TRAFFIC CONGESTION AND TRAVEL RELIABILITY

How Bad is the Situation and

What is Being Done About It?

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Why Do We Have Congestion?

Taken in a long historical sense, congestion has been around forever. Periods without significant congestion of some kind have probably been relatively limited. Our current congestion levels may be higher than we desire, but they may not be all that unusual. What affects our current view is that one of the l ow congestion periods happened during the 1960s and 1970s. The Interstate construction era provided much greater expansion in travel capacity than the growth in travel over the same period— traffic congestion decreased in many large cities. Some of the current debate is focused on returning mobility levels to those very good conditions.

If the development patterns of ancient society are examined, it is possible to draw a conclusion that the average time for travel to work locations has been relatively stable for a few thousand years!! What has changed is the mode of travel and the development patterns.

- When everyone walked, cities were rarely more than 100,000 population, houses were close together and small.
- "Suburban office and commercial centers" we re developed as entirely new cities when existing towns grew too large.
- With rail passenger service, towns could have new developments farther from the city center and still have 20 to 30 minute average travel times to work. Houses were developed near stations, and farm/ranch/vacant land was left between the rail lines.
- Auto travel increased the ability to develop land between the rail lines.
- As houses moved to the suburbs the commute times for auto trips grew longer. Work locations began to move outward from the center city to be within acceptable travel times of the workers' homes (*1*).

We will continue to live in cities and use autos as a basic mode of transportation. The question is how much impact will our travel mode decisions have on our quality of life and economic competitiveness. Travel time is one aspect of the decision process— the amount of time it takes to reach the destination no matter which mode or route is used. And the variation in travel time is another relatively simple concept that has been a part of most discussions in recent years. Cost, or some sort of economic impact evaluation, is another factor in congestion or mobility discussions. These are key components of the decisions that travelers and shippers make every day. Other aspects include security, comfort, and convenience. Options for travel mode, route and cost are also part of the decision process. Finally, location choice itself can always be changed. Businesses and people simply choose to locate where congestion costs are lower. This can mean the far suburbs, but it can also mean an entirely different state or region.

The growth in population and travel needs will continue— the challenge is for the growth to be handled in ways that don't make travel time considerations an undue burden. While congestion—in traffic, transit, Internet, or other forms— will not be eliminated, there are many improvements that can make congestion easier to deal with. Some of these require construction or behavioral changes. Several others a re comparatively simple changes in the way the system is managed by agencies and used by travelers and freight shippers. This paper explores some of the issues of traffic congestion and mobility in U.S. cities at the beginning of the 21st Century.

The Wile E. Coyote Theorem of Freeway Performance

Freeway performance on congested and nearly congested roadways can perhaps best be explained by analogy to the Warner Bros. Road Runner cartoons.

First, let's talk about the cartoon. In a familiar Road Runner scene, Wile E. Coyote chases the Road Runner across the mesas of New Mexico. They run along a mesa until the Road Runner simply runs off the end, into thin air. Unaware, the Coyote follows him, running on thin air. Then something happens: he looks down. The Road Runner, safe as ever, whips out a taunting sign, and suddenly the Coyote realizes he is hanging in air. Zoom! Down he plunges for hundreds of feet….ending in a small puff of dust.

This same scenario is a very good description of urban freeway operations.

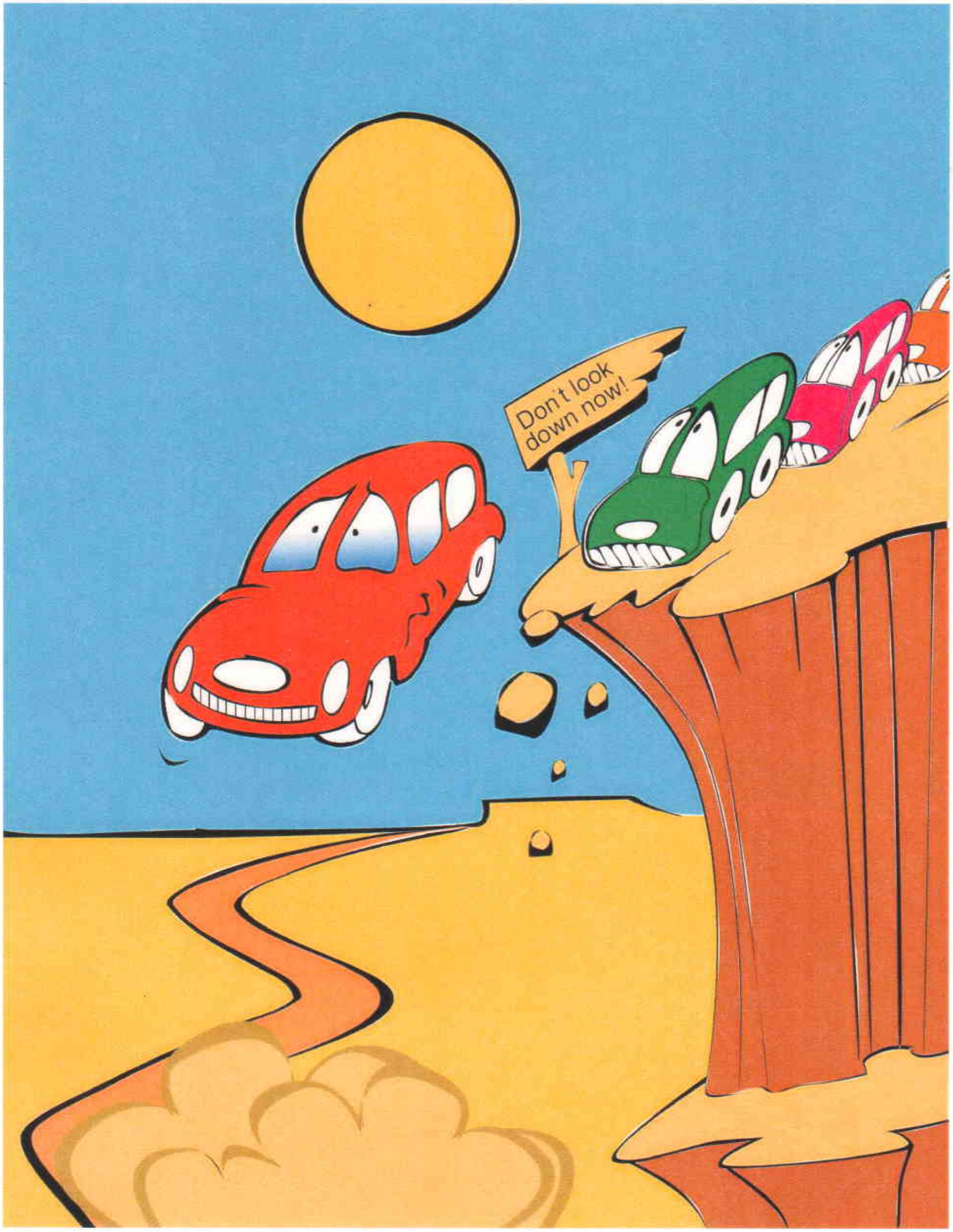
Detection systems now measure freeway volumes that are 20 percent greater than what was once considered their theoretical maximum. However, under these volume conditions, when any type of disturbance in flow occurs, dramatic decreases in vehicle volumes and speeds result.

