an increase of 26 percent on urban Interstates. Further analysis shows that traffic volumes per available lane increased by 35 percent on rural Interstates compared with 23 percent on urban Interstates.

Figure 3.8 Percentage of Highway Segments with over 10,000 Trucks Per Day
Comparison of 1998 to 2020



Source: Analysis of data from the Freight Analysis Framework.

Table 3.3 Growth in Interstate Highway Traffic
1992-2002

Traffic Statistic	Rural Interstate Growth	Urban Interstate Growth
Total Daily Volume	+36%	+25%
Daily Volume per Traffic Lane	+35%	+21%

Source: Analysis of Highway Performance Monitoring System data.

Forecasts of future traffic on the National Highway System demonstrate the magnitude of this problem, assuming that the existing highway system is not improved by 2020. Specifically, by comparing Figures 3.9 and 3.10 side-by-side, it is apparent that the congestion-causing potential for trucks is great. Without trucks, most congestion would reside within major metropolitan areas (Figure 3.9). When trucks are added to the highway system, congestion spreads into what are now essentially rural corridors (Figure 3.10).[19]

Analysis of major urban bottlenecks with regard to trucks also is revealing (Figure 3.11). This analysis used the bottleneck locations identified in the recent American Highway Users Alliance study along with the same truck forecasts used in Figures 3.9 and 3.10 at these locations. When trucks are removed from these bottlenecks, delay is substantially reduced, but is still present at relatively high levels. Since these bottlenecks are dominated by weekday commuter traffic, this is to be expected. Trucks can be expected to have a greater proportional effect on congestion where bottlenecks are located in smaller urban, urban fringe, and rural areas.

In addition to these bottlenecks which are primarily related to mixing urban commuting and trucking, bottlenecks that primarily affect trucks also exist. These include border crossings with Canada and Mexico and local access highways to intermodal facilities, such as ports. In fact, a recent study of border crossings indicates that trucks can be delayed on average 30 minutes each time they try to cross from Mexico into the United States.[20] Border delays – and the increased transportation costs they create – can seriously affect international trade between the United States and Canada and Mexico. Also, because trade is increasing between Canada and Mexico, delay to shipments on interior U.S. highways increases the costs of performing this trade. In essence, ***congestion on U.S. highways has become an international – not just a national – problem.***

[19]The Freight Analysis Framework provided the data for Figures 3.9 and 3.10.

[20]Texas Transportation Institute and Battelle Memorial Institute, *International Border Crossing Truck Travel Time for 2001*, prepared for Office of Freight Management and Operations, FHWA, April 2002.

Figure 3.9 2020 Congestion Forecasts, No Trucks

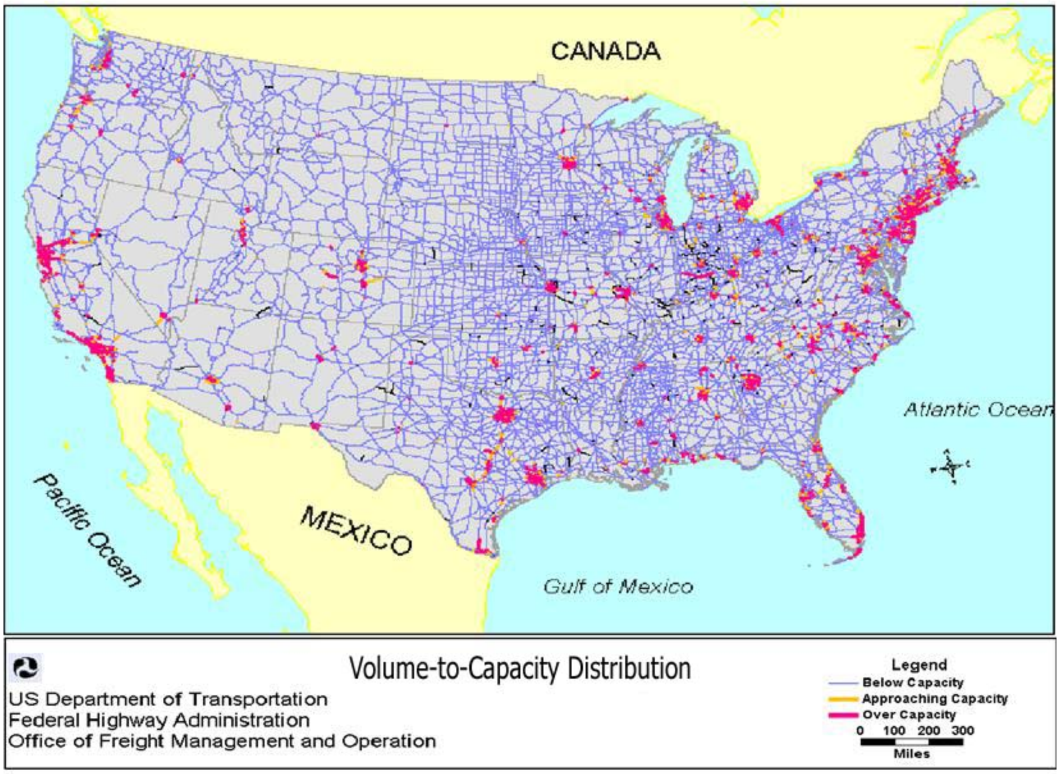


Figure 3.10 2020 Congestion Forecasts, With Trucks

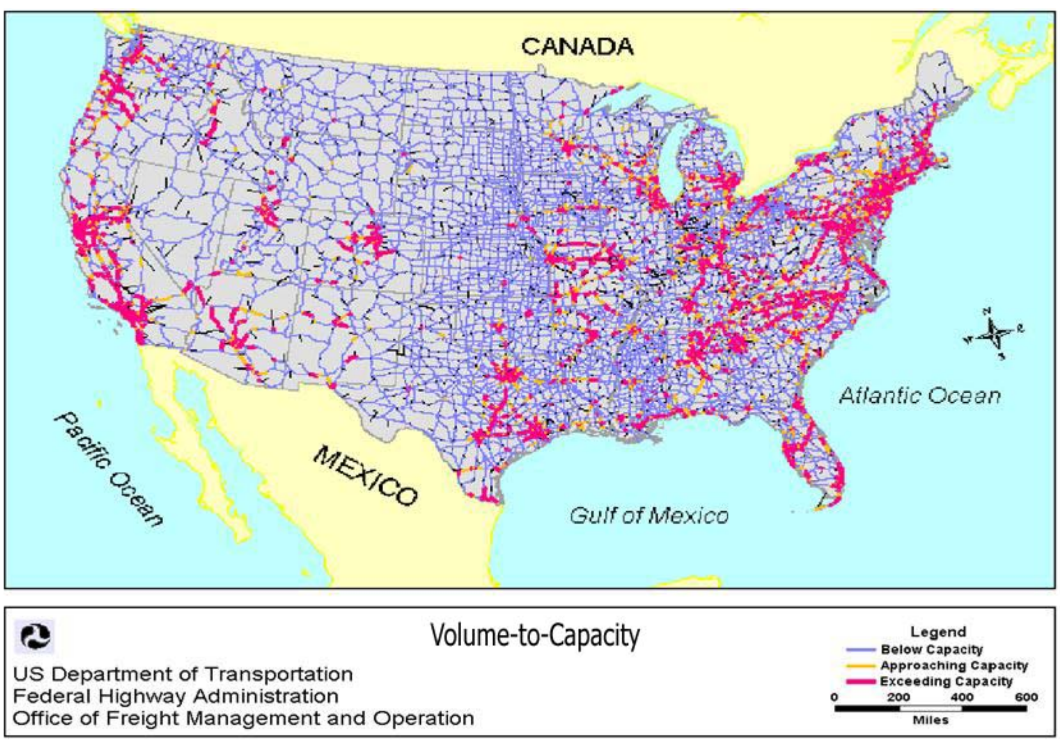
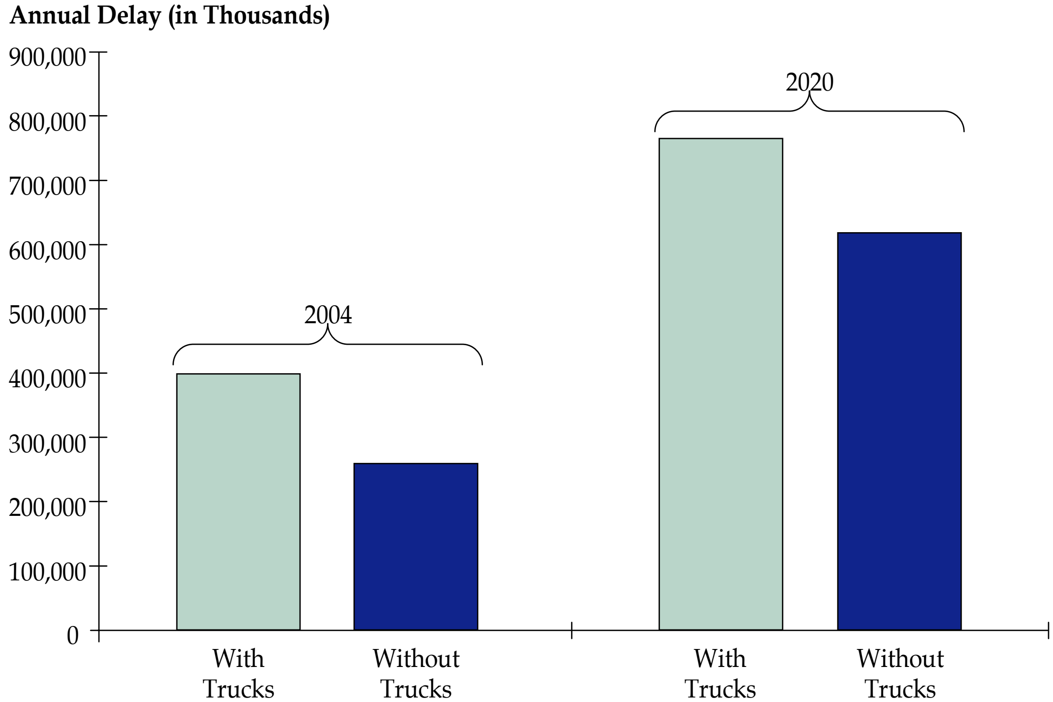


Figure 3.11 Effect of Trucks on Delay at the 50 Worst Urban Bottlenecks



Source: Unclogging America's Arteries, American Highway Users Alliance, 2004 and analysis of Freight Analysis Framework data.

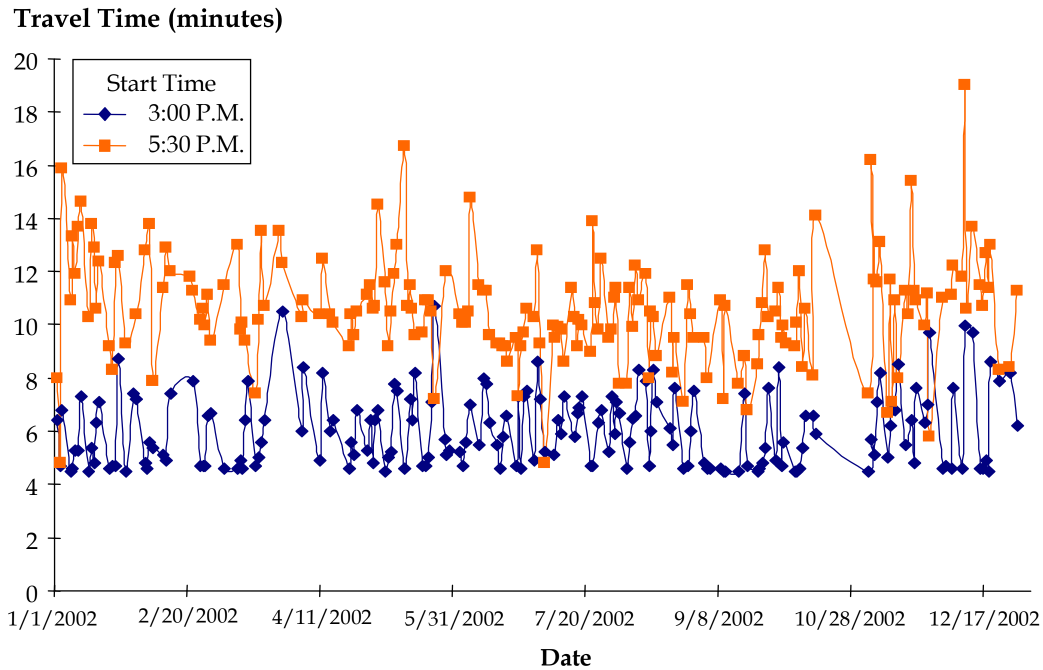
3.2 Congestion and Everyday Life

Transportation professionals tend to think of congestion in aggregate terms – congestion is a "system" problem that happens on our highway system. Yet every day, travelers are faced with the consequences of congestion and must manage their daily activities around it. In this section, we explore how congestion affects everyday life in the United States.

1. A Traveler's-Eye View of Reliability

The statistics and measures presented earlier offer transportation professionals insight into the nature of travel time reliability. However, travelers probably take a slightly different view of the situation. Returning to the data from I-75 in central Atlanta used earlier in Section 2.0, we take a more traveler-oriented perspective on travel times in the corridor. Consider a traveler who has the flexibility to adjust his or her work schedule so that they can be traveling the corridor either at 3:00 p.m. or 5:30 p.m. on most days (Figure 3.12).

Figure 3.12 Travel Times in Central Atlanta, I-75 Southbound
I-85 to I-20

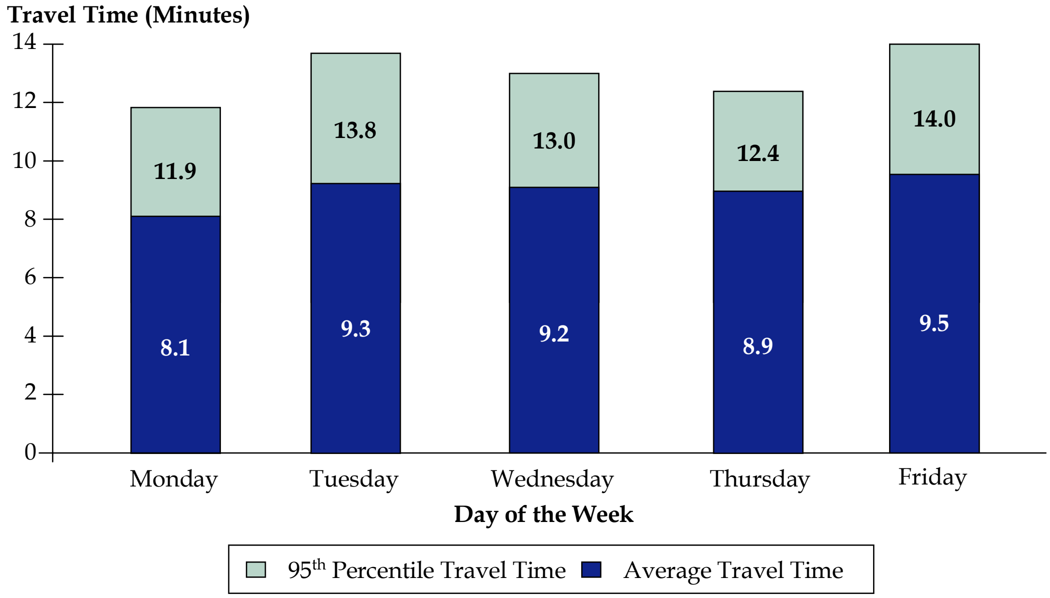


Source: Analysis of data from FHWA's *Mobility Monitoring Program.* The highway segment covered is 4.05 miles long. Travel times are for trips that begin at the northern end of the corridor starting at 3:00 p.m. and 5:30 p.m., traveling south. Trips that begin at 3:00 p.m. take less time to make it through the corridor AND are more reliable (less "noise" in their day-to-day fluctuations).

From these data, it is clear that travel at 3:00 p.m. is both less congested and more reliable (less variable). In other words, the traveler can better ***predict*** what travel time will be at 3:00 p.m. than at 5:30 p.m. Why is this important? If a commuter has a routine activity that must occur every day – such as picking up children from day-care – it means that at 5:30 p.m. they must plan on an extra amount of trip time just to be sure they do not arrive late. The same goes for local trucking firms engaged in pickup and delivery of goods.