High volumes can be compared to the Coyote running along the top of the mesa. Volumes above about 2000 vehicles per lane per hour can be viewed as the Coyote running in air. As long as nothing happens to remind him that he is doing the impossible, he's okay. And as long as nothing happens along the roadway, traffic will continue flowing.

The problem is, "things happen." Accidents occur. Even small disruptions, such as a distraction on the side of the road (a catchy billboard, a police car pulled over) are analogous to the Coyote looking down. At very high volumes, one vehicle's small hesitation can cause other vehicles to brake more heavily to avoid a collision. The disruption in flow then cascades, and suddenly both speed and throughput volume rapidly decrease. Like the Coyote, roadway performance plummets, and vehicle throughput vanishes in a small puff of dust.

And tomorrow, the Coyote will do it all again.

Once again life imitates art.


Don't look
down now!

What's Happening to Rush "Hour?"

In just about every city over 1 million people, it's longer than an hour in the morning and an hour in the evening and needless to say, few people are "rushing" anywhere (*2*). The growth in travel demand and traffic congestion has followed a very predictable, evolutionary pattern. This pattern is illustrated in Exhibits 1 and 2.

...at a spot on a freeway.

Initially, traffic levels grow immediately before the start of the work day and immediately after the end of the work day (the green line). As traffic reaches the roadway's capacity during those times, travelers begin to leave 10 or 15 minutes earlier or later in the day to avoid the resulting congestion or they allow more time for travel. This spread of travel demand soon creates a true "peak hour" of volume. As growth continues, like it has in most major cities, the "peak hour" becomes the "peak period," since limitations in roadway capacity allow growth in traffic to occur only at the beginning and end of the "peak period" (see the red line in Exhibit 1). The sharp morning or afternoon peak in travel thus becomes a wide mesa. In many areas, particularly suburban areas, these peak movements stop being one-directional (people traveling from the suburbs to the central city in the morning and back in the afternoon) and become two -directional as people travel among multiple suburban locations.

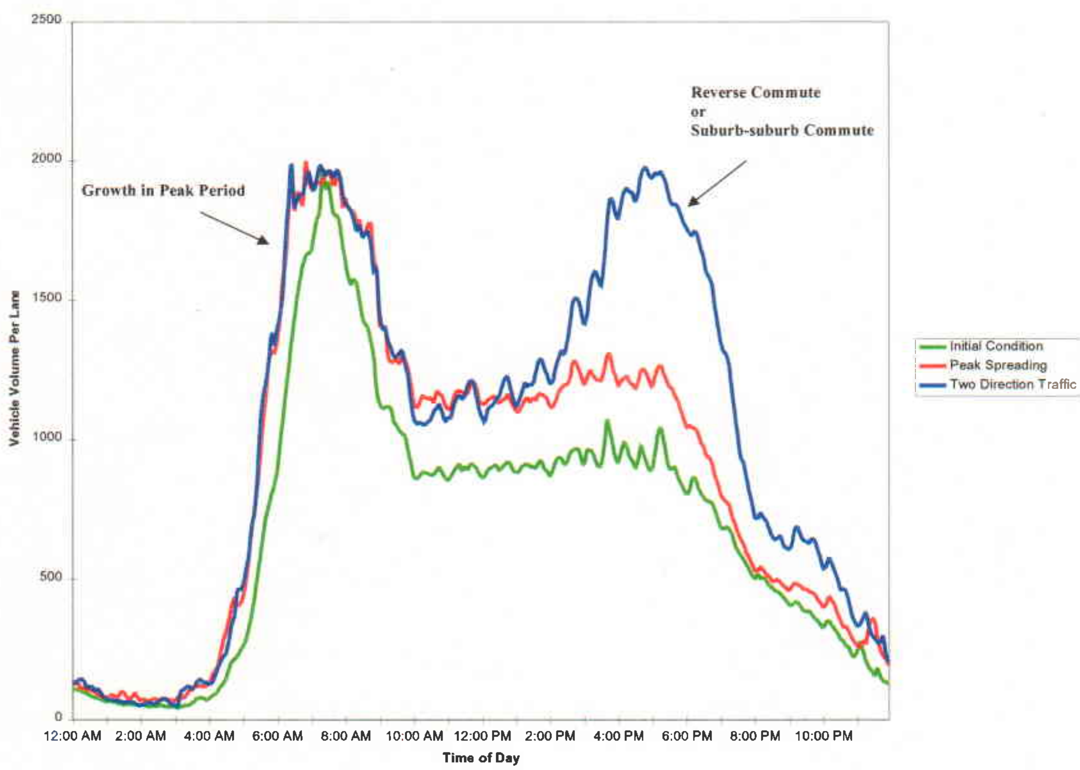


Exhibit 1. Typical Volume Growth Over Time[1]

[1] Volume in this graph is shown for a single direction. The direction selected shows a typical suburb to city center directional movement. Volumes are shown for a typical freeway. Source: (*3*)

As the evolution of congestion continues, travel on heavily used (and frequently congested) roads actually becomes almost constant throughout the day. Finally, as growth pressure continues, congestion in the peak periods can become so severe that average peak period volumes actually *decline* because congestion decreases the volume of vehicles a road can accommodate. These later stages of traffic volume growth are illustrated in Exhibit 2.