Savvy commuters also understand that some days predictably are worse than others. Figure 3.13 shows the average travel and the 95th percentile travel time (the Planning Time Index) by day of week for this four-mile corridor. Fridays are clearly the worst, and if travelers must plan on a travel time of 14 minutes (average speed of 17 mph) just to be reasonably safe. It is also easy to predict that congestion and unreliable travel times will be worse than normal on days when adverse weather (snow, rain, fog, etc.) occurs.

Figure 3.13 Central Atlanta, I-75 Southbound
Weekdays between 4:00 and 7:00 p.m.

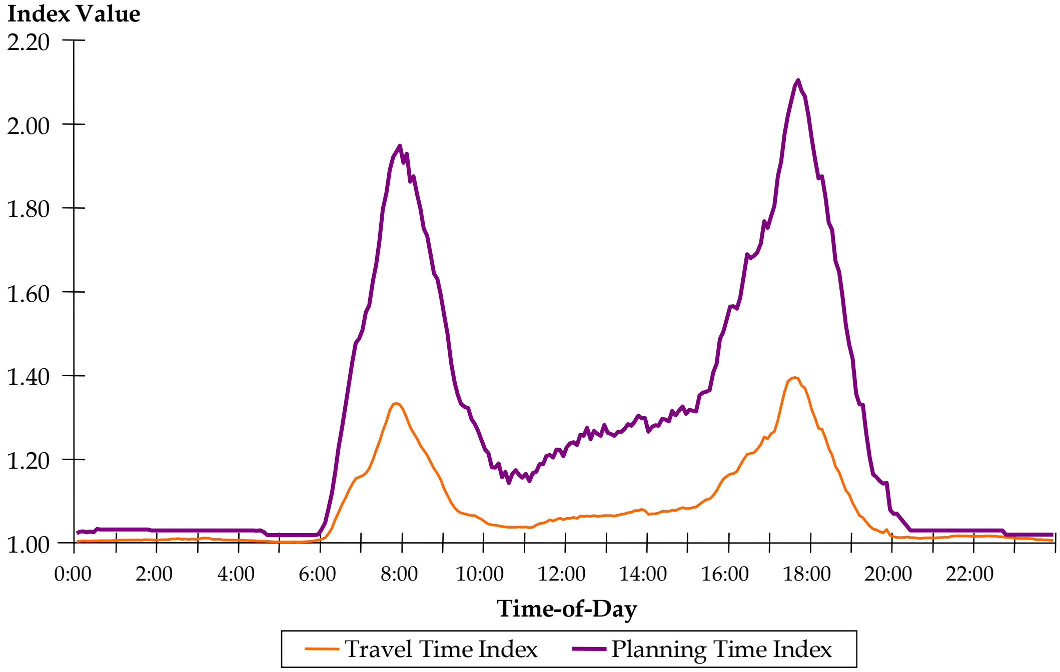


Source: Analysis of data from FHWA's *Mobility Monitoring Program.* The 95th percentile travel time indicates what travel time is on some of the "worst traffic days."

2. Local Businesses Learn to Deal with Congestion

Travel time reliability problems only get worse as the system gets more congested. People react by trying to alter their trip departure time or route. Businesses might increase the number of delivery trucks, or move their product overnight or in the middle of the day to avoid traffic tie-ups. But at some point, the inefficiencies take a toll. Manufacturers must devote more plant space to storing inventory because they cannot be as sure of the delivery schedule. Service providers need more staff, vehicles, and equipment to cover the same area. This might mean more jobs, but each job does not produce as much income when work time is spent "in-route" rather than "on-the-job." Figure 3.14 dramatically displays the problem. Shippers must base their plans by adding a "buffer" to normal travel times to account for unpredictability in the transportation system. In other words, they must use the Planning Time Index, not the Travel Time Index which only describes average conditions.

Figure 3.14 Variations in Congestion by Time-of-Day



Source: Analysis of data from FHWA's *Mobility Monitoring Program*. The Planning Time Index is the 95th percentile Travel Time Index.

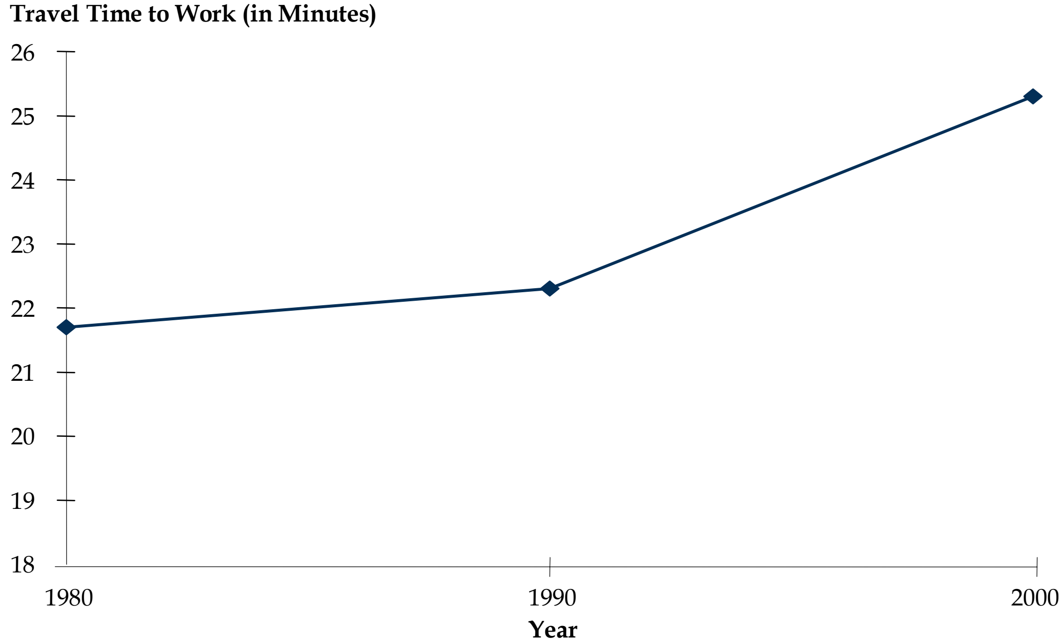
3. Changing Lifestyles, Changing Travel

As people move through life, two significant choices they make are where to live and where to work. These choices can change over time and influence where, when, and how much congestion occurs on highways. For example, a young couple just entering the job market may decide to live in an urban setting while older couples with children may choose to live in the suburbs. Often these suburbs are in formerly rural areas on the urban fringe, and are significant distances away from traditional downtown employment areas. The decision to move into these fringe areas is influenced by a number of factors – affordable housing, newer schools, more open space, and, in some cases, avoiding congestion close in to cities. In response, many employers are following, moving their business locations closer to where prospective employees live and taking advantage of lower land prices.

This ability of both residents and employers to move around the urban landscape has effects on congestion. First, by housing and jobs moving further out into the suburbs, individuals can keep their travel times to work relatively stable. However, these new travel patterns also result in congestion on roadways that were previously only lightly used. Of course, some folks will still choose the longer commute into central areas – this will cause an increase in congestion on those already crowded roads.

The stability in work trip travel times may be a temporary condition. Recent evidence from the decennial Census suggests that even those who live and work in the suburbs may be experiencing increased travel times to work (Figure 3.15).

Figure 3.15 Average Travel Times to Work
1980-2000



Source: Census Journey-to-Work data, as compiled by Alan Pisarski.

Between 1980 and 1990, work travel times were relatively stable, but have increased by three minutes per trip between 1990 and 2000. While three minutes per trip (six minutes per day for trips to and from work) may not seem like a lot, it is 25 extra hours each year. The increase indicates that we may not be able to escape congestion just by spreading our activities to larger areas. Also, as shown earlier, as congestion grows, so does the unreliability of travel times. Therefore, as congestion builds, commuters have to budget even more time onto their trips if they do not want to be late.

4. Congestion and Trucking: How Congestion Costs Us All

Congestion has real costs for all travelers, including truckers (both long-haul and local pickup and delivery), household and business service providers (such as plumbers, computer technicians, police, and ambulance services), and personal travel (such as commuters, vacationers, and shoppers). Congestion causes more fuel to be used and more emissions to be produced. The extra time spent in congestion causes service providers to make fewer calls per day, leading to higher prices for consumers; this is particularly important for emergency medical, fire, and police services which may be unnecessarily delayed from attending to medical, crime, and disaster situations. Companies with production schedules timed to take advantage of trucks delivering components to an assembly line as they are needed must instead plan for items to arrive early. This consumes space and inventory, expending resources that could otherwise be spent on productive activity. For personal travelers, congestion "steals" time that could be put to better use in the workplace or for social or recreational purposes.

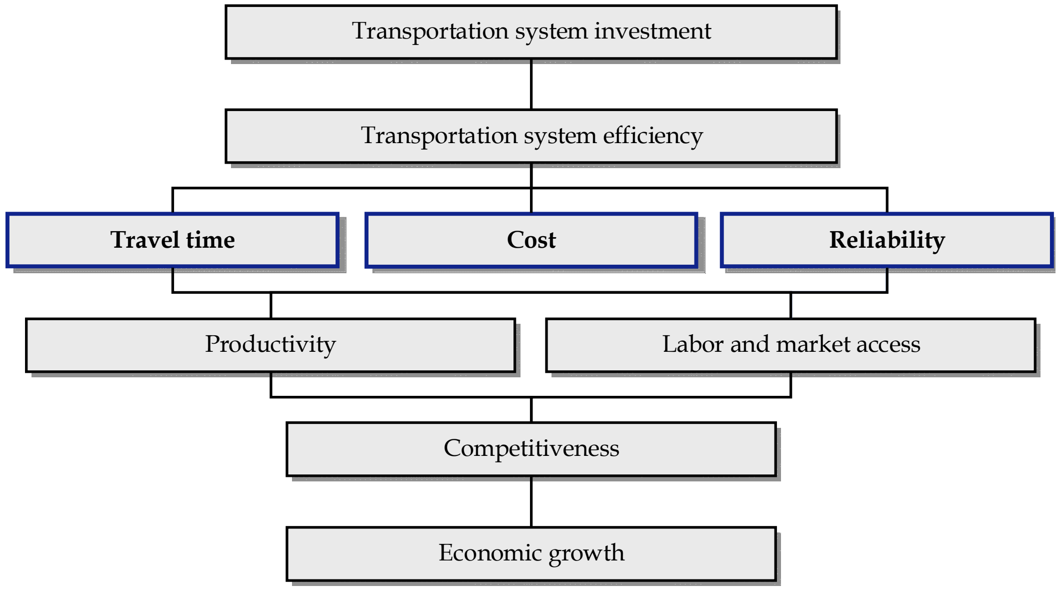
In recent decades, the freight transportation system has been in transition from an era focused primarily on system construction toward an era that will focus increasingly on system optimization. Past efforts at developing the transportation infrastructure were oriented around system construction. The railroads in the 19th century and the highway system in the twentieth century connected all parts of the nation, and opened up markets for moving freight and passengers. Today, these systems are extensive and mature. Ports, airports, and other freight systems have been developed, and technological and management change has increasingly focused on optimizing the use of available physical assets. Those mature assets require large expenditures of resources to maintain and preserve asset conditions, meaning that fewer resources are available to build new capacity.

Freight transportation has gone through many changes over the past 20 years as it has adapted to changes in business practices. Within this new operating environment, freight operations and productivity have been optimized to work closely with other aspects of business activity. Deregulation has resulted in excess capacity being eliminated from the highway and rail freight systems. Intermodal services and facilities have revolutionized international trade. Ports and airports have seen services and demand grow rapidly. Freight services are now more efficient and in many cases lower in cost (in constant dollars) than in previous decades. But the elimination of excess capacity has resulted in systems with less redundancy and less ability to withstand shocks or disruptions. Congestion is growing on many key freight segments of the transportation system, and congestion can drastically reduce the productivity of the overall freight network. The delay caused by congestion could vastly increase the costs of those freight movements that are today managed to exacting schedules.

Time is literally money for trucking interests. As shown in Figure 3.16, a direct linkage exists between transportation investment, travel conditions (congestion and reliability) and economic productivity. For trucking, two key trends identified above will have a substantial impact on the total cost of moving freight:

1. As congestion spreads into the midday period, which is the peak travel period for trucks, more direct costs will be incurred; and
2. Reliability – for trucks, the ability to hit delivery windows predictably will decrease and will add even more costs as firms struggle to optimize delivery schedules. This is especially a problem for truckers who must meet "just-in-time" delivery schedules set by shippers and manufacturers.

Figure 3.16 Economic Effects of Transportation



In 1999, purchases of transportation-related goods and services accounted for 10.6 percent ($980 billion) of GDP.[21] The diverse and extensive list of purchases includes the services of for-hire freight carriers, vehicles, parts, maintenance, and fuel. Only housing, health care, and food account for a greater share of GDP. Transportation accounts for a share of the final price of a product, ranging from one percent to 14 percent, depending on the commodity and distance moved.[22] Thus, changes in the physical condition and operating characteristics of the highway system can have a major effect on the final price of goods and services. Improvements in freight transportation productivity (such as reduced costs due to congestion) contribute to the economy by helping the United States remain competitive in international trade.

All of this adds up to a staggering amount of costs imposed on travelers by congestion. The Texas Transportation Institute estimates that in 75 of the largest U.S. cities in 2001, $69.5 billion dollars are wasted in time and fuel costs.[23] (The costs are a composite of automobile and truck travel costs in urban areas.) The time value costs used for trucks in this calculation are conservative – they include only the cost of truck operating time, primarily the cost of drivers' wages and equipment. The value of the cargo and the response of firms to higher

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[21] Status of the Nation's Highways, Bridges, and Transit: 2002 Conditions and Performance Report.

[22] U.S. Department of Transportation, Bureau of Transportation Statistics, Transportation Satellite Accounts.

[23] Schrank, D. and Lomax, T., 2003 Annual Urban Mobility Report, Texas Transportation Institute.

transportation costs are not included, yet recent work suggests these costs can be significant. These costs include:

- **Foregone Investment Opportunities –** Higher transportation costs due to congestion reduce a firm's ability to invest in making more products, improve product quality, and introduce new products; and
- **Decreases in Regional Employment or Decreases in the Rate of Growth of Regional Income** – Higher transportation costs are passed onto other sectors of the economy and hinder general economic efficiency.[24]

[24] ICF Consulting, HLB Decision Economics, and Louis Berger Group, *Freight Benefit/Cost Study: Capturing the Full Benefits of Freight Transportation Improvements: A Non-Technical Review of Linkages and the Benefit/Cost Analysis Framework*, May 11, 2001.

4.0 How Can We Deal with Congestion?

4.1 The Toolbox for Congestion Relief

What Can We Do About Traffic Congestion?

The Atlanta experience described above is a good synopsis of potential strategies that can be used against congestion. Transportation engineers and planners have developed a variety of strategies to deal with congestion (Figure 4.1). These fall into three general categories:

1. **Adding More Capacity – Increasing the Number and Size of Highways and Providing More Transit and Freight Rail Service.** Adding more lanes to existing highways and building new ones has been the traditional response to congestion. In some metropolitan areas, however, it is becoming increasingly difficult to undertake major highway expansions because of funding constraints, increased right-of-way and construction costs, and opposition from local and national groups. However, it is clear that adding new physical capacity for highways, transit, and railroads is an important strategy for alleviating congestion. In many locations, it is the lack of physical capacity that contributes the most to congestion. In such locations, the addition of new capacity is critical. Further, the addition of new capacity presents an excellent opportunity to combine it with other types of strategies. This often means that highway designers must think "outside the box" and find creative ways to incorporate new designs that accommodate all stakeholders' concerns. Since the worst highway bottlenecks tend to be freeway-to-freeway interchanges, advanced design treatments that spread out turning movements and remove traffic volumes from key merge areas have been developed, often by using multilevel structures that minimize the footprint of the improvement on the surrounding landscape.

   Adding new freeways or additional lanes to existing freeways will add large amounts of capacity to the roadway network. However there are other components of the transportation system that can be enhanced that will alleviate congestion, albeit in a more localized area. Widening arterial roads, providing street connectivity, provide grade separations at congested intersections and providing high-occupancy vehicle (HOV) lanes all will help to mitigate congestion. Also, adding capacity to the transit system, whether it is to the bus system, urban rail system or commuter rail system will assist in relieving congestion on the roadway network. Finally, adding capacity to the intercity rail system can reduce the use of highways by trucks.

Figure 4.1 A Variety of Strategies, When Used in Combination, Can Effectively Deal with Congestion

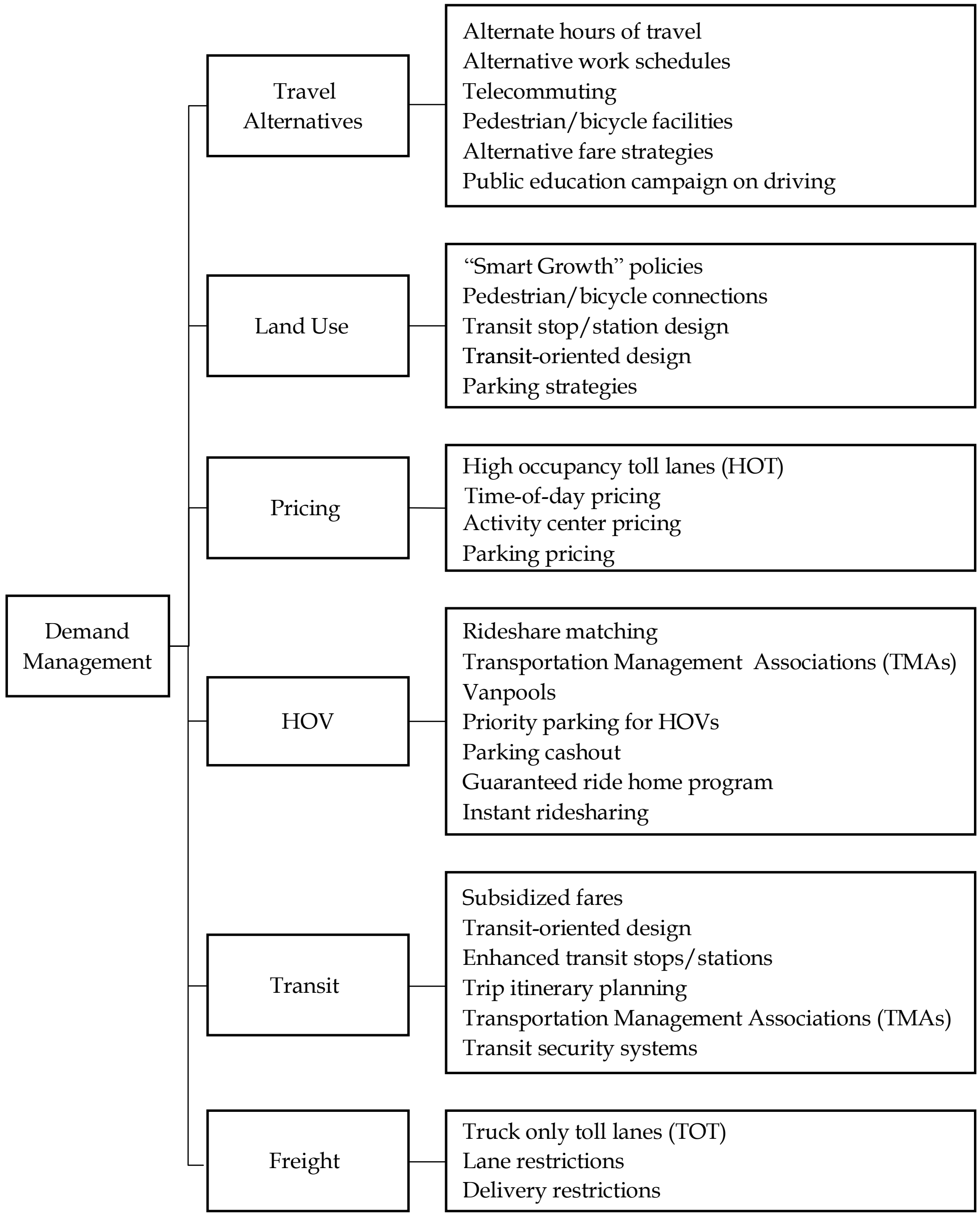
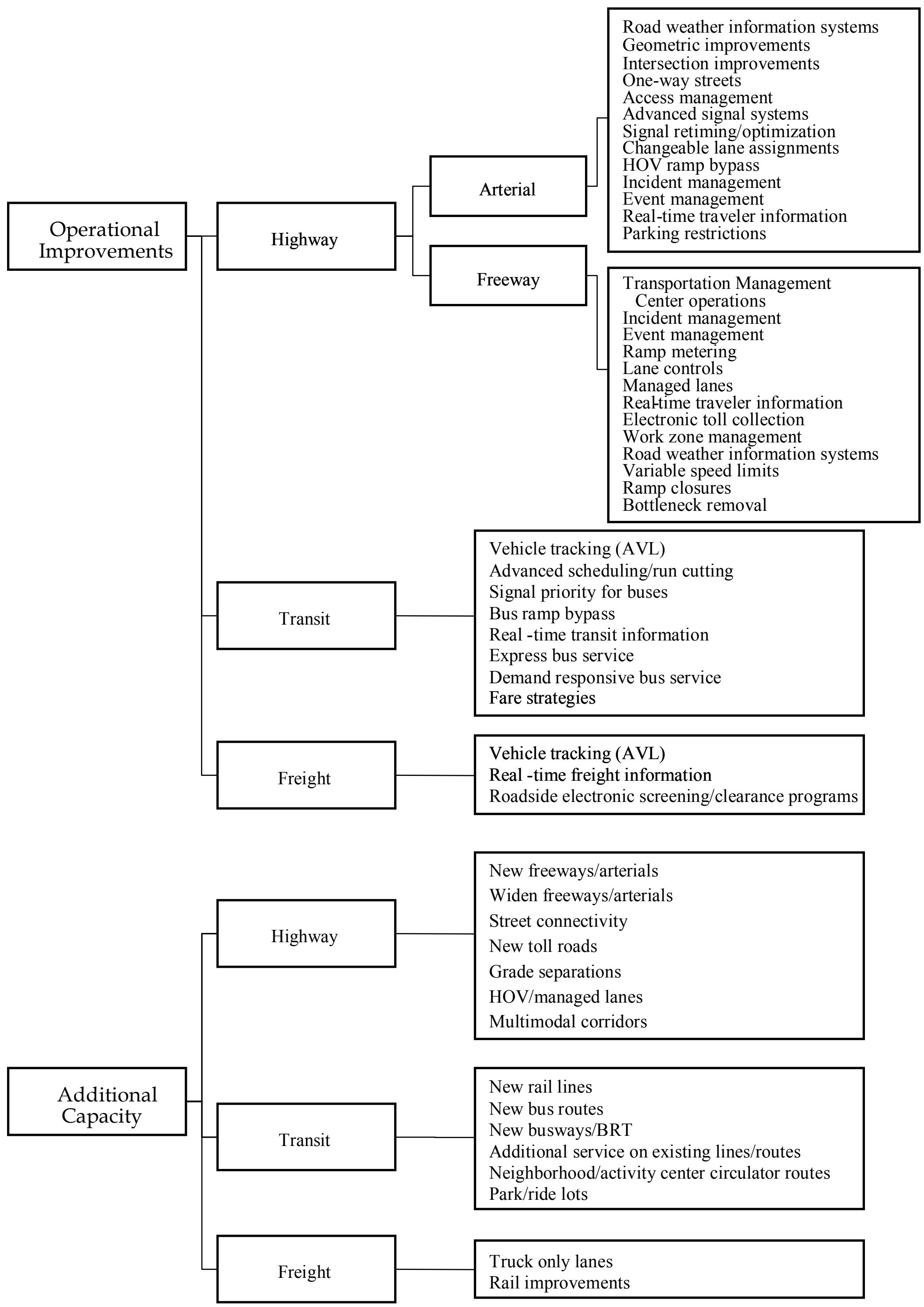


Figure 4.1 A Variety of Strategies, When Used in Combination, Can Effectively Deal with Congestion (continued)



2. **Operating Existing Capacity More Efficiently – Getting More Out of What We Have.** ("Operational Improvements" in Figure 4.1). In recent years, transportation engineers and planners have increasingly embraced strategies that deal with the *operation* of existing highways, rather than just building new infrastructure. The philosophy behind Transportation System Management and Operations (TSM&O) is to mitigate the effects of roadway events and to manage short-term demand for existing roadway capacity. TSM&O includes the application of advanced technologies using real-time information about highway conditions to implement control strategies. Collectively referred to as Intelligent Transportation Systems (ITS), real-time control of highway operations through a transportation management center (TMC) has become a major activity undertaken by transportation agencies. ITS control strategies take many forms: metering flow onto freeways, dynamically retiming traffic signals, managing traffic incidents, and providing travelers with information about travel conditions, alternative routes, and other modes. ITS is also used to improve transit service and freight activities. In addition to ITS, other TSM&O strategies to improve the efficiency of the existing road system have been implemented, including reversible commuter lanes, movable median barriers to add capacity during peak periods, and restricting turns at key intersections. There are numerous congestion mitigation strategies that are enhanced by the use of advanced technologies or ITS. These strategies are highlighted in italics in Figure 4.1. There are several other effective strategies that do not rely on advanced technology, including geometric improvements to roads and intersections, converting streets to one-way operations and access management.

   The idea behind TSM&O strategies is to increase the efficiency of the *existing* transportation infrastructure. That is, roadway events essentially "steal" roadway capacity and TSM&O seeks to get it back. The deployment of TSM&O strategies and technologies is increasing and evaluations have shown their impact to be highly cost-effective. However, relying on TSM&O alone is a limited approach to addressing the congestion problem. A sound base infrastructure already must exist before TSM&O can be used. Also, only so much extra efficiency can be squeezed out of an already stressed highway system.

   Improving the efficiency and reliability of the freeway, street, transit, and freight systems is an aspect of the transportation program that in many cases can be accomplished in shorter time, with more public support and at a lower cost than some other strategy groups. The size of the benefits from any single project may not be of the magnitude of a new freeway lane or rail transit line, but the cost and implementation time also are not as high. One key to understanding the benefits from operational projects is to think of these strategies as enhancing the return on investment in the infrastructure projects.

3. **Encouraging Travel and Land Use Patterns that Use the System in Less Congestion Producing Ways – Travel Demand Management (TDM), Non-Automotive Travel Modes, and Land Use Management.** ("Demand Management" in Figure 4.1.) Other approaches to the problem of congestion involve managing the demand for highway travel. These strategies include putting more people into fewer vehicles (through ridesharing or dedicated highway lanes for high-occupancy vehicles), shifting the time of travel (through staggered work hours), and eliminating the need for travel altogether (through telecommuting). The major barrier to the success of TDM strategies is that they require an adjustment in the lifestyles of travelers and the requirements of employers. Flexible scheduling is simply not possible for a large number of American workers, which limits the effectiveness of TDM strategies. Investing in non-automotive modes of travel – such as rail and bus transit systems and bikeways – is another strategy for reducing the number of personal use vehicles on the highway system. These approaches can be an excellent supplement to the highway system, particularly for commuter trips. However, in most metropolitan areas, the level of investment required to meet transportation demand solely through these means is massive and infeasible. Another approach that is being recently considered in many urban areas is managing demand through pricing schemes. Pricing strategies include charging for the use of HOV lanes either by the number of persons in the vehicle or by time of day or both and variable parking charges depending on location, vehicle occupancy, or time of day. Still, when considered as part of an overall program of transportation investments, TDM and non-automotive modes of travel can contribute substantially to a metropolitan area's transportation system.

   Land use management is another type of strategy that can influence congestion. The historical cycle of suburban growth has led to an ever increasing demand for travel. Suburban growth was originally fueled by downtown workers who moved from city centers to the urban fringe to take advantage of lower land prices and greater social amenities. In the past 20 years, businesses also have moved to the suburbs to be closer to their employees and to take advantage of lower rents. This in turn allows workers to live even further away from city centers, thereby perpetuating suburban expansion. To influence these processes, strategies that attempt to manage and direct urban growth have been used in several metropolitan areas. These include land use controls (zoning), growth management restrictions (urban growth boundaries and higher development densities), development policies (transit-oriented design, which provides land use densities and forms to favor transit use) and taxation policy (incentives for high-density development). The main problem with many of these strategies is that they often are contrary to market trends, burdening consumers with extra costs and dampening economic efficiency, at least in the short term. Unless a truly regional approach is followed – with cooperation of all jurisdictions within the region – sprawl may simply be pushed into areas not conforming to growth policies.

4.2 Using Vision-Oriented Planning And Regional Collaboration to address congestion

Perhaps the most important first step to addressing congestion is to have a transportation "vision" for the region that is easily understood, communicated and a part of a consensus-building effort across the region. The traditional transportation planning process, which has been used successfully in metropolitan areas for the past 40+ years, provides a starting place for this activity. Transportation planning begins with establishing a vision, which is then translated into a series of more specific goals. In turn, projects and policies are developed to meet the goals. There may be different goals and solutions for each part of the region, but places that have made progress have had broad support from business, elected officials, and the public for a set of strategies and the funding package to enact them.

Atlanta, Georgia, metropolitan Washington, D.C., and the eight larger cities in Texas are creating vision-oriented long-range plans that add information to the public debate about how transportation investments should be made. In addition to questions like which projects to pursue and what the future growth rate will be, these areas are broadening the financial discussion. These plans are not justifications for additional public spending. They identify a broad range of funding options and the benefits of providing a mix of projects, programs, and policies to improve transportation, along with consideration of the implications for communities and the environment. The goal of these efforts is for the public to understand the choices between funding and the condition of the transportation services. Taxpayers and travelers can decide on the mix of spending and congestion levels that match their expectations.

Incorporating "visioning" into the planning process is nothing new, but what distinguishes these recent efforts is that they are more accelerated, more visible, more inclusive of stakeholders, and focus not just on the long term but on short-term activities that try to achieve "early successes."

In Atlanta's "Aspiration Plan," a key part of this process is the re-examination of near-term improvements and interactions between some plan elements. Some examples include:

- Seeking solutions to bottlenecks in the road and transit networks. These are places where improving a constriction can allow remaining portions of the system to accept more traffic, and can be done over the next few years.
- Is there enough traffic incident management funding and are the responders clearing crashes and vehicle breakdowns as rapidly as possible? Are there good working relationships and defined procedures among the responders? Atlanta has a reputation for extensive operations, but are there other actions

that, with some additional attention and funding, could improve the services and system performance?

- Coordinate the traffic signals. This will require local agencies to work together, which will have other benefits. It also is an improvement that is relatively quick to enact and has good public support. It may, however, require a reallocation of operating budgets and may lead to an increase in the Aspirations Plan funding levels, as well.

Atlanta's Aspiration Plan highlights an important aspect of Vision-Oriented Planning – ***the need to think regionally about solutions to congestion problems.*** In fact, FHWA is promoting the concept of regional partnerships as a means to implementing effective operations. These partnerships provide a platform for interagency coordination and joint delivery of operations-based services. These partnerships focus on convening a wide variety of stakeholders. They address activities that cross functional and jurisdictional boundaries such as traffic incident management programs, real time traveler information services, response to weather events, and emergency management. Regional partnerships emphasize the importance of linking operations to the existing transportation planning process. Examples include:[25]

- **Baltimore Regional Operations (B-ROC) Project –** more than 20 jurisdictions and agencies are participating in B-ROC with the goals of enhancing operational coordination for traffic incident management and to develop a regional framework for operations. Transportation agencies as well as fire and police agencies are all cooperating in B-ROC.
- **Cross-Jurisdictional Signal Coordination in Phoenix –** was initiated to improve the efficiency of commuting across the Phoenix region. Multiple jurisdictions participated in sharing data and signal control plans that made commuting in long corridors relatively seamless to travelers.
- **Capital Wireless Integrated Network (CapWIN) –** is an integrated transportation and criminal justice wireless network instituted in the Washington, D.C. region. With CapWIN, agencies will be able to communicate directly with each other and access information for use in planning and implementing traffic control during major incidents.

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[25] Federal Highway Administration, *Regional Transportation Operations Collaboration and Coordination: A Primer for Working Together to Improve Transportation Safety, Reliability, and Security*, http://www.itsdocs.fhwa.dot.gov//JPODOCS/REPTS_TE//13686.html.

4.3 THE DIVERSITY IN FUTURE CONGESTION SOLUTIONS

From all that has happened in the past decades regarding congestion, a fundamental principle emerges: ***No single strategy can adequately address the problems of metropolitan congestion.*** However, a balanced, comprehensive approach to traffic congestion can lessen the stifling gridlock found on many of our highways. Metropolitan areas are engaged in similar processes of identifying the benefits of additional transportation capacity, operations improvements, changes in demand patterns and land use arrangements, and the costs of achieving those. The outcome of these processes, however, is not similar and it is important to recognize the many reasons for the differences – they go to the heart of local decision-making.