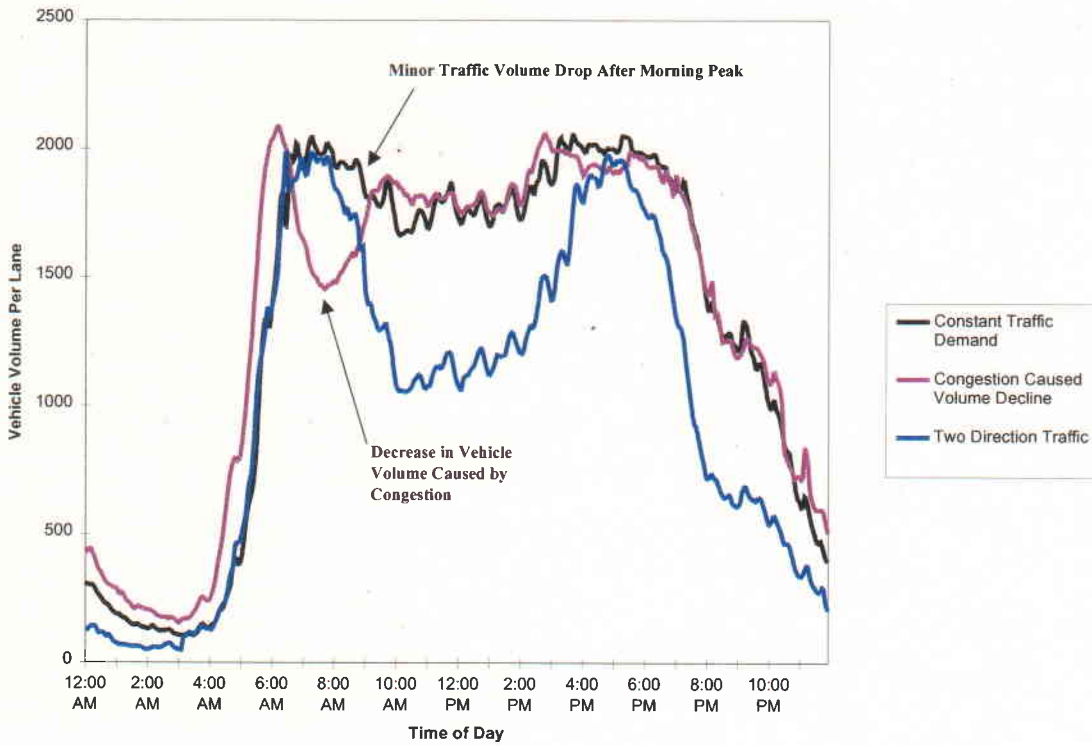


Exhibit 2. Later Stages of Traffic Volume Growth

Source: (*3*)

...at the urban area level

Congestion is growing in areas of every size. TTI's 2001 Annual Urban Mobility Report (*2*) shows more severe congestion that lasts a longer period of time and affects more of the transportation network in 1999 than in 1982 in all urban population categories. The average annual delay per person climbed from 11 hours in 1982 to 36 hours in 1999. And delay over the same period quintupled in areas with less than 1 million people. The time to complete a trip during the congested period also continues to get longer.

The Travel Rate Index (TRI) measures the amount of additional time needed to make a trip in the peak period rather than at other times of the day. This measure is based solely on the regular traffic congestion on the roadways. This gives us an idea of how much of the change in traffic congestion is due solely to more cars using the roadways and/or not enough travelers choosing one of the other travel modes or travel options.

Trends for the four urban area population categories in the 2001 Annual Report (*2*) indicate increasing congestion since 1982 (Exhibit 3). The Very Large category shows the effect of the economic slowdown in Los Angeles and San Francisco -Oakland—2 of the Very Large cities—in the early and mid 1990s. All other categories show steady increases over time resulting in Travel Rate Index values that indicate time penalties from two to four times higher in 1999 than 1982.

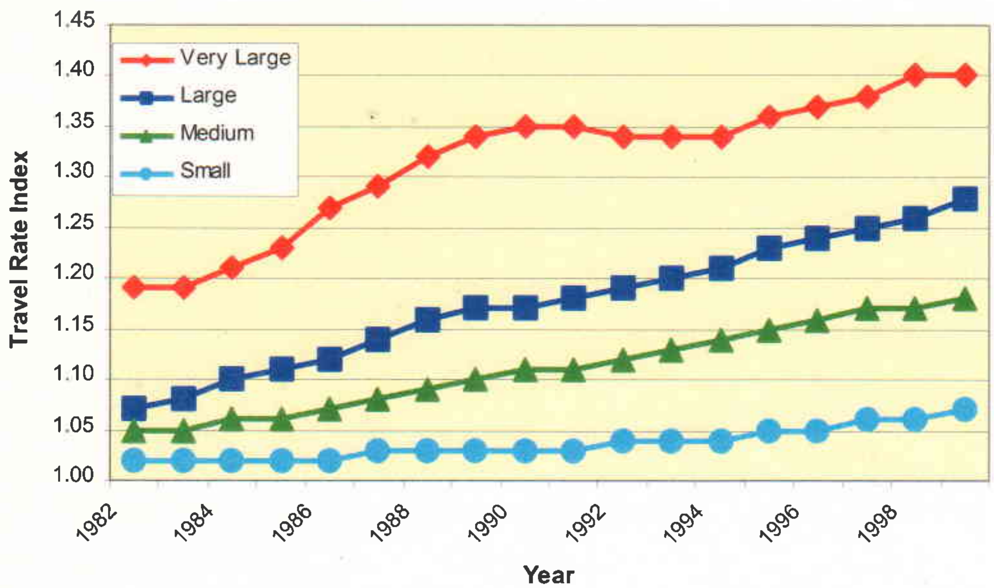


Exhibit 3. Congestion Trends in Urban Areas

Source: (*2*)