Cities have always had to balance issues of economic development, environmental and social effects, population and employment growth and mobility. What might affect decisions in the future is the evolution in the job market. If the U.S. economy continues a shift away from manufacturing and toward service and information jobs, location may not be as important as it has been in the past. Cities may compete for jobs and population on the basis of quality-of-life issues especially among workers and companies who could locate anywhere.

The decision variations also are present within metropolitan regions:

- More established areas that are not projected for population and employment growth may not have as much need for capacity expansions as developing regions.
- There will always be a role for using what system we have as efficiently as possible. Aggressively managing the transportation system and ensuring that travelers know their travel options are good business practices.
- There are some corridors that will be targeted for treatment because they are important to regional and national freight shipment or person movement.
- Land use pattern changes in redeveloping areas or new growth areas also are part of the solution set. These decisions will vary by jurisdiction.
- All areas will program their funds and efforts toward a variety of goals that include congestion or mobility. But transportation efficiency will not be the only goal and the solutions implemented in each area will reflect that diversity in focus.

With congestion increasing in cities of all sizes and a focus on identifying the best congestion reducing treatments, there is a need for analysis techniques and data to provide some perspective on possible solutions. The move in some large metropolitan areas, such as Atlanta, Washington, D.C., and the large cities in Texas, to craft vision-oriented plans will provide more informed decision-making. Estimating the amount of projects, programs, and policies required to achieve congestion reduction can help focus the public discussions on alternative investment levels and their benefits.

Congestion treatments in the three groups of strategies discussed above have situations that allow their attributes to be cost-effectively used to address congestion problems, quality of life goals and other factors that urban residents, businesses, and travelers desire. The objective of transportation plans and agencies is to identify the right mix of programs, policies, projects, and plans that can be funded by agencies or in partnership with others. Some strategies require planning time, significant funding, and long construction periods, while others can be deployed or enacted in a week. An effective, comprehensive program will include some of the components from each group.

4.4 The Positive Effects of Operational and Combined Strategies on Congestion

Is Success Possible Against Congestion? Yes, but past success tends to be localized. Multiple and systematic strategies for addressing congestion are required, given that demand is increasing on an already stressed highway system. The following four examples illustrate how success can be achieved by aggressively pursuing a variety of congestion mitigation options.

Results of a Study of the Benefits of Full Operational Deployment

Background

Deployments of operations strategies have been shown to produce significant benefits. Furthermore, these individual operations and ITS improvements can be tied together to achieve even greater benefit than they can alone. Recognizing that the whole is often greater than the sum of its parts, the U.S. DOT and numerous local agencies have launched initiatives to encourage deployment and integration of these systems in order to maximize their potential benefits.[26]

The U.S. DOT selected Tucson, Cincinnati, and Seattle for case studies representing small, medium, and large metropolitan areas, respectively. Hypothetical scenarios were identified comprised of a wide range of operations and ITS deployments at an appropriate, logical scale for each area. These scenarios were then evaluated to estimate the regionwide benefits and costs.

Although the deployments analyzed did not include the full range of strategies discussed in this report, they did contain a large number of freeway, arterial, traffic incident, and transit management systems and traveler information components. These included ramp metering, integrated traffic incident management,

[26] Publication of this research is forthcoming.

and coordination of traffic signals as well as many other types of strategies. The findings of this study illustrate the potential of operations strategies to help mitigate congestion.[27]

What Were the Benefits

In all three regions, the analysis of the full operations and ITS deployment showed positive impacts on all performance measures studied, including:

- Decreased travel times;
- Increased vehicle speeds;
- Decreased delay;
- Decreased number and severity of crashes; and
- Decreased environmental impacts (reduced emissions and fuel use).

Table 4.1 shows examples of the impacts estimated in the three regions.

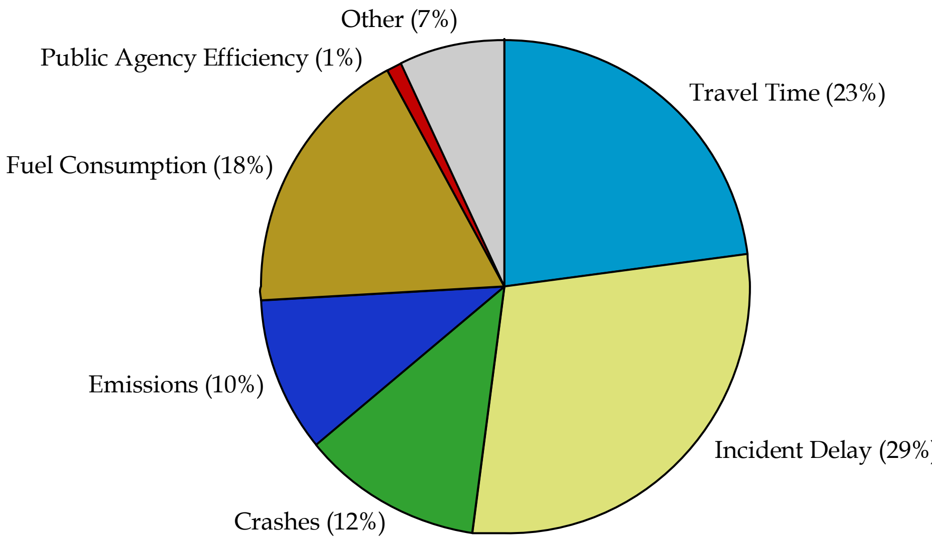
Table 4.1 Impacts of Fully Deploying Operational Strategies in Three Urban Areas

	Tucson	Cincinnati	Seattle
Delay	-15%	-18%	-15%
Travel Time	-2%	-4%	-4%
Fatal Crashes	-7%	-9%	-8%
Injury and Property Damage Crashes	-3%	-3%	-3%
Emissions	-10% to -16%	-18% to -25%	-16% to -21%
Fuel Use	-11%	-24%	-19%

As Table 4.1 shows, the regionwide impacts were significant in all three regions. Further, the positive impacts tended to be greatest during congested peak commute periods, and on major roadways and transit facilities that were the focus of many of the deployments. When dollar values were applied to the estimated impacts, the annual benefits due to the operational deployments were estimated to be $455 million $1,160 million and $1,610 million for Tucson, Cincinnati, and Seattle respectively. These benefits were broad-based as shown in Figure 4.2, which illustrates the proportion of benefits that were estimated for the Tucson region. Similar distribution of benefits also were observed in Cincinnati and Seattle.

[27] The ITS Deployment Analysis System (IDAS) model was used to study the effects of fully deploying operation strategies in the three cities by the year 2020. Costs were also derived using the IDAS model. The results are therefore simulated, rather than based on direct measurements.

Figure 4.2 Proportion of Benefits Value of Full Operations Deployment in Tucson



When the annual benefits deployments were compared with their costs, the investment in operations strategies was shown to be very efficient, returning $6.30 to $12.20 in benefits for every dollar invested, as shown in Table 4.2.

Table 4.2 Comparison of Benefits and Costs of Fully Deploying Operational Strategies in Three Urban Areas

Region	Annual Benefit	Annual Costs	Benefit/Cost Ratio
Tucson	$455	$72	6.3
Cincinnati	$1,160	$98	11.8
Seattle	$1,610	$132	12.2

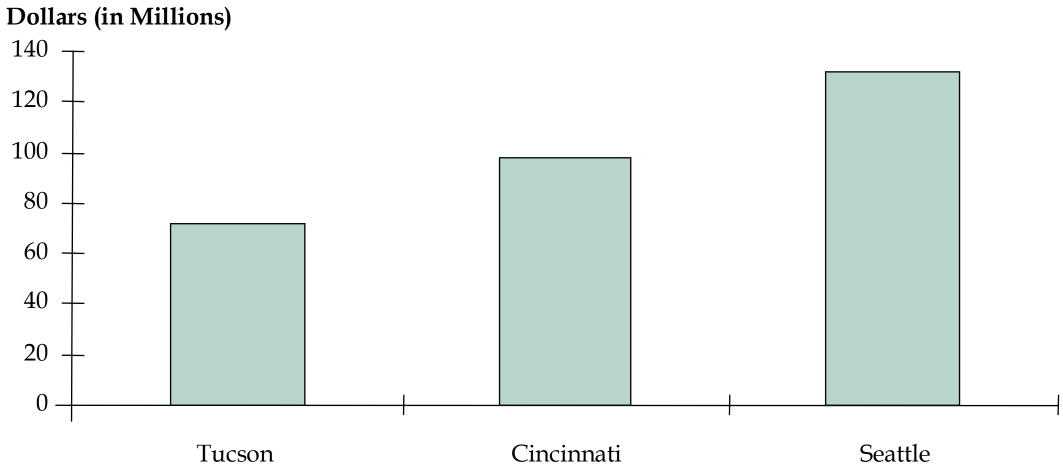
A substantial amount of the benefits were due to assuming the deployment of a fully integrated traffic incident management system. By addressing the traffic incident portion of total congestion, total delay to motorists was decreased and travel reliability increased. This demonstrates the point made earlier that by treating roadway events that cause unreliable travel, the double benefit of decreased delay and increased reliability can be achieved.

What Will It Cost?

Many transportation agencies have found it difficult to add system capacity to keep pace with growing congestion. Many times, traditional approaches to congestion mitigation, such as building a new lane or adding a new transit service, are too expensive to be considered as viable options. Operational strategies have been increasingly used to squeeze more efficiency out of the existing system. These strategies can often be implemented at a fraction of the cost of capacity improvements. This is not to say that these strategies do not have significant costs.

In the case studies of full operational deployments, discussed above, the costs of deploying the operations strategies at the specified level of intensity in Tucson, Cincinnati, and Seattle would cost $78 million, $98 million, and $131 million respectively (Figure 4.3). These costs represent a hypothetical deployment of operations strategies at an intensity greater than currently deployed in these regions, and represent the full cost of implementing the strategies from the ground up. In reality, many of these implementation costs already have been made by the regional transportation system managers.

Figure 4.3 Comparison of Potential Annual Costs in Tucson, Cincinnati, and Seattle



Ramp Metering Strategies in the Twin Cities

In the fall of the year 2000, a unique experiment was conducted in the Minneapolis/St. Paul (MSP) region of Minnesota to answer questions regarding the ability of particular operational strategies to reduce congestion and improve travel safety in the region.[28] The findings from this experiment provide a tangible example of success in the campaign against congestion. The MSP region was one of the first in the nation to deploy the strategy, and since that time the system has expanded to be one of the most comprehensive systems in the nation – covering over 430 individual ramps by the year 2000.

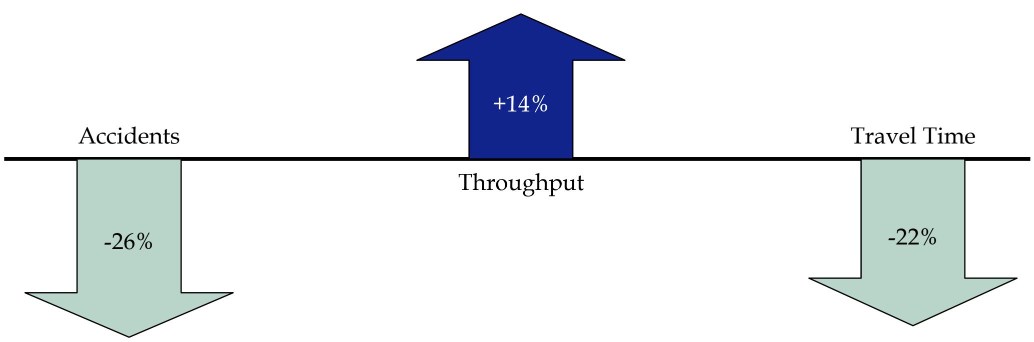
[28] Cambridge Systematics, Inc., Twin Cities Ramp Meter Evaluation – Final Report, Prepared for Minnesota Department of Transportation, February 2001. http://www.dot.state.mn.us/rampmeterstudy/pdf/finalreport/finalreport.pdf.

Although the DOT maintained a strong belief that the ramp metering strategies provided significant benefits, only an isolated number of evaluations had been performed and the information on the regionwide impacts was very limited. The experiment called for the ramp meters to be turned off for a six-week period in order to evaluate how the system operated without ramp meters, as opposed to conditions when the meters were operating.

What Were the Impacts of Turning Off the Ramp Meters?

- When the ramp meters are operational, they are used to manage the number of cars entering the freeway. This lessens congestion on the freeway and makes it easier for cars entering the freeway to merge into traffic.
- When the meters were turned off, cars were able to enter the freeway during peak congestion hours without being held on the ramps. This eliminated the time previously spent waiting on the ramp signal; however, it also meant that more cars were attempting to enter the freeway at the same time. Bottlenecks were created when people had more difficulty merging into traffic. This slowed traffic on the freeways creating longer freeway travel times. The traffic data showed that the time savings from eliminating the wait on the ramp was more than offset by the longer freeway travel times. This observed impact was consistent with the reported experiences of individuals participating in the surveys.
- When the traffic conditions were compared, it was observed that there were 26 percent fewer crashes on the freeways and ramps when the ramp meters were working. The freeways also were observed to operate at higher speeds with ramp metering. This resulted in more throughput and reduced travel times as a result of ramp metering as shown in Figure 4.4.

Figure 4.4 Observed Benefits of Ramp Meters in the Twin Cities

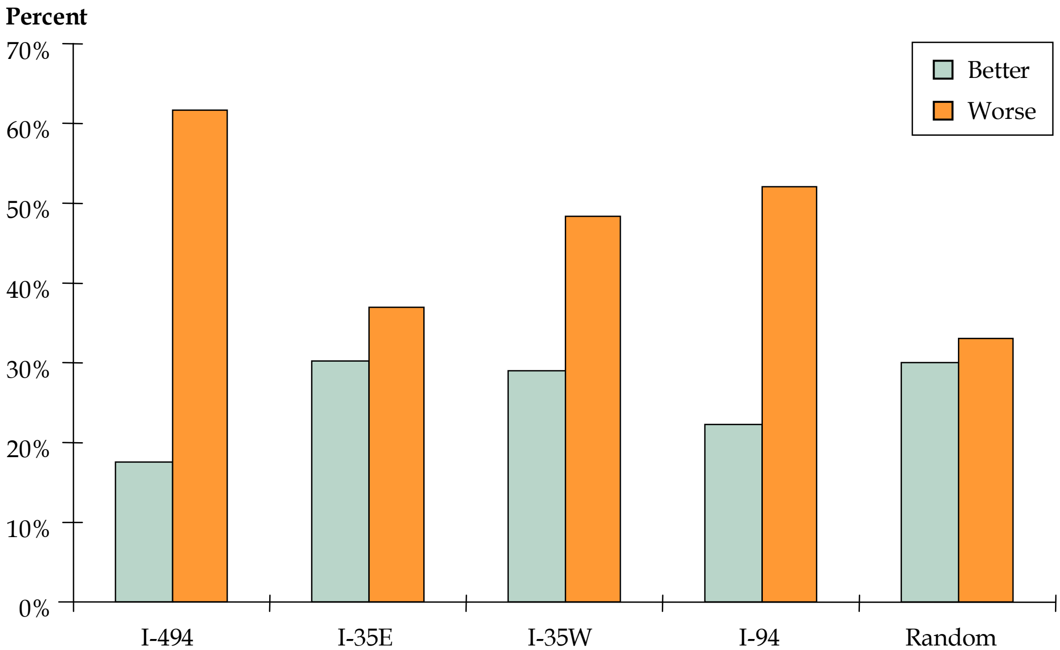


Note: Throughput is the number of vehicles passing over a stretch of freeway in a given time. Usually expressed in vehicles per hour, it indicates that the physical carrying capacity of the freeway has been increased due to using ramp meters.

- Travel times also were observed to be nearly twice as predictable when the ramp meters were operational compared when they were turned off.

- The results from the surveys and focus groups also revealed that most residents felt that the ramp metering system was beneficial to them. Figure 4.5 shows the responses of survey participants who typically traveled on various regional freeway corridors when asked if traffic conditions were better or worse when the ramp meters were turned off. These responses show that more travelers felt that traffic conditions were worse when the meters were turned off than conditions had been when they were operational. The surveys also revealed that approximately 80 percent of the residents supported the use of ramp metering in the region following the experiment.

Figure 4.5 Reported Changes in Traffic Conditions after the Shutdown



I-25/I-225 Interchange Bottleneck Removal in Denver[29]

The Southeast Corridor has long been recognized as one of the Denver region's highest priority travel corridors. The corridor follows I-25, the only north-south freeway in the State, for approximately 14 miles, and I-225, which provides access to I-70, the region's major east-west freeway, for approximately four miles. The Southeast Corridor connects the two largest employment centers in the region: the Denver Central Business District, with approximately 112,000 employees in the mid-1990s, and the Southeast Business District, with approximately 120,000 employees in the mid-1990s. With employment centers at both ends, the Southeast Corridor is the highest volume, most congested corridor in

[29] http://www.trexproject.com/.

the region. Located approximately in the middle of the corridor is the I-25/I-225 interchange. According to Colorado DOT information, I-25 currently experiences "severe congestion" for several miles on either side of the interchange, and I-225 experiences "moderate congestion." Although several locations in this corridor are potential traffic bottlenecks, the I-25/I-225 interchange is a major one.

Identified as the 14th worst bottleneck in a 1999 study of national bottlenecks, Colorado DOT has since undertaken a massive reconstruction project in the I-25 corridor – nicknamed T-REX (for Transportation Expansion). The project was initiated in 2001 with an anticipated completion date of 2006. The T-REX Project is one of the most extensive multimodal transportation projects in the history of Colorado (Figure 4.6).

T-REX exhibits of the principles being applied to complex bottleneck mitigation projects across the country: a single solution is rarely effective but when multiple strategies are applied, real progress can be made. T-REX is considered by CoDOT to be one their next generation of transportation projects. By combining light rail, highway, bike, pedestrian and other transit options, a multimodal approach is being used to address congestion and safety problems. The T-REX project involves:

Transit Strategies

- Adding 19 miles of double-track light rail connecting to the existing system at Broadway in Denver and extending along the west side of I-25 to Lincoln Avenue in Douglas County and in the median of I-225 from I-25 to Parker Road in Aurora;
- Building 13 stations with park-and-rides at 12 of the stations;
- Adding 34 light rail vehicles to RTD's fleet; and
- Constructing a new light rail maintenance facility in Englewood.

Highway Strategies

- Adding one through lane in each direction from Logan Street to I-225 (for a total of four lanes each way);
- Adding two through lanes in each direction from I-225 to the C470/E470 interchange (for a total of five lanes each way);
- Reconstructing eight interchanges, including I-25/I-225;
- Reconstructing and widen numerous bridges;
- Adding and improving shoulders;
- Improving ramps and acceleration/deceleration lanes;
- Design and construct a quality project; and
- Complete the project on or before June 2008.

Figure 4.6 The T-Rex Project in Denver, Colorado

In 1999, it was estimated that the I-25/I-225 interchange causes 11.3 million hours of annual delay to motorists. When the proposed improvements are completed in 2006, it is estimated that this will be reduced to 2.0 million hours of delay **without considering the positive effects of the light rail system** (level of service "D" for the interchange). When light rail is factored in, the potential exists to almost entirely reduce delay due to the bottleneck.[30]

[30] CoDOT estimates that the peak capacity of the light rail system is 4,500 people per hour in one direction. That is equivalent to more than one and half additional lanes of highway in one direction!

Aggressive Operations

As part of TTI's ongoing analysis of congestion trends, deployments of three operational treatments were studied for the top 75 urban areas (based on population) in 2001: freeway entrance ramp metering, freeway traffic incident management and arterial street signal coordination. These are three important, widely used and easily recognized improvements that reduce travel delay and improve the reliability of travel conditions. The effects of the three treatments also do not overlap, so there is little need to consider double-counting issues. The amount of the system treated, the road section congestion level and the delay reducing effect of the treatment are considered in the estimates.

Table 4.3 identifies the deployment characteristics for the three operations treatments. Signal coordination is the most deployed with all of the cities having some coordination and an average of half of the street system treated. Traffic incident management is deployed in two-thirds of the urban areas and about half of the freeway miles within those areas. Entrance ramp metering is the least often deployed, with one-third of the areas having some treatment and an average of one-quarter of the freeway lane-miles being included in the treated group.

Table 4.3 2001 Urban Mobility Improvement Techniques
Existing Operations

			Delay Reduction	
Technique	**Number of Cities**	**Percent of System in Cities**	**Millions of Hours**	**Percent of Delay**
Freeways				
Ramp Metering	26	23%	73	3.1%
Incident Management	53	54%	117	5.0%
Streets				
Signal Coordination	75	54%	16	1.4%
Total			**206**	

Source: Schrank, D. and Lomax, T., *2003 Annual Urban Mobility Report*, Texas Transportation Institute.

The effect of integrated traffic incident management is the most significant, reducing freeway travel delay by 5.0 percent. This includes not only deployment of technologies to detect and verify traffic incidents, but more importantly, increased coordination and communication between transportation agencies and emergency responders. Ramp metering deployment has somewhat less effect on overall freeway delay owing to the less extensive implementation. Signal coordination has lower improvement effect for each arterial street, but current levels show a 1.4 percent decline in street delay in the 75 areas studied.

If all the roads were treated with the three strategies, the delay deductions would be as shown in Table 4.4. A total of more than 500 million person-hours of delay are estimated for this option, more than double the current operations treatment amount. This is equivalent to slightly more than three years of congestion growth at the current rate, or just less than 15 percent of total delay.

Table 4.4 2001 Mobility Improvement Techniques
Full Deployment of Operations

Technique	Number of Cities	Percent of System in Cities	Delay Reduction	
			Millions of Hours	Percent of Delay
Freeways				
Ramp Metering	75	100%	270	11%
Traffic incident Management	75	100%	215	9%
Streets				
Signal Coordination	75	100%	34	3%
Total			**519**	

Source: Schrank, D. and Lomax, T., *2003 Annual Urban Mobility Report,* Texas Transportation Institute.

Comparison with System Expansion Alternatives

Method 1

The current rate of system expansion in the 75 urban areas is approximately 640 freeway lane-miles and 890 arterial street lane-miles per year. The best estimate we have developed indicates this is about half of what would be needed to stop the growth of congestion. This suggests that 1,530 lane-miles would alleviate an increase of 150 million hours of delay.

If the current deployment percentages are increased from the current levels to 100 percent of both freeways and streets, the role of operational treatments can be compared to the system expansion alternatives. The 300 million hours of delay difference between current and 100 percent deployment rates, if it were allocated over five or 10 years, would suggest an annual rate of decrease between 30 million and 60 million hours of delay. This would be 20 percent to 40 percent of the current congestion growth rate. This might suggest that operational treatment deployments would be responsible for the equivalent of 300 to 600 lane-miles of capacity expansions each year for a total of more than 3,000 lane-miles of freeway and street.

Method 2

Another estimate of the operational treatment deployment benefits can be developed by modeling an expansion of the entire road system in the 75 urban areas. This analysis adds both freeway and street lanes to the road systems, and performs congestion analyses on the resulting expanded system. Table 4.5 illustrates that a two percent increase in road mileage would come close to matching the 300 million hours of delay savings growth between current and 100 percent deployment. This is equivalent to 1,590 freeway lane-miles and 1,630 lane-miles of arterial streets.

Table 4.5 2003 Urban Mobility Report Added Roads
2001 Data

Percent Added Roadways	Total Delay (Millions of Hours)	Delay Reduction (Millions of Hours)
Base Condition	3,600	–
+2%	3,320	280
+3%	3,190	410
+4%	3,070	530

Note: Greater than 530 million hours of delay reduction would require 3,180 Freeway LM and 3,260 Principal Arterial LM.

Source: Schrank, D. and Lomax, T., *2003 Annual Urban Mobility Report,* Texas Transportation Institute.

Three operational treatments, if deployed on all major roads in 75 urban areas would develop a delay savings of more than 500 million hours each year. With current delay estimates in the range of 3.5 billion hours, these savings would be very significant. To achieve a similar delay reduction with system expansion alternatives would require 3,100 freeway lane-miles and 3,200 arterial street lane-miles. The 6,300 lane-mile savings would be a one-time savings and would not add to the total each year. But if the operations programs were expanded from current levels to 100 percent of the system over the next five to 10 years, they would significantly change the congestion growth rate, reducing the projected rate of growth by 20 percent to 40 percent per year.

4.5 SUMMARY

Success against congestion is achievable. Numerous strategies exist in our Toolbox to battle congestion. Previous experience suggests that to be effective, however, two basic principles should be followed:

1. Strategies should be targeted at specific problems. Knowing the nature and extent of congestion problems in an area or corridor is the first step toward a solution; and
2. Strategies should be used in combination, rather than individually. Because many strategies are complementary, using them together provides synergy. This is particularly true of operations strategies – when used in conjunction with reconstruction, they can provide additional congestion relief by targeting other aspects of congestion besides physical capacity (e.g., incidents). In some cases where bottlenecks are a significant problem, there will be no getting around the need to add new capacity.

5.0 Next Steps

5.1 How Can Everyone Pitch In Against Congestion?

Success against congestion requires not only attacking it on multiple fronts with strategies from our Tool Box. It also requires cooperation between transportation agencies, businesses, and the public. Since we are all affected congestion, it is important that we all work together to address the congestion problem. Here are some ways that transportation agencies, businesses, and the public can collaborate to mitigate congestion.

Take Ownership

The first step is for all parties to recognize they have a stake in the congestion problem. Public agencies are in the business of serving customers the same way that any private firm is – except that the customers (the public and businesses) are buying efficient and safe travel. The public, elected officials, and businesses are more than just consumers – they are shareholders too. These consumers also should examine their own decisions and policies to identify changes that can improve their quality of life while recognizing that the agencies cannot solve the problem by themselves. The ongoing transportation planning process, which has been successfully used in major metropolitan areas for the past 40+ years to address transportation problems, provides an excellent framework for promoting ownership of congestion problems. A major part of the transportation planning process is establishing a Vision that outlines what the future transportation system should look like. The Vision leads to more specific statements of desired actions to achieve these states or characteristics. The Vision is also an opportunity to educate all stakeholders on the nature of congestion in your area and the importance of mitigating it.

Identify Where the Congestion Problems and Opportunities Are

Both technical analyses and anecdotal information from the public are useful in identifying where the major congestion problems currently are and what causes them. Discuss where the problems are likely to occur in the next five, 10, and 20 years. The existing transportation planning process in metropolitan areas can be tapped as a resource for this purpose. Provide realistic assessments on what can reasonably be done in each case, and what the expected improvements might be. FHWA supports a wealth of information on expected improvements from operational strategies, such as the ITS Benefits and Cost Database.[31] The process should include considering:

- **Strategies –** What types of treatments should be considered?
- **Coverage –** How much area does the treatment cover?
- **Density –** How well is congestion treated?
- **Congestion Target –** What aspect of congestion is treated?
- **Effect –** What is the delay reduction effect? Are there secondary effects, such as on safety? What are the spillover effects on other facilities and neighborhoods?

Develop Plans, Programs, Policies, and Projects

Solutions that effectively address congestion can take a variety of forms, as shown in the Tool Box in Section 4.1. Think broadly – no single tool will be highly effective against the congestion problem. But when used in combination – and tailored to specific circumstances – congestion mitigation strategies can be successful. The strategies should be action-based – things we can actually accomplish in a reasonable timeframe and at a reasonable cost. Consider all types pf strategies including adding new highway and rail capacity, improved operations, and better land use planning. For congestion, both immediate and long-term actions should be developed. Recognize that many transportation and community plans already exist and should be tapped as mechanisms for carrying out the Vision. In fact, acting on a list of "things we can do now" will help galvanize support for congestion mitigation over the long term.

Operate the Transportation System Proactively and Regionally

Focus on addressing system reliability by targeting capital and operations strategies to specific conditions. Anticipate problems and take corrective actions early. Also, regional and multimodal cooperation is key to the success of deploying effective operations – many different agencies have a stake in the congestion problem. Therefore, a broad perspective should be taken in applying capital and operations strategies – avoid a narrow, facility-oriented view.

Use Performance Measures to Track Progress

One of the main actions that transportation agencies can contribute to the process is the tracking of congestion trends over time. Trends provide a basis for determining how well your actions are working and can identify changes in the underlying congestion problem (e.g., traffic incidents may become more important in your area). Use of performance measures also brings an element of **accountability** to the process – what we are really getting for our investments –

[31] http://www.mitretek.org/its/benecost/BC_Update_2003/index.html.

just as private firms do. Several principles may be followed in establishing a performance monitoring program:

- ***Sound Information Leads to Sound Decisions***. By their nature, operational strategies require continuous involvement in the day-to-day, hour-to-hour activities of the transportation system. Continuous involvement in the transportation system requires feedback at a detailed level so that strategies can be adjusted. In the era of TSM&O, we can no longer afford to be "flying blind."
- ***When You Measure, Measure Like You Mean It.*** Production of congestion trends is a valuable tool for self-assessment and public relations. However, to realize its full potential, performance measurement must be taken to the next level: active use in decision-making. Once performance measurement is embedded in agency culture and procedures, increased attention will be focused on the data, yielding higher quality and greater coverage. Evaluate projects you've done using your measurement process. Determine if the project produced the expected improvements in congestion and if not, why not? Identify aspects of the project that could be improved next time.
- ***Measure Where You Can, Model Everything Else.*** Performance measurements based on real-time operations data represent the best combination of accuracy and detail, but they do not cover all major roads in urban areas. However, transportation agencies have many other data and modeling resources that could be used in performance monitoring. Do not wait for perfect data – start performance monitoring now and improve data as you go.

5.2 ACTIVITIES AT THE FEDERAL HIGHWAY ADMINISTRATION

Future Reports on Congestion Trends

This report is the first in a series of planned annual reports on congestion trends, effects, and solutions. Several years ago, FHWA embarked on a support and outreach program to address the many causes of congestion and to improve highway safety through increased use of operational strategies. We are constantly learning more about the basic nature of congestion, where it is going, its impacts, and what can be done about it. As we learn more, additional information will be woven into future reports. Some of what we are learning will come from programs as outlined below.

Congestion Monitoring Activities

Part of the effort to improve support and outreach for operations was establishing national-level performance programs. The programs started small and have built to the point that enough data exists for enough cities to report trends; this report has presented some of these data. Future reports in this series will continue to use these sources.

The **Urban Congestion Report (UCR)** effort yields a monthly snapshot of roadway congestion in 10 urban areas and three national composite measures. UCR utilizes efficient, automated data collection procedures (colloquially known as “screen scraping” or “web mining”) to obtain travel time directly from traveler information web sites and archives them at five-minute intervals on the weekdays when these services are available. Concurrent with the travel time data collection, other UCR acquisition programs obtain web-based data on weather conditions, traffic incidents, and work zone activity.

The **Mobility Monitoring Program (MMP)** calculates system performance metrics based on data archived at traffic management centers (TMC). These data are highly detailed measurements from roadway surveillance equipment installed for operational purposes; data from spot locations (volumes and speeds) are used as well as travel time estimates from probe vehicles (where available). For each participating city, the MMP develops congestion metrics at both the corridor and area levels; 23 cities participated in 2002 and close to 30 are reporting data for 2003. The concepts, performance measures, and data analysis techniques developed and used in the MMP are being considered for adoption and implementation by several state and local agencies.

The **Intelligent Transportation Infrastructure Program (ITIP)** is an ongoing program designed to enhance regional surveillance and traffic management capabilities in up to 21 metropolitan areas while developing an ability to measure operating performance and expanding traveler information through a public/private partnership involving the FHWA, participating state and local transportation agencies, and Mobility Technologies. Under this partnership, Mobility Technologies is responsible for deploying and maintaining traffic surveillance devices, and integrating data from these devices with existing traffic data to provide a source of consolidated real-time and archived data for the participating metropolitan areas. Deployment has been completed in Philadelphia, Pittsburgh, Chicago, and Providence, and is under way in Boston, Tampa, San Diego, the Washington D.C. region, Phoenix, Los Angeles and San Francisco. Negotiations are currently active in 10 additional cities.

Congestion Resources and Research

FHWA continues to develop and compile information for transportation agencies and the public on how improved operations can effectively manage congestion. Table 5.1 provides an overview of these activities, which are organized around the components of congestion as identified in this report. By addressing congestion by its root causes, both overall congestion levels and reliability are targeted.