The need for attention to transportation projects is als o illustrated in these trends. Major projects or programs require a significant planning and development time— 10 years is not an unrealistic timeframe to go from an idea to a completed project or to an accepted program. At recent growth rates, the urban area average congestion values will jump to the next highest classification—medium areas in 2009 will have congestion problems of large areas in 1999. Shorter term operational programs and policy options, thus, become even more important.

Congestion is typically viewed by travelers relative to their normal day-to-day experiences. Travelers accustomed to low speeds and congestion delays for 12 hours each day may not consider 10 minutes of delay per trip a problem. These travelers have learned to budget extra time or find other ways to cope with the delay. Travelers accustomed to light traffic and reliable trips might consider 5 minutes of delay per trip unacceptable and a problem worth noting at the next City Council meeting. A key aspect of a congestion management strategy is identifying the level of "acceptable" congestion and developing plans and programs to achieve that target.

The Answer Is Simple, Isn't It? More Roads And More Transit?

Yes and No. Roads and transit are part of the solution. But neither by itself will solve the expected mobility problems in growing cities over 500,000 without a significant shift in travel or funding patterns. Even together they don't typically provide the necessary amount of travel capacity improvements. The pro blem is that travel is growing faster than funding, public support and environmental clearances.

Roadway additions made significant differences in the growth of travel delay in urban areas between 1982 and 1999 (*2*). The analysis (Exhibit 4) shows that changes in roadway supply have an effect on the growth in recurring delay— delay due to heavy traffic demand —in an area. Additional roadway reduces the rate of increase in travel time to make peak period trips. In general, as the lane-mile construction "def icit" gets smaller (meaning that urban areas add

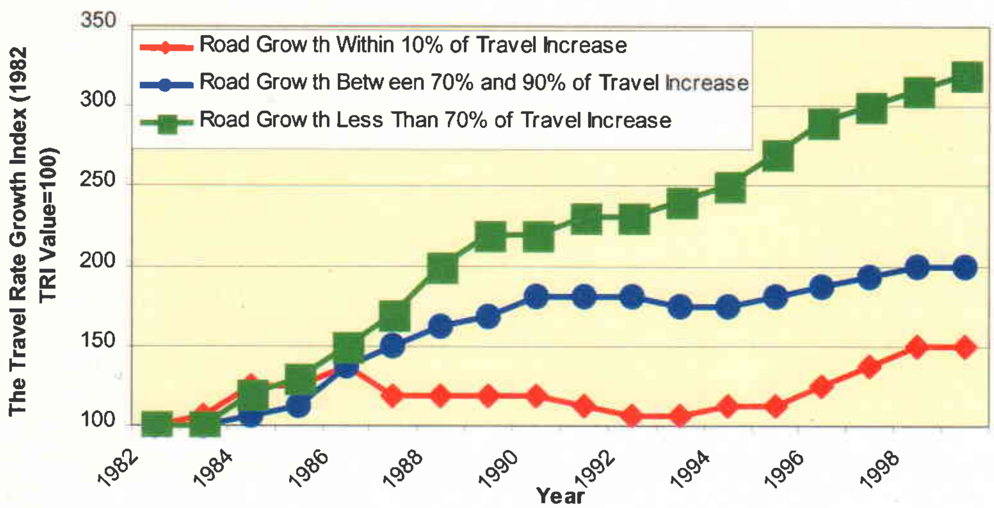


Exhibit 4. The Effect of Roadway Increase on Travel Rate (1982 to 1999)

Source: (*2*)

capacity at about the same rate that travel increases) the travel time increase is also smaller.

This period includes several instances of rapid population growth, usually accompanied by road congestion growth. The length of time needed to plan and construct major transportation improvements means that very few areas see a rapid increase in economic activity and population without a significant growth in congestion.

The amount of new roadway needed in the future is difficult to estimate for at least two reasons:

- Most urban areas implement a wide variety of projects and programs to deal with traffic congestion. Each of these projects or programs can add to the overall mobility level for the area. Thus, isolating the effects of roadway construction is difficult because these other programs and projects are making a contribution at the same time.

- The relevancy of the congestion analysis is questionable. Many areas have focused on managing the growth of congestion, particularly in rapid growth areas. The analysis presented here is not intended to suggest that road construction is the best or only method to address congestion, but some readers will interpret it that way.

The data show that it would be almost impossible to maintain a constant congestion level with road construction only. Over the past 2 decades, only about 50 percent of the needed mileage was actually added (Exhibit 5) (*2*). This means that something on the order of twice the level of current-day road expansion funding would be required to attempt this road construction strategy. An even larger problem would be to find projects on which to spend this funding for several years. Most urban areas are pursuing a range of congestion management strategies, with road widening or construction being one of them.