Table 5.1 Selected FHWA Congestion Relief Resources

Congestion Strategy	Action	Example Resources
Reducing Non-Recurring Congestion	Traffic Incident Management	• NCHRP – Synthesis – Safe and Quick Clearance of Traffic Incidents • Quick Clearance and "Move-It" Best Practices – I-95 Corridor Coalition • National Traffic Incident Management Self Assessment
	Work Zone Management	• National Traffic and Road Closure Information • QuickZone (Traffic Impact Analysis) Tool and Training • Work Zone Self-Assessment Tool
	Road Weather Management	• Maintenance Decision-Support System Project • Best Practices for Road Weather Management • Fundamentals of Road Weather Management Training Course
	Special Events Traffic Management	• Training course on Managing Travel for Planned Special Events • Managing Travel for Planned Special Events Handbook
Reducing Recurring Congestion	Freeway Management	• Configuration Management for Transportation Management Systems • Freeway Management and Operations Handbook • Freeway Management and Traffic Operations Training Course
	Arterial Management	• Access Management, Location and Design Training Course • Adaptive Urban Signal Control and Integration (AUSCI) Final Evaluation Report
	Corridor Traffic Management	• Brochure, primer and handbook on managing and controlling traffic between freeways and surface streets
	Travel Demand Management	• HOV Systems Training Course • ITS Professional Capacity Building Program • TDM Reference Guide – 2004 • Brochure on Managing Demand Through Traveler Information
Improving Day-to-Day Operations	Operations Asset Management Real-Time Traveler Information Traffic Analysis Tools	• Changeable Message Sign O&M Handbook • Resource 511 Web Site • Portable Changeable Message Sign Handbook • ATIS Standards
Creating a Foundation for 21st Century Operations	Regional Transportation Operations Collaboration and Coordination (RTOCC)	• Guidance on Regional Collaboration • Guidance on Linking Planning and Operations • Advancing TSM&O Executive Session • Advancing TSO&M Course • Guidance on Regional Concept for Transportation Operations
	Performance Measurement	• Technical guidance and case studies in performance measurement
	Facilitating Integrated ITS Deployment	• Standards development • Architecture compliance
Improving Global Connectivity by Enhanced Freight Management and Operations	Freight Analysis Freight Professional Development Intermodal Freight Technology Truck Size and Weight	• Freight Analysis Framework • Integrating Freight in the Transportation Planning Process • Cargo*Mate Logistics Information Management • Electronic Intermodal Supply Chain Manifest – Freight Operational Test Evaluation Final Report • Border Wizard
Improving Mobility and Security through Better Emergency Management	Emergency Transportation Operations (internal)	• Public Safety and Security Program Brochure
	Emergency Transportation Operations (external)	• FHWA Order 5181.1, Emergency Notification and Reporting Procedures

Source: http://ops.fhwa.dot.gov/. Many more examples are provided by this reference.

A. Data Sources

Data Sources Used in This Report

This report draws on several current efforts to produce a composite of the national congestion picture. These include the following efforts.

The **Urban Mobility Study (UMS)** has been in existence since 1982 and is sponsored by a consortium of state DOTs and private interest groups.[1] The study is conducted by the Texas Transportation Institute. The UMS tracks congestion patterns in the 75 of the largest metropolitan areas and has been instrumental as both a source of trend information and development of the concepts and metrics for congestion monitoring, for example, the widely used Travel Time Index is an innovation of the UMS. The UMS relies on the Highway Performance Monitoring System (HPMS) as it source of information. It uses the average annual daily traffic (AADT) and number of lanes data in HPMS as a basis for its estimates; these are then translated into congestion metrics using predictive equations that have been developed and tested specifically for the UMS. Beginning in 2002, the UMS is also considering the positive effects that operational strategies have on system performance; these are accounted for as adjustments to the base performance predicted by AADT and number of lanes. The UMS has widespread visibility both within the transportation profession as well as with the general public; annual release of the UMS report generates a significant amount of media coverage.

The **Urban Congestion Report (UCR)** sponsored by FHWA is an effort that yields a monthly snapshot of roadway congestion in 10 urban areas and three national composite measures. UCR utilizes efficient, automated data collection procedures (colloquially known as "screen scraping" or "web mining") to obtain travel time directly from traveler information web sites and archives them at five-minute intervals on the weekdays when these services are available. Since a monthly report can be rapidly constructed (within 10 working days) UCR serves as an early warning system for changes in urban roadway congestion. Concurrent with the travel time data collection, other UCR acquisition programs obtain web-based data on weather conditions, traffic incidents, and work zone activity. This allows the UCR monthly report to include not only congestion level, but a range of possible contributing factors. A one-page overview tells the congestion story each month in a graphical manner for the analyst or administrator wanting a timely composite overview of congestion trends on a month-to-month basis.

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[1] http://mobility.tamu.edu.

The **Mobility Monitoring Program (MMP)** sponsored by FHWA calculates system performance metrics based on data archived at traffic management centers (TMCs).[2] These data are highly detailed measurements from roadway surveillance equipment installed for operational purposes; data from spot locations (volumes and speeds) are used as well as travel time estimates from probe vehicles (where available). For each participating city, the MMP develops congestion metrics at both the corridor and area levels; 23 cities participated in 2002 and close to 30 will be analyzed for calendar year 2003. Early work from this project has provided a basis for measuring travel time reliability; the Buffer Index used by the UCR and several state efforts was first defined by the MMP, but was based on a concept identified precursor studies to the UCR effort. Beginning with 2002, traffic incident data is being collected from TMCs where these data exist. Also, continuous traffic data from signalized highways is being explored as a potential source for system performance monitoring. The concepts, performance measures, and data analysis techniques developed and used in the MMP are being considered for adoption and implementation by several state and local agencies. A few of these agencies have contacted the project team to request technical assistance or additional detailed information on performance monitoring or operations data archiving. Specifically, one of the two primary objectives of the Mobility Monitoring Program was to provide incentives and technical assistance for the implementation of data archiving systems to support performance monitoring. Several examples of these technology transfer and implementation activities are:

- Data quality control procedures have been developed for archived TMC data. Many locally developed archives are now using these procedures.
- Customized local analyses have been performed on a selective basis. As a way to promote local use of archived data, the MMP team has demonstrated how their data may be used to supplement traffic counting programs (Phoenix and Cincinnati) and as input to air quality models (Louisville and Detroit).
- A database of TMC-generated data that has been quality controlled and put into a standard format is available for research and other FHWA purposes. For example, the data are being used now in FHWA's *Estimating the Transportation Contribution to Particulate Matter Pollution* project and is being considered as a validation source for FHWA's *Next Generation Traffic Simulation Models* project.

The Intelligent Transportation Infrastructure Program (ITIP) is an ongoing program designed to enhance regional surveillance and traffic management capabilities in up to 21 metropolitan areas while developing an ability to measure operating performance and expanding traveler information through a

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[2] http://mobility.tamu.edu/mmp/.

public/private partnership involving the FHWA, participating State and local transportation agencies, and Mobility Technologies. Under this partnership, Mobility Technologies is responsible for deploying and maintaining traffic surveillance devices, and integrating data from these devices with existing traffic data to provide a source of consolidated real-time and archived data for the participating metropolitan areas. Deployment has been completed in Philadelphia, Pittsburgh, Chicago, and Providence, and is under way in Boston, Tampa, San Diego, the Washington D.C. region, Phoenix, Los Angeles and San Francisco. Negotiations are currently active in 10 additional cities.

Part of ITIP is the production of performance measures on a routine basis. The metrics used to report performance are based on those in the Mobility Monitoring Program: annual person-hours of delay, percent congested travel, travel rate index, and buffer index. Performance measure reports are to be provided to the U.S. DOT on a monthly and annual basis. The monthly reports for each metropolitan area will be based on monthly data and will be presented with similar content, and in a format, consistent with the "city summary reports" that are part of the Mobility Monitoring Program.

The **Freight Analysis Framework (FAF)** sponsored by FHWA is a tool set developed to estimate trade flows on the Nation's infrastructure, seeking to understand the geographic relationships between local flows and the Nation's overall transportation system. The framework will help identify areas of improvement to increase freight mobility, including highlighting regions with mismatched freight demand and system capacity, and encouraging the development of multistate and regional approaches to improving operations.

The FAF examines transportation for four key intermodal modes: highway, railroad, water, and air. A comprehensive database for different modes was developed from various government and private sector databases. To evaluate the effect of anticipated volumes on the network, the FAF includes economic forecasts for the years 2010 and 2020, assigned to the network and linked to transportation infrastructure databases. Current work in the FAF concentrates of truck flows on the highway system, and this is the information borrowed for this Report.

The **Travel Times in Freight Significant Corridors** project undertaken by FHWA develops truck travel times and other performance measures in major intercity corridors that are heavily used by trucks. The study is prototyping the measurement of travel times using satellite tracking of selected trucks. Truck travel times indicate how well the intercity highway network is performing for all travelers. Data from this study can also be used to calibrate network assignment models and to understand the level of truck activity by time-of-day.

The **American Highway Users Alliance (AHUA) National Bottleneck Study** was a privately sponsored effort to identify the worst traffic bottlenecks in the country and to estimate the benefits of improving them.[3] The study surveyed state DOTs to identify their worst bottlenecks, then applied modeling methods used by FHWA in the Highway Economic Requirements System model to estimate delay, safety impacts, fuel consumption, and emissions. The study also examined the effect of improving the bottlenecks, using actual improvement plans where available.

Additional Data Sources

Other data sources besides those mentioned above can be used to monitor and measure congestion. The above sources are focused on measuring congestion conditions on highways. Another way to approach congestion measurement is to track how users experience entire trips, from their origin to their destination. This has been traditionally done through the use of surveys, but emerging technologies may allow trip-tracking on a real-time basis.

At the national level, the **National Household Travel Survey (NHTS)** provides a long history for trends in congestion. The NHTS is the nation's inventory of daily and long-distance travel. The survey includes demographic characteristics of households, people, vehicles, and detailed information on daily and longer-distance travel for all purposes by all modes. NHTS survey data are collected from a sample of U.S. households and expanded to provide national estimates of trips and miles by travel mode, trip purpose, and a host of household attributes.

The daily travel surveys were conducted in 1969, 1977, 1983, 1990, and 1995. This data series provides a rich source of detailed information on personal travel patterns in the U.S. Longer-distance travel was collected in 1977 and 1995. The 2001 NHTS collects both daily and longer-distance trips in one survey.

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[3] http://www.highways.org.

B. State of the Practice: Performance Measurement for Congestion and Operations

B.1 Trends in the Use of Congestion and Operations Performance Measurement by Transportation Agencies

The use of performance measures has been growing in recent years, and ranges from site-specific operations analysis to corridor-level alternative investments analysis and to areawide planning and public information studies. In the past few years, the issue of performance monitoring has been elevated by transportation agencies to be responsive to the demands of the public and state legislatures and the Transportation Equity Act for the 21st Century's (TEA-21). Reauthorization of Federal highway activities is likely to continue this emphasis on performance monitoring, particularly with regard to congestion and system operations and management. Simultaneously, the deployment of intelligent transportation systems (ITS) technologies has the potential to make a vast amount of data available for analysis.

However, many challenges lie ahead before performance measurement becomes "standard practice" and is imbedded in the transportation decision-making process. These challenges include the following below.

- The transportation profession is only beginning to define and measure performance in objective terms.
- Based on what data are available, we can observe that congestion is growing in areas of every size.
- Performance must be viewed from several perspectives; both the facility and the user perspectives are important, performance measures are useful in both planning and operations and homeland security issues must be addressed.
- The concept of "reliability" is growing in importance. Measuring reliability requires continuous data, something that has been in short supply traditionally. While advances in performance concepts have been made, data limitations hamper their implementation.
- In the short term, some combination of surveillance data, planning data, and modeling must be used to support performance measurement.

- Communication of performance monitoring results also is crucial.
- How performance measures are to be used in the transportation decision-making process is still evolving.

Recent research in congestion and operations performance monitoring[4] suggests eight principles that should be addressed when developing a performance measurement program. These are listed below.

- **Principle 1 –** Mobility performance measures must be based on the measurement of travel time.
- **Principle 2 –** Multiple metrics should be used to report performance.
- **Principle 3 –** Traditional Highway Capacity Manual-based performance measures (V/C 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 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 "outcomes."
- **Principle 7 –** Three dimensions of congestion should be tracked with mobility performance measures: source of congestion, temporal aspects, and spatial detail.
- **Principle 8 –** The measurement of reliability is a key aspect of 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.

Figure B.1[5] depicts the relationship between mobility or congestion (outcome) measures and operations or efficiency (output) measures. The output measures related to operations, which is usually described as the traffic incident management process, are at the bottom of the chart. The graphic indicates that incident duration, whether nonrecurring or planned, has influence on the outcome measures of travel time and throughput shown at the top of the chart.

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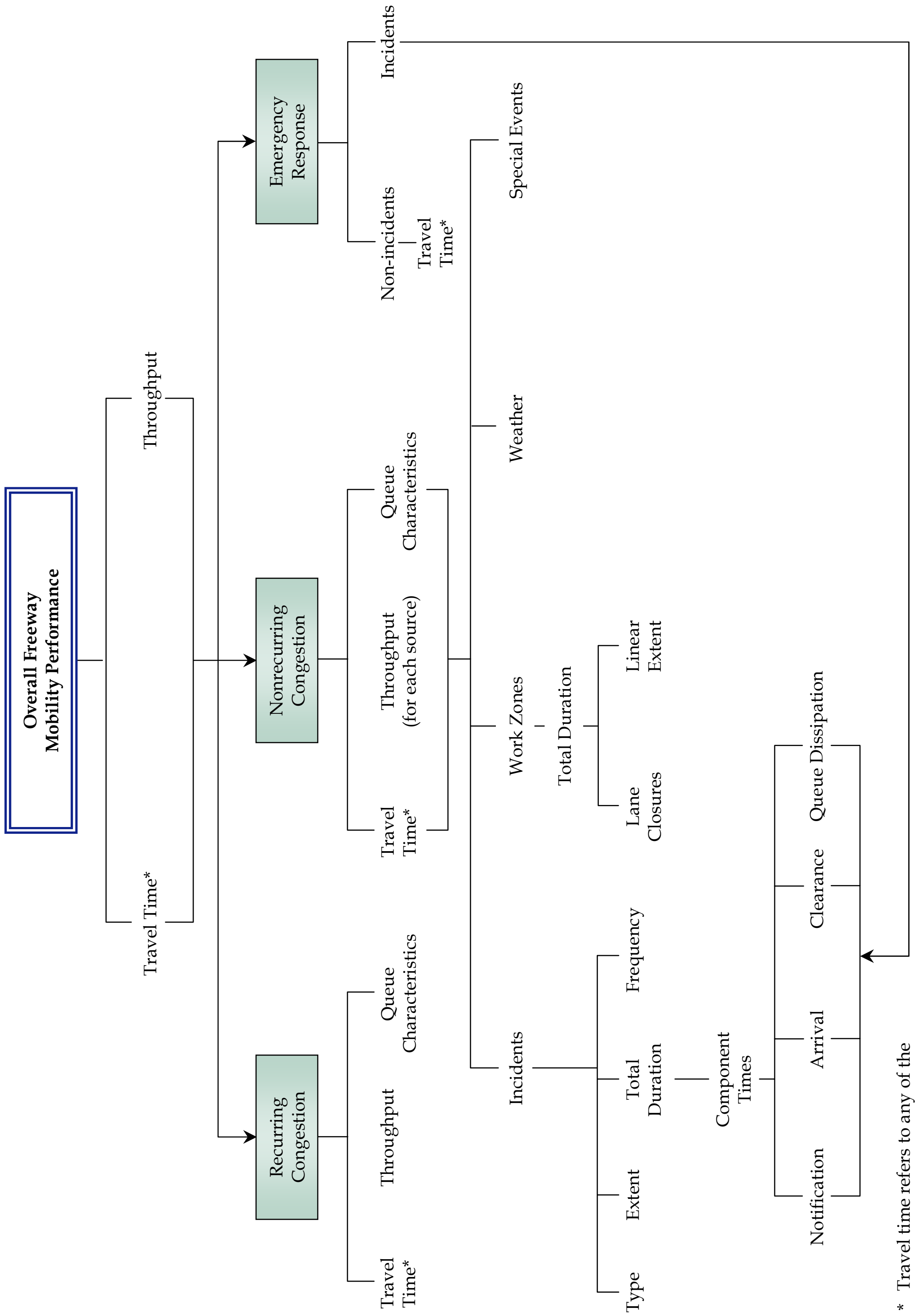
[4] NCHRP 3-68 (*Guide for Effective Freeway Performance Measures*) Tasks 1 and 2 Draft Report.

[5] NCHRP 20-7(173) (*Measuring and Communicating the Effects of Incident Management Improvements*).

One concept that is clear is that ***performance must be viewed from several perspectives.*** A debate within the transportation profession has arisen over the proper perspective for measuring performance. With regard to mobility performance, some have suggested that it is the view of the **user** (traveler) that is the most appropriate while others argue it is the view from the **facility** that is the correct perspective. The authors have found this to be a phony argument: both perspectives are needed. The user perspective is important because that is how the system is experienced by transportation customers; this relates to characteristics of users' trips. The facility perspective is important because transportation professionals mainly manage facilities; trips are also managed by such strategies as traveler information and demand management but to a lesser degree than facilities.

Figure B.1 General Taxonomy of Mobility-Based Performance Measures



* Travel time refers to any of the travel time-based metrics discussed in this report.

B.2 Challenges Ahead

B.2.1 Data

In order to gain a better understanding of the current state of congestion and trends over time, additional analysis is required. Some of the most significant challenges to this effort are related to the availability, coverage, quality, and consistency of traffic data across the nation. This section examines each of these challenges. Table B.1 describes what challenges are created by these issues. Subsequent sections address these challenges in more detail.

Table B.1 Potential Challenges to Accurately Assessing Congestion

Issue	Why Is It a Problem?
Availability	• Continuous streams of data are not readily available in many regions. The snapshot nature of data availability makes it difficult to analyze conditions during unique events or over time.
Coverage	• Data is only available for a portion of the transportation network. Therefore, it is difficult to accurately assess the entire impacts of congestion.
Quality	• Data sets often contain erroneous data or have gaps of missing data. The data sets need significant cleaning before they can be used and accuracy is compromised.
Standards	• Data is not consistently collected, analyzed, and stored across different regions, and often times within the same region. Standardization is needed to provide for the meaningful comparison of conditions in different regions.

Availability

Continuous streams of data, covering all periods and conditions, need to be made available to properly assess these conditions and allow for meaningful comparison of trends over time. However, data simply isn't available to conduct many analysis, and even when it is has been collected, there are often problems that make the data unsuitable.

Traffic data has historically been collected on a periodic basis providing snapshot views of congestion. Transportation planners have often planned data collection activities to avoid special events, inclement weather, and traffic incidents to provide information of conditions representative of a "normal" day. This provides an incomplete picture of the full range and characteristics of congestion.

Even in areas that have continuous data collection capabilities built into their traffic management programs, specific data may be difficult to obtain. Many traffic management centers simply "spool off" the collected data for storage, with no real data management plan. The large files that are created make the data difficult to work with or inaccessible in many cases.

A potential solution to this challenge is the development of formal Archived Data Management Systems (ADMSs), which are currently under development in many regions around the country. ADMSs take a more formal approach to archiving data and making them accessible to a variety of users.

Coverage

The limited coverage of performance measurement restricts the usefulness of the data. Data coverage in many areas is limited to particular jurisdictions or facilities. Often, monitoring coverage is limited to several freeway corridors. This requires the analyst to interpolate performance measures for parts of the system that are not covered which increases the possibility of introducing errors to the data, limiting its accuracy. This partial coverage does not provide a complete picture of the nature and impacts of congestion.

Greater data coverage is needed to provide a greater understanding of the full impacts of congestion. Fortunately, many initiatives are underway to increase the coverage by introducing performance monitoring to new jurisdictions, increasing the freeway coverage in existing jurisdictions, and expanding coverage to include signalized arterials and public transportation systems. The expansion of coverage of monitoring activities will increasingly provide a more accurate picture of the full nature of congestion.

Quality

The quality of data sets in many locals is often inadequate to perform meaningful assessments of congestion. If not corrected, these data errors can result in inaccurate measurement of congestion.

The errors in the data sets can be caused by a number of sources including improperly calibrated or poorly maintained field equipment, and the lack of formal data management systems and processes. There is often very limited funding and resources for these critical tasks.

These data quality problems can be alleviated or minimized through data cleaning and validation, increased data checking and quality control and the development of more formal data archiving and management programs. These activities will require that more resources and funding be provided to support these activities.

Standards

The lack of standards present problems for analyst attempting to compare different regions or identify trends. Different jurisdictions and agencies collect, analyze, and archive data differently based on their own needs. For example, traffic incident data in a region may be collected by a number of different agencies responsible for responding to traffic incidents (e.g., Fire Department, State Highway Patrol, Transportation Authority, or others). Each of these agencies may collect different data on the incidents to which they respond. This lack of standardization limits the meaningful comparison of the data between agencies.

Further, there is currently little consensus of the analysis methods and performance measures used to assess congestion on a national basis. Different regions often monitor and analyze different performance measures, and archive data in different formats than used in other regions. This creates difficulties in tracking trends and comparing performance between different regions.

Initiatives to develop standards for archived data are gaining momentum. The success of these initiatives in promoting the adoption of standardization will provide for more meaningful analysis, especially in the comparison of trends across different regions.

B.2.2 Modeling versus Measurement

Most transportation agencies utilize some sort of modeling to analyze congestion. These models may be used to enhance field data measurement by providing predicative capabilities, or may be used in place of field data measurement when data is unavailable due to the challenges presented earlier. Recent advances in data management technology has provided improvements in the accuracy, functionality, and usefulness of both modeling and measurement processes. Future advances will likely provide further opportunities for improvement and integration of these tools.

When Should They Be Used?

A common rule of thumb that is suggested in analyzing congestion is "Measure where you can, model everything else." This recognizes that measurement using operations data often represents the best combination of accuracy and detail. However, the use of measurement data is also not feasible due to lack of availability, coverage, quality, or standardization. In these situations, modeling may be the better option. In using one or both of the analysis processes it is important to understand that modeling and measurement each have their own relative strengths and weaknesses. In general:

- Modeling provides an estimate of what would likely happen as a result of a particular change in the system assuming that individuals reacted similarly to past behaviors.
- Measurement provides an accurate assessment of what *has* happened or what *is* happening (for real-time systems), but has less ability to draw conclusions about what *will* happen.

Table B.2 provides additional detail on the relative advantages and limitations of these two approaches to analyzing congestion.

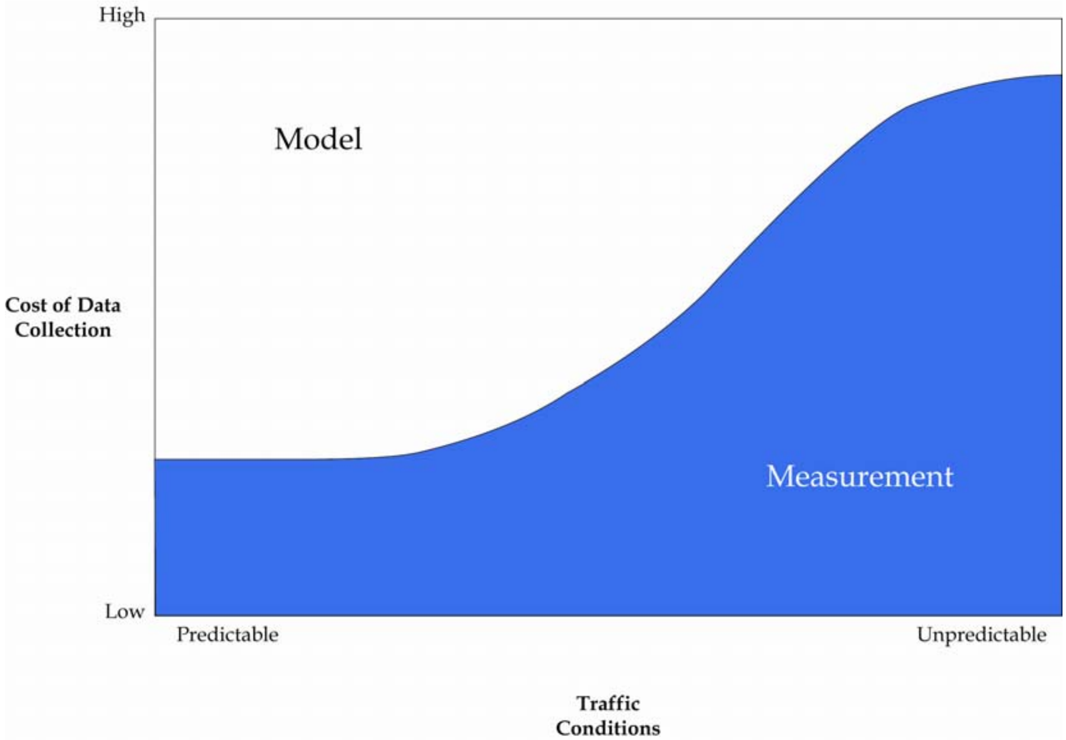
Table B.2 Comparison of the Relative Advantages and Limitations of Modeling Versus Measurement

	Advantages	Limitations
Modeling	• Provides predictive capabilities. • Once developed, can provide rapid analysis of multiple scenarios. • Can be developed to provide micro- or macro-level analysis. • Technology advances in data management are providing for more advanced and accurate models.	• Only as good as the data used to develop the models. • Provides only a simulation of what is happening in the real-world. Results must be validated against observed data. • Difficult to predict travelers reactions to unique conditions or innovative strategies. • Can be costly to develop initial models.
Measurement	• Provides a more accurate assessment of what is happening on the ground. • Can be used to analyze traveler reactions to specific conditions or unique events. • Technology advances in data collection and better data management are providing improved measurements.	• Data availability and quality issues may limit usefulness of the data. • Can be costly to implement extensive data collection programs or systems.

Since models are based on observed behaviors, they are most accurate when analyzing predictable conditions. Utilizing models to analyze extreme conditions, innovative operations strategies, or situations where traveler behaviors would be unpredictable is less advised. When the traffic conditions are extremely unpredictable, modeling should only be used if measurement is cost-prohibitive.

Figure B.2 shows the tradeoffs between the relative cost of the analysis and the conditions being analyzed, demonstrating the general areas of strength for both models and measurement.

Figure B.2 Modeling Versus Measurement – When Should They Be Used?



Are Modeling and Measurement Processes Compatible?

Many agencies still view modeling and measurement as mutually exclusive processes with different end uses; however, many progressive agencies are increasingly integrating the processes to provide even more powerful tools for analyzing congestion.

Examples of the benefits that can be achieved through the integration of measurement and models include:

- Data sets obtained through measurement can be used in the development and validation of models;
- Models can be tied to real-time data measurement to add the capability to predict future conditions based on current real-world conditions;
- Models can be used to extrapolate localized measurement data to a regional scale; and
- Data generated by models can also be used to provide sensitivity testing as a reality check on measurement tools and data sets in order to help identify potentially erroneous data or alert personnel of inoperative data collection equipment.

B.3 What We Have Learned

The trends and lessons learned presented in this section were originally presented in the report, *Congestion and System Performance Activities at FHWA: Trends, Lessons, and Future Direction.*

Traffic Data Trends

Real-time traffic data collection and archiving processes have been developed independently in most of the cities and the details of these processes vary among the cities. As a general rule, TMCs at least have the capability to archive data from their surveillance systems. In a few cases, this capability is not used because of priorities elsewhere in the TMC, but it is clear that TMC software is being constructed with archiving as a function. However, the state of the practice in TMC archiving is still fairly primitive. The most common practice is to transfer the data to a storage device where they reside in simple file formats without an active information management system. Quality control is rarely performed at this level and access to the data is provided on a case-by-case basis without the benefit of a query or reporting structure – data are simply provided in whatever file formats are used to store them.

There are several process steps that are relatively common to nearly all cities. The data collection and archiving process typically includes the following steps:

- Data are collected by traffic sensors and accumulated in roadside controllers. These field measurements are collected for each individual lane of traffic. At 20-second to two-minute intervals, the roadside controllers transmit the data to a central location, typically a TMC;
- Some cities perform quality control on field-collected data, but this checking is simple and based on minimum- and maximum-range value thresholds;
- Cities that use single inductance loop detectors as sensors can measure only volumes and lane occupancies directly. In these cases, speed estimation algorithms are used to compute speeds from volumes and lane occupancies. These speed estimation algorithms vary among cities;
- Internal processes at the TMC aggregate the traffic data to specified time intervals for archival purposes. These time intervals vary from 20 seconds (no aggregation) to 15 minutes. In some cases, the data are also aggregated across all lanes in a given direction at a sensor location; and
- The aggregated data are then stored in text files or databases unique to each TMC. CDs are routinely created at the TMCs to offload some of the storage burden and to satisfy outside requests for the data.

Calibration and maintenance of field equipment and communications are universal problems. The main impediment is lack of resources to devote to these tasks; TMC budgets are limited and must be used to address a multitude of issues. Calibration – at least to very tight tolerances – is not seen as a priority, given that operators focus on a broad range of operating conditions rather than precise volume and speed measurements. Or in some cases traffic managers may be willing to accept a certain level of data quality to satisfy only their current operations applications. This philosophy may be changing as a result of more stringent data requirements for traveler information purposes (e.g., travel time messages on variable message signs). However, we found the current data resolution used by TMCs to be quite coarse for supporting their traditional operations activities, such as traffic incident detection and ramp meter control.

Maintenance is a problem (due primarily to funding limitations) even when loops are known to be producing erroneous or no data. The problem is exacerbated where loops are used because most agencies are reluctant to shut down traffic on heavily traveled freeways just for loop repair. This is not to say that faulty loops are never repaired, but maintenance is often postponed to coincide with other roadway activities, which helps spread the cost burden as well.

Field checking of sensors is done periodically but no standardized procedures are used across all cities. If a detector is producing values that are clearly out of range, inspection and maintenance are usually performed. However, calibration to a known standard is rarely, if ever, performed. This means that more subtle errors may go undetected. Bearing in mind that TMCs typically do not require highly accurate data for most of their operations, this approach is reasonable and practical. Work zones exacerbate these problems and often contractors unknowingly sever communication lines or pave over inductance loops.

Traffic Incident Data and Other Event Data Trends

Archiving of traffic incident data is becoming more prevalent at TMCs. However, the nature of the data collected and the structure of the storage formats are extremely diverse. This is a larger problem than for traffic data, where the basic measurements are fairly well known and understood. By comparison, even the definition of an "incident" is subject to interpretation. The resulting inconsistency in reporting formats for traffic incidents limits analysis opportunities.

The UCR has gained some experience and insights using traffic incident, weather, and work zone event data. For example, the month of February 2002 featured a number of significant snowstorms in the northeast, affecting four of the 10 UCR cities (Pittsburgh, Philadelphia, Boston, and Cincinnati). The February storms featured large snowfall totals that rendered roadways largely impassable and suppressed travel demand for several days. The resulting UCR measures in these cities showed briefer periods of less intense congestion than on a typical workday in the days just following snowstorms. After the local roads had been cleared, however, and access to freeways opened, congestion was particularly long-lasting throughout the day and more intense than on a typical workday. The snowstorm example shows how weather and travel time data can be utilized jointly to provide insight on the mobility impacts of weather or other capacity-reducing events.

Data collected by UCR and MMP processes during traffic incident conditions tend to diminish the effect of the traffic incidents, while the UMS process incorporates a relatively simple estimate for the effect of traffic incidents. Just as in the snowstorm conditions, trips divert from the freeway mainlines when a traffic incident occurs. This diversion frequently results in traffic demand going to a major street that is not monitored by the data collection equipment. The effect of this diversion is to decrease the volume of traffic that appears to be affected by the traffic incident, and also decreases the amount of extra delay associated with the traffic incident. Until data is collected for more of the system, this problem will affect delay and traffic condition assessments.

Local Use of Congestion Performance Measures and Archived Data

As mentioned above, nearly all TMCs "spool off" their traffic data for storage, but formal data management rarely occurs. The resulting files are very large and relatively inaccessible, limiting the use of the data in many applications. However, several formal Archived Data Management Systems (ADMSs) are under development around the country. ADMSs take a more formal approach to archiving data and making them accessible to a variety of users. A variety of government and even private agencies are involved in ADMS development and operation. Universities are heavily represented in this category, but state DOTs and some metropolitan planning organizations (MPO) are also involved.