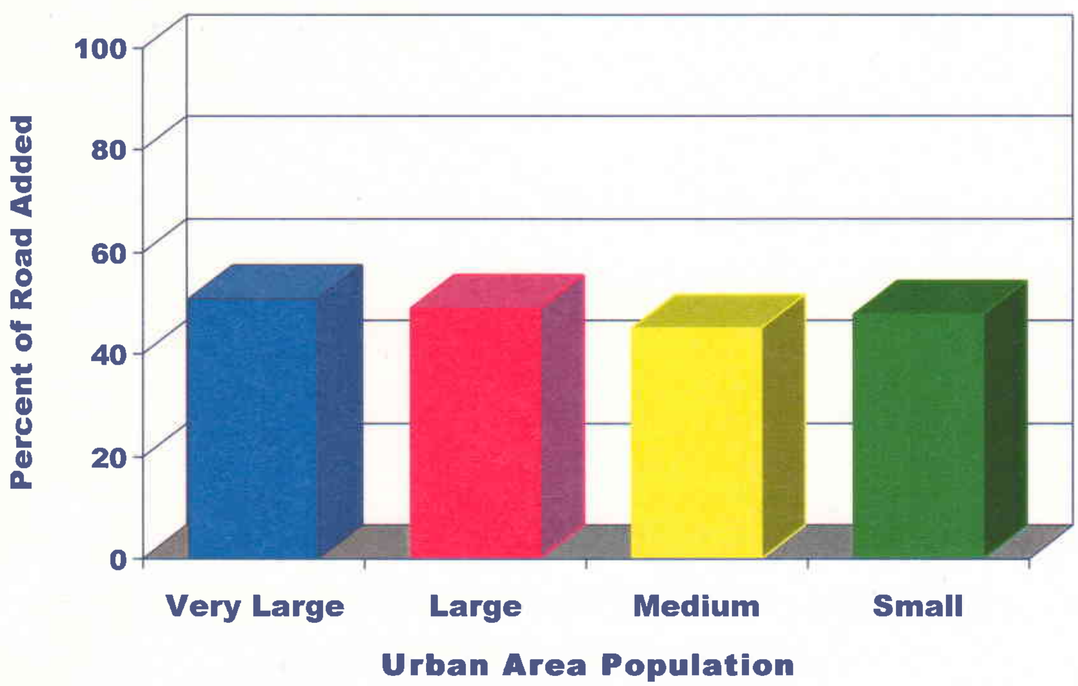


Exhibit 5. Percent of Roadway Added (1982 to 1999) to Maintain Congestion Level

Source: (*2*)

The transit and ridesharing picture is not any better. Just as "roadway construction only" solutions have not provided the answer, it doesn't appear that techniques that emphasize changes in occupancy level can accommodate all of the travel growth either. An increase of 0.04 persons per vehicle would have to occur every year to keep pace with increasing demand (Exhibit 6) (*2*). Every year would have to see an increase in daily carpool and bus usage of four percent of the person trips, approximately 6 million daily trips. This is about 2/3rds of the annual U.S. transit ridership. Even given the recent growth in transit ridership, it will be difficult to convince this many persons to begin ridesharing. As a point of comparison, transit agencies deservedly pointed with pride to the growth in transit ridership from 1999 to 2000— an increase of 320,000 daily trips.

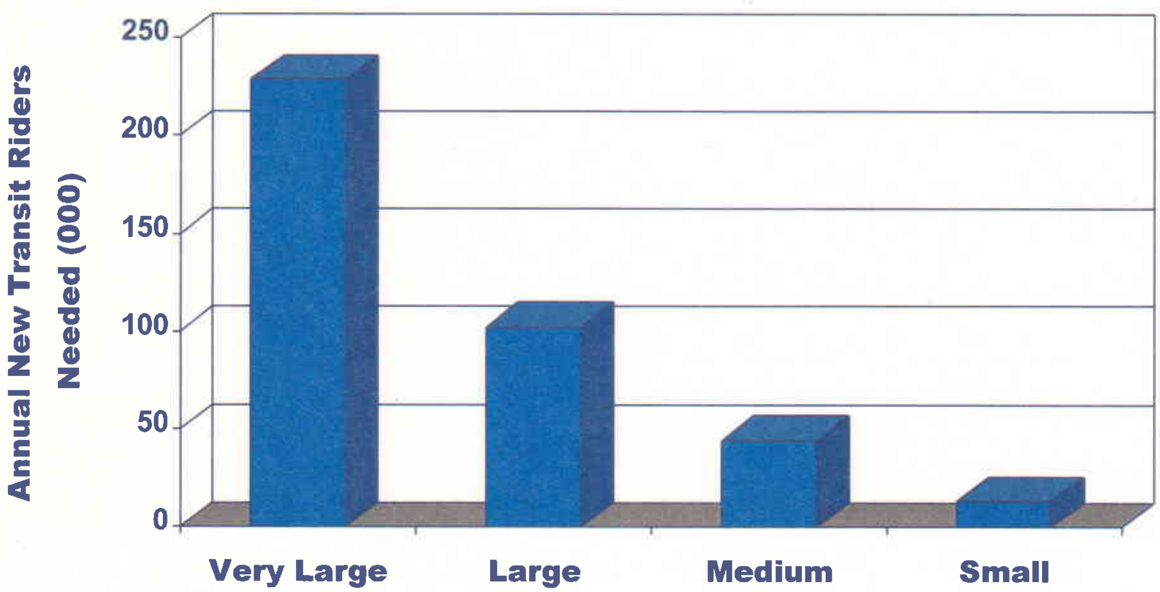


Exhibit 6. New Transit and Rideshare Riders Needed Each Year to Accommodate Travel Growth

Source: (*2*)

How Does Congestion Affect Customers? Transportation Agencies?

The ever widening peak period is not only a major source of frustration for motorists, but the loss of vehicle throughput during the peak hour is of major importance to highway agencies. To the motorist, rising congestion in the worst of the peak period means that travel times slowly increase. However, more noticeable to travelers than the gradual increase in average travel time is the increase in how often "really bad" days occur. This increase means that travelers have to build more time into their travel schedule whenever they have to reach key activities on time.

Congestion, and particularly unexpected congestion, has a very strong impact on travelers' attitudes. Motorists and transit riders want to know what to expect. The public almost always views provision of accurate traveler information to motorists very positively (*4*). Having accurate information about roadway performance significantly improves the perception of a trip because information allows motorists to make decisions that give them the perception of having more control over their life. (Such decisions may be to cancel the trip altogether, to change routes or destination, or even to simply let someone know that dinner will be late).

Providing travelers with information about delays that can be expected from major construction projects is now commonplace. The public demands it —not only because it reduces the delay and improves the safety of the construction project, but because it allows the public to make plans in anticipation of those expected delays. This significantly improves the public's attitudes toward these necessary projects.

Studies of traveler information show that most travelers want to know what is happening regardless of whether they choose to change their travel behavior (*5*). Understanding that an accident has occurred 1/2 mile ahead and that the delay is 10 extra minutes is appreciated, even if it does not mean the traveler will change routes to avoid the delay. This is because knowing the extent and duration of congestion not only gives the motorist better options, it removes a significant stress point, the unknown. (For example, a motorist trying to reach his daughter's softball game realizes that the 10-minute delay won't force him to miss the first pitch; therefore, he can relax and approach the accident site more cautiously.) Thus the perception of the congestion improves significantly. Conversely, when information is not available, the anxiety associated with the unknown reason for, and length of, the delay causes the motorist to perceive the delay as longer than it really is and creates a much more negative opinion of both the traffic congestion and, ultimately, how well the highway agency is using taxpayer resources.

Commercial freight carriers notice the growing lack of reliability even more. These companies experience increasing costs from having to pay large quantities of overtime because their trucks are stuck in unexpected traffic. Costs also increase from an inability to schedule work for their vehicles over the complete workday, as the companies lengthen expected delivery times just to ensure that they don't have to pay overtime. Inefficiencies caused by unreliable roadway travel times add to the costs that slow moving traffic create by making each trip last longer.

Congestion not only delays motorists, but, as discussed above, it actually *reduces* the vehicle volumes a roadway can serve. To highway agencies this loss of vehicle throughput in the peak period is distressing because capacity in peak periods is already scarce.

To keep roadways operating at peak volumes as efficiently as possible requires effective operational control systems and strategies. By using modern control systems, highway agencies can actively manage the roadways. Effective roadway management reduces the size and extent of congestion and increases the capacity of existing facilities. Because most highway agencies have difficulty funding and building new roadway capacity in congested urban areas, more and more agencies are implementing modern traffic control and management systems to maximize the efficiency of the roadways that already exist.

How Does Congestion Affect Transit Operations?

Congested roadways slow transit vehicles and their passengers. Clearly, passengers who are delayed are affected by congestion, but the transit service operator is affected as well. To maintain on-time arrivals, transit operators have to accommodate recurring congestion delays by increasing vehicle trip times in transit schedules. This necessitates increasing the hours that drivers must be paid. In some cases, even minor increases in transit vehicle travel times require the addition of vehicles to be able to offer the same number of trips. Transit operator then have two choices: either increase the budget to maint ain the same level of service, or cut service to be able to continue operating at the same budget level.

Strategies that improve the speed and reliability of transit services not only directly affect transit customer satisfaction, thus encouraging transit use, but also lower the cost of providing transit services. These strategies include bus-only or high-occupancy vehicle lanes on freeways, arterials, and city streets and transit signal priority systems that reduce the delay that transit vehicles experience at traffic lights.

Non-recurring congestion poses significant problems for transit operations as well. Delays that aren't built into the schedule result in late buses, overloads, and frustrated passengers. These delays erode the perceived reliability of transit services and discourage use of transit just when transit is needed to help mitigate the effects of congestion.

Transit operators are increasingly relying on global positioning systems to monitor the location of transit vehicles in "real time." Using this technology, dispatchers can quickly respond to unexpected adverse traffic conditions and transit service interruptions. In metropolitan areas with sophisticated traffic monitoring technologies, transit operators are able to monitor congestion and incidents on the road network and instruct transit drivers to avoid congested areas when possible. Having systems that track the location and on-time status of transit vehicles also enables agencies to provide waiting passengers with the current status of bus services. This eases the frustration and anxiety generated by unexpected traffic -related delays and increases the attractiveness of transit as an alternative to driving alone.

What Operational and Management Strategies Are Being Pursued to Relieve Congestion, and Are They Working?

U.S. transportation agencies are generally using three strategies to relieve or manage congestion:

- construction
- improving operations
- managing travel demand.

While all of these strategies can improve mobility, they are rarely implemented in enough magnitude to significantly reduce congestion in big cities. The goals, then, are more typically to manage congestion, provide travel options and improve travel reliability.

Construction

Construction, whenever it is feasible, tends to be the first choice of most politicians and many transportation agencies. It provides a visible increase in vehicular capacity. Whether it is politically popular depends on the cost of the construction project and its impacts on land uses and the environment.

But construction has several drawbacks. There isn't enough funding or projects being implemented to address the needs. It often provides only temporary relief for congestion because it tends to encourage further development and therefore traffic growth. In many cases, particularly in busy urban areas, it only moderates existing congestion rather than eliminates it because building sufficient capacity to meet existing levels of demand is not feasible.

Most importantly, construction is becoming increasingly difficult to do. In urban areas, where congestion tends to be greatest, land prices, public resistance, and environmental mitigation requirements severely limit the size of capacity improvements. They also increase the time required to gain the necessary permits, thus raising costs dramatically. These problems limit both the public's acceptance of new construction and their willingness to pay for those roads.

Improving Operations

Since new construction is often not feasible or insufficient to significantly reduce congestion, transportation agencies are turning to operational improvements to reduce congestion, limit the growth of congestion, or increase the number of people the existing roadway will carry. A variety of strategies have been used successfully to improve roadway operation in a few cities. Among the most common are:

- advanced traffic management systems
- incident management systems
- traveler information
- managed lanes

Each operational approach works effectively under specific conditions, but most improvements individually achieve only modest reductions in congestion. Their real contribution is to significantly improve the efficiency of the existing infrastructure, while increasing the reliability of the transportation system operation.

Advanced Traffic Management Systems use modern detection and observation technologies to detect unusual traffic conditions or congestion. Special computer programs then adjust the available traffic control mechanisms (e.g., traffic signal timing, ramp metering rates) to improve facility performance. By more carefully managing vehicle movements, roadways can be operated at peak volume levels for longer periods. This significantly decreases delay, reducing the number of people caught in congestion and the duration of congestion when it occurs. For example, the ramp metering system on Minneapolis' freeways (even without a state -of-the-art control program) was shown to improve peak-hour volumes by 14 percent, provide over 25,000 person-hours of time savings annually (despite the delays from the ramp meter), and help reduce accidents by over 1,000 crashes per year (*6*). The benefit to cost ratio for the entire traffic management system was estimated to be 5 to 1.

Surveillance and adaptive control functions allow transportation agencies to maximize the use of the roadway, decreasing delay and increasing throughput. They are particularly effective at optimizing roadway performance during unusual conditions, such as major events or accidents.

Incident Management Systems are designed to detect and quickly clear disabled vehicles and other "events" (such as debris) from the roadway that would detract from facility performance. Incidents both reduce capacity and decrease safety, and they are the cause of 40 to 60 percent of all congestion in urban areas (*2*). The primary intent of incident management is to prevent incidents from reducing capacity, but when they do, to restore that capacity as quickly as possible. This prevents backups and significantly decreases the occurrence and severity of congestion.

Incident management programs vary from location to location. They can include:

- service patrols (vehicles specifically intended to look for and help disabled motorists)
- incident management teams (interagency working groups formed to develop faster and more efficient responses to accidents and other major incidents)
- traveler information systems
- surveillance systems for detecting incidents and determining how to respond to them.

The benefits of incident management vary from location to location. In general, where roadways are already operating at capacity, even minor incidents can dramatically increase congestion. At these locations and times, an effective incident management system can significantly reduce congestion. Clearance of a single blocking car from a three-lane (one direction) freeway increases capacity by 50 percent. However, most motorists do not perceive these improvements because routine congestion (caused by geographical bottlenecks or simply too many vehicles) still exists. The biggest effect of incident management is in significantly reducing congestion and delay caused by major accidents. Although motorists still experience delays caused by these accidents, an effective incident management system can reduce what might be a 4-hour long, 5-mile traffic jam into a queue of less than 1 mile that lasts less than an hour.

Traveler Information Systems both reduce congestion and significantly improve public perception of and attitudes toward the congestion that does occur. Provision of traveler information provides choices for travelers. They can travel on different routes, on different modes, at different times, or even to different destinations. Their ability to choose improves their trip. Because many travelers choose to avoid backups, congestion decreases from what it would have been had no traveler information been available. Thus even those who must still use the congested roadway benefit. In addition, travelers have a much more positive perception of even an unpleasant situation when they have knowledge about it (e.g., "The airplane you are meeting will be arriving 20 minutes late" is far better than standing at the gate wondering where the plane is, and when it might be arriving). This knowledge reduces stress and limits risk taking behavior, thus producing better travel conditions.

"Managed Lanes" is a new term for a combination of techniques that have been used for many years. The basic concept of "managed lanes" is to employ operational tools to maximize the productivity of the available roadway. "Managed lane" concepts can include the following:

- HOV lanes—to encourage more people to use high capacity modes of travel, thus moving more people in a single roadway lane
- HOT lanes—which allow vehicles to purchase access (through tolls) to under-used HOV lane capacity, thus 1) maximizing vehicle use of HOV lanes without sacrificing HOV speed and reliability, and 2) providing revenue to help pay for HOV lane construction, maintenance, and operation
- Reversible and contra-flow roadways— which allow increased use of under-utilized lanes when traffic volumes in one direction far exceed traffic volumes in the opposite direction
- Express roadways—which limit the number of entrances to and exits from roads, decreasing merge/diverge congestion and increasing performance
- Congestion pricing—which uses tolls to shift travel demand from congested times and locations to other times of the day or to other facilities that are not congested
- Truck-only facilities—which both improve freight movement and limit truck/car interaction, thus increasing safety and decreasing the effect that heavy trucks have on passenger car performance.

When the appropriate strategy is chosen and implemented effectively, congestion can b e reduced significantly. For example, on I-15 in San Diego, HOT lanes serve 23 percent of peak volumes and yield time savings of up to 20 minutes per trip (*7*). On the New Jersey Turnpike, accident rates on roadway segments where trucks are separated from cars are between 20 percent and 35 percent lower than on segments where trucks are not segregated (*8*).

Facility management allows roadway operators to prioritize travel movements and make them more efficient. It can be used to increase freight mobility and thus the economic vitality of a region, to promote high occupancy vehicles, or to generate revenue streams that can be applied to general transportation system improvements.

Managing Travel Demand

A variety of government- and employer-sponsored programs can be designed to reduce vehicle trips during congested periods and in congested locations. These programs include flexible work schedules that allow employees to travel off -peak, amenities to improve the safety and efficiency of biking and walking, ridematching services for vanpools and carpools, community-based carsharing, employer-subsidized transit passes, guaranteed emergency rides home for transit users, and incentives to decrease employer-paid parking.

In Washington State, the Commute Trip Reduct ion law was enacted to reduce traffic congestion, along with congestion-related air pollution and fuel consumption. The law requires major employers to offer employees a variety of programs designed to reduce travel demand. A report by the Washington State Department of Transportation Commute Trip Reduction Task Force concludes that the Commute Trip Reduction program removes 18,500 vehicles from the state's roadways every morning (*9*). The report goes on to state that if these vehicles were added back "the equivalent of 22.5 additional lane miles would be needed to accommodate the demand."

Transit-Oriented Development is another form of travel demand management in which the goal is to develop housing and employment centers near transit services thereby encouraging transit use and reducing dependence on roads and automobiles. Unlike conventional developments, transit-oriented developments are designed to support bicycling and walking and offer relatively little parking.

How Does Congestion Affect Highway Safety?

Highway safety has numerous components but for the purpose of this discussion we will focus on characteristics of crashes: crash potential, types of collisions, and crash severity. Exhibit 7 presents a conceptual model of the interaction between congestion and these highway safety components. The basic theory behind the interaction is that congestion leads to higher vehicle densities (i.e., more closely spaced vehicles on a roadway), which provides more opportunities for conflict. Congestion also reduces vehicle speeds, which implies that when vehicles are engaged in a crash, the collision forces are lower, thus reducing the injury to occupants. Another aspect of the model is the concept of "secondary" crashes —crashes that occur due to conditions produced by an existing crash. Some of these conditions— which wouldn't exist without the occurrence of the first crash— include rapid backward queue formation (as vehicles suddenly stop to avoid the first crash), rubbernecking by drivers, and the maneuvers of emergency vehicles. Finally, the flow restrictions produced by crashes worsen existing congestion.

However, the details of the relationships in the conceptual model presented in Exhibit 7 are not well understood. With the exception of lower crash severi ties, which have been documented in a general way for congested conditions, the exact nature of the linkages are highly uncertain. Based on the limited work that has been done, a few tentative conclusions may be drawn:

- Crash potential (e.g., crashes per vehicle-mile traveled) probably increases as congestion increases.
- There is a lower proportion of single vehicle crashes (e.g., run -off-road, rollover, collision with fixed object) during congested conditions and a higher proportion of multiple vehicle crashes.

- Crash severities (extent and nature of personal injuries) are lower during congested conditions; due to lower vehicle speeds at the moment of crash impact.

Assuming the relationship in Exhibit 7 is correct, any operational improvement that reduces congestion will lead to fewer crashes. The severity of crashes that occur will be higher, however, and it is likely that a greater proportion will be single vehicle crashes. Knowing these facts can target mitigation strategies to single vehicle crashes and higher severities— such as wider roadside recovery zones, protection of highway "furniture," and coordination with emergency medical services. The interrelationships diagrammed in Exhibit 7 indicate that an Operations philosophy must take a systems-oriented view, where the consequences of a specific action (e.g., flow improvements) consider linked impacts such as safety.

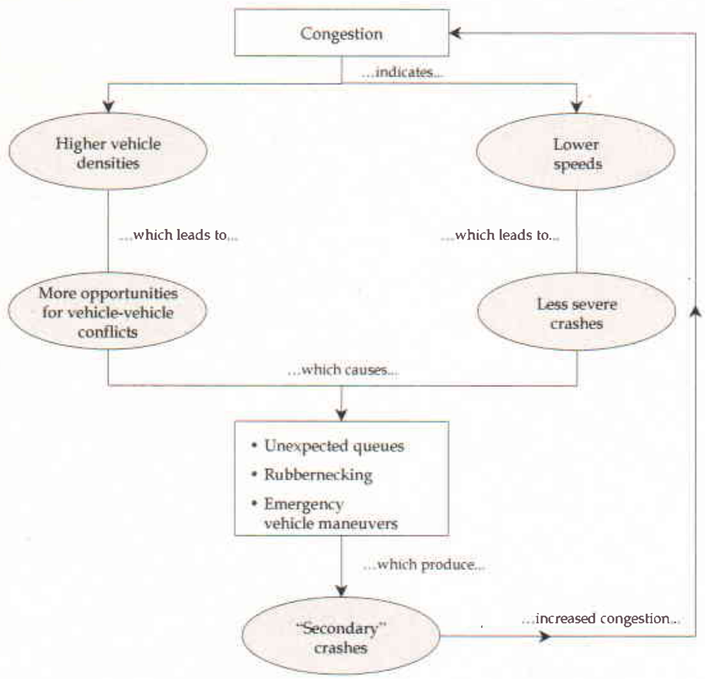


Exhibit 7. Conceptual Model for the Relationship Between Congestion and Safety

What Does All The Information Mean?

The quality of transportation is partly a function of two elements— congestion and reliability. Road congestion is slow speeds caused by heavy traffic and/or narrow roadways due to construction, incidents, or too few lanes for the demand. The variation in congestion levels over time periods is a measure of reliability, and is especially important to some business travelers and freight shippers. Both of these concepts have corollaries in transit, sidewalks and the Internet. Over the last 20 years, traffic volumes have increased faster than road capacity and the alternative modes have not provided the needed relief, either because they are not extensive enough, or they are not used for enough trips.

Urban residents trade off a variety of factors and cost elements in the search for the best situation. Transportation professionals, as well as developers, land planners, government officials, and others, are realizing that these trade-offs are made across a spectrum of niche markets—combinations of home, job, schools, shops, parking, health care and many other issues—that represent the variety of options. Transportation issues compete in this marketplace for attention and investment.

The trends over the last two decades might be summarized in a few basic statements.

1. We are not doing enough—There aren't enough improvements to the system to keep congestion from growing. Hours of delay, the time of day and the miles of road that are congested have grown every year.
2. It will be difficult for most big cities to address their mobility needs by only constructing more roads. This is partly a funding issue— transportation spending should probably double in larger cities if there is an interest in reducing congestion. It is also, however, an issue of project approval since many Americans are reluctant to accept the destruction of their existing urban environment (homes, businesses) in order to allow expansion of existing roadway right-of-way. It is difficult to imagine many urban street and freeway corridors with an extra 4, 6 or 8 lanes, but it is entirely possible that will be required if the goal is to significantly reduce congestion by adding roads.
3. A greater emphasis will be placed on system operations. Operational improvements allow for maximum return on the investment already made in roadway and guideway infrastructure and rolling stock by making sure that the systems operate at high levels of efficiency as often as possible, are relatively inexpensive compared to major right-of-way expansion in urban areas, can be implemented without the time consuming