In addition to archiving ITS-generated data, many states and MPOs have embraced the concept of performance measurement. This trend is developed a substantial amount of inertia and can no longer be seen as theoretical – transportation agencies are imbedding performance measurement into their day-to-day activities. Examples include:

- **Arizona –** Both the Arizona Department of Transportation (ADOT) and the Maricopa Association of Governments (MAG) are supporting performance monitoring programs. ADOT has folded the implementation of a scaled down CMS (based on the MMP's reliability index) into the Arizona state transportation plan (MoveAZ Plan).
- **Minnesota –** The Minnesota Department of Transportation (MnDOT) is studying adoption of the primary performance measures in MMP, namely the travel time index as a mobility measure and the buffer time index as a reliability measure. The MMP team has worked with both MnDOT staff and their consultants as they have performed demonstration and feasibility projects for implementing these measures.
- **Oregon –** The Oregon Department of Transportation (ODOT) Traffic Management Section is studying several of the measures used in the MMP reports. TTI is providing technical assistance as they conduct a demonstration project to study the travel time index, the buffer time index

and other measures for local and statewide implementation. The goal is to use the archived data in combination with other, more widely available data to construct a method to evaluate operations on the entire roadway network.

- **California –** The California Department of Transportation (Caltrans), with the technical support of the University of California-Berkeley, is in the process of developing and integrating a statewide data archive and performance monitoring system called PeMS (Freeway Performance Measurement System). The PeMS program has supplied data for Los Angeles for 2000 and 2001.
- **Virginia –** The University of Virginia and the Virginia Transportation Research Council (VTRC), the research arm of Virginia DOT, have been designated the official data archive managers for the State of Virginia. Their staff has supplied data from Hampton Roads and Northern Virginia to the MMP team. Additionally, they have conducted several feasibility studies of the performance measures used in the MMP reports and are considering adoption of some of the mobility and reliability measures.
- **Washington –** The Washington State DOT has a research and implementation effort to develop a set of mobility performance measures. The University of Washington, the primary analyst of archived data for WsDOT, is conducting the research and produces one of the premier annual congestion performance reports in the country.

C. Delay and Reliability Measures

Travel time index (TTI) is a comparison between the travel conditions in the peak period to free-flow conditions. It uses the units of travel rate due to the ease of mathematical calculation and due to the data elements included in the MMP database. The TTI could also use direct travel time comparisons for trips of the same length. The equation below presents the calculation of the travel time index. The travel time index is also similar to the travel rate index (TRI) used in the Texas Transportation Institute's Annual Mobility Report. The TRI only includes the effect of recurring congestion, while the TTI includes recurring and nonrecurring congestion – the conditions measured with continuous data collection equipment.

$$\text{Travel Time Index} = \frac{\left(\dfrac{\text{Freeway Travel Rate}}{\text{Freeway Free-flow Rate}} \times \text{Freeway Peak Period VMT}\right) + \left(\dfrac{\text{Principal Arterial Street Travel Rate}}{\text{Principal Arterial Street Free-flow Rate}} \times \text{Principal Arterial Street Peak Period VMT}\right)}{\left(\text{Freeway Peak Period VMT} + \text{Principal Arterial Street Peak Period VMT}\right)}$$

The index can be applied to various system elements with different free-flow speeds. The travel time index compares measured travel rates to free flow conditions for any combination of freeways and streets. Index values can be related to the general public as an indicator of the length of extra time spent in the transportation system during a trip.

The **Buffer Time Index** (BTI) expresses the amount of extra "buffer" time needed to be on-time 95 percent of the time (late 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. The index is calculated for each road segment and a weighted average is calculated using vehicle-miles of travel as the weighting factor.

$$\text{Buffer Time Index} = \text{Weighted Average of All Sections (Using VMT)} \left[\frac{\text{95th Percentile Travel Rate (in minutes per mile)} - \text{Average Travel Rate (in minutes per mile)}}{\text{Average Travel Rate (in minutes per mile)}} \times 100\%\right]$$

The **Planning Time Index (PTI)** is simply the 95th percentile travel time index. It is used as a supplemental measure for reliability. Because reliability is related to the distribution of travel rates, the 95th percentile indicates an excessively high travel rate, one that only five percent of all travel rates exceed for the time period under consideration.

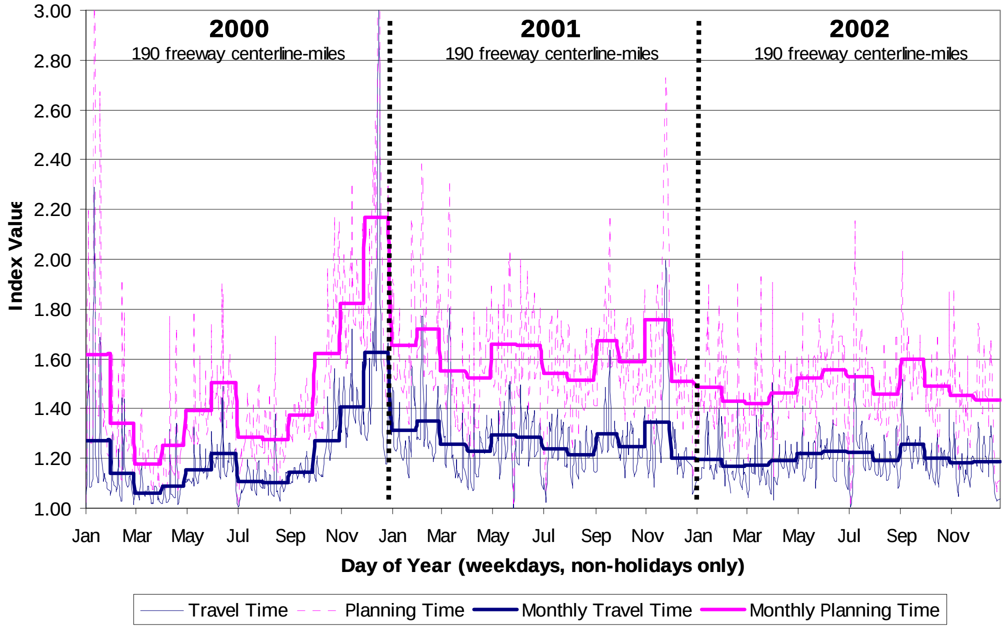
D. City Level Trends in Reliability

To supplement the TTI analysis, we have conducted a series of case studies using data from the Mobility Monitoring Program for four cities: Los Angeles, Minneapolis, Seattle, and Atlanta. These data come from instrumented freeways which tend to be the higher congestion locations. Figures D.1 through D.4 present congestion trends for the period between 2000 and 2002. In these figures, daily statistics ("travel time" and "planning time") are shown as the faint and highly variable background lines. (Planning time is the 95th percentile travel time, a measure of reliability.) Monthly summaries are also shown as means to determine long-term trends.

- Minneapolis showed a sharp upturn in both base congestion level and unreliability toward the end of 2000. Beginning in October, an experiment was conducted there to examine the effect of ramp metering by turning the meters off – this led to worsening of congestion and reliability. In December, the area was also hit with a series of winter storms. From 2001 to 2002, congestion eased very slightly.
- Atlanta has shown a steady increase in congestion and unreliable travel times from 2002 to 2002. Some of this may be the fact that the surveillance system has expanded to new highways over the period, but the base system covered in 2000 already includes some of the worst areas (e.g., the central Atlanta section discussed in Section 2.0).
- Congestion and unreliable travel times are on the increase in Los Angeles.
- Congestion in Seattle was relatively flat for the period 2000-2002. However, an interesting seasonal pattern is evident: congestion and unreliable travel times are lower early in the year and increase toward the end of the year.

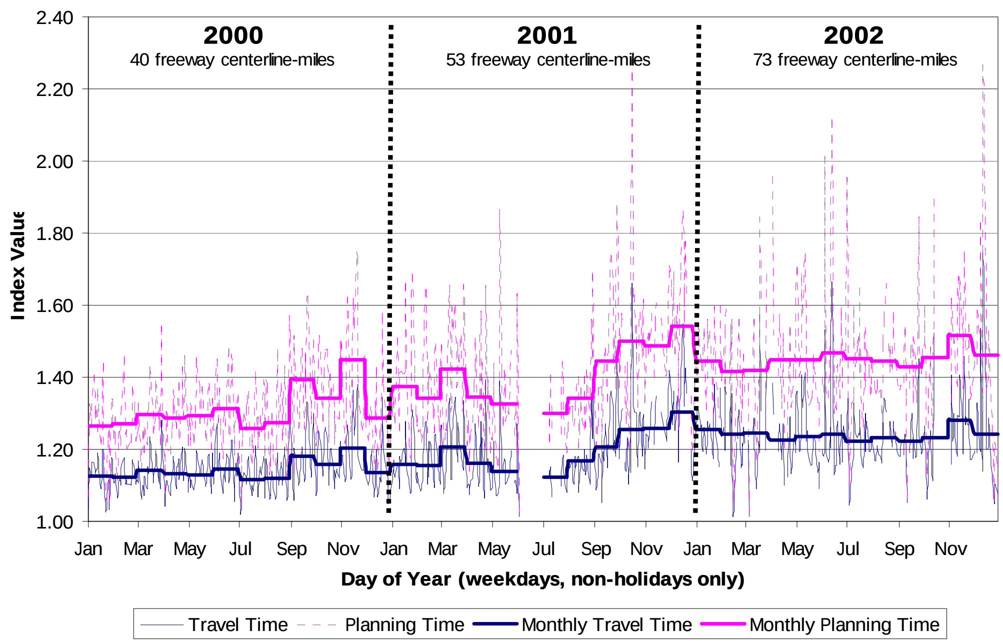
Another way to measure reliability is to consider the Buffer Index computed for the entire year (Figure D.5). Except in Minneapolis – where the effect of the "ramp meter shutdown" and winter storms in late 2000 caused extreme unreliability – the cities show a slow increase in unreliable travel times from 2000 to 2002.

Figure D.1 Congestion Trends on Minneapolis Freeways



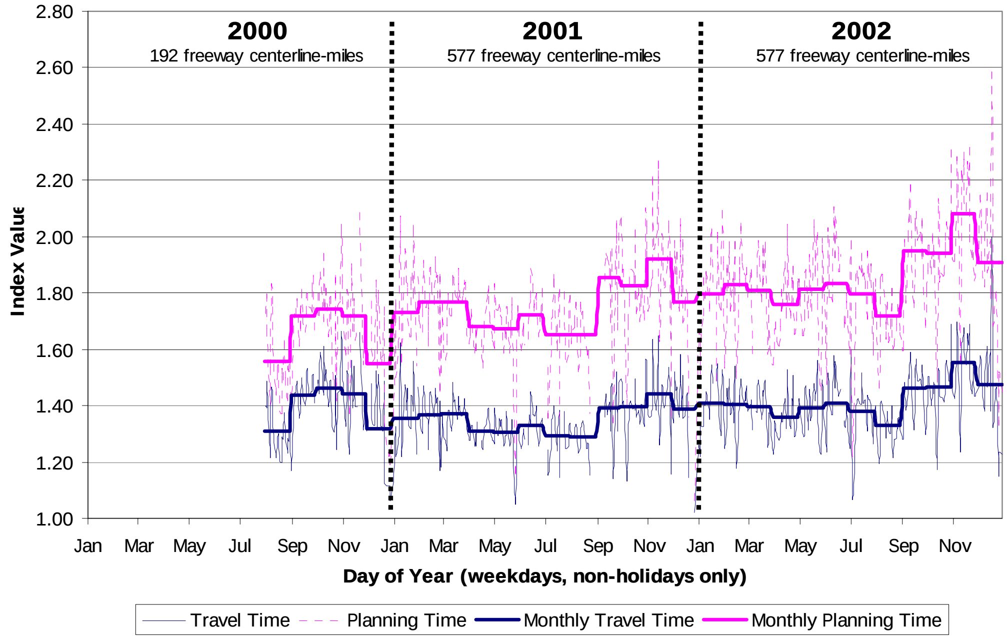
Source: Analysis of data from FHWA's *Mobility Monitoring Program.*

Figure D.2 Congestion Trends on Atlanta Freeways



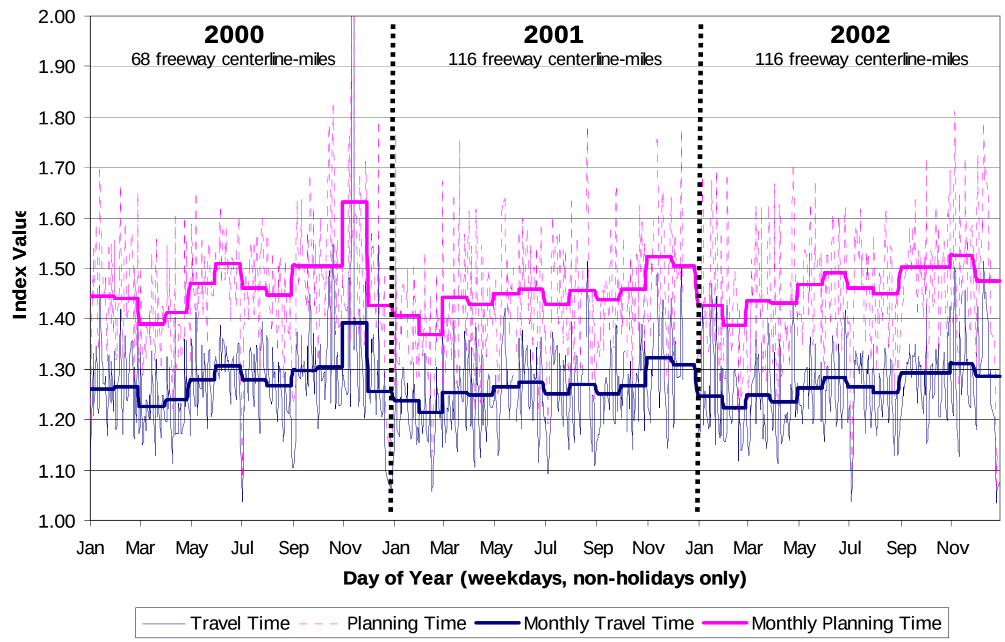
Source: Analysis of data from FHWA's *Mobility Monitoring Program.*

Figure D.3 Congestion Trends on Los Angeles Freeways



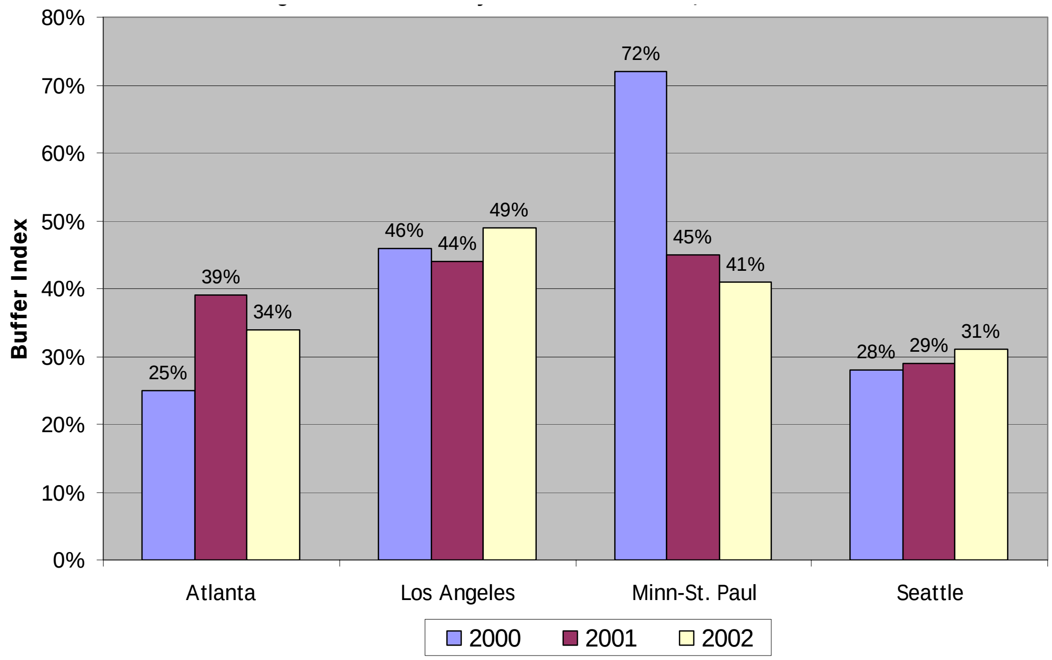
Source: Analysis of data from FHWA's *Mobility Monitoring Program.*

Figure D.4 Congestion Trends on Seattle Freeways



Source: Analysis of data from FHWA's *Mobility Monitoring Program.*

Figure D.5 Reliability Trends in Four Cities
2000-2002



Source: Analysis of data from FHWA's *Mobility Monitoring Program.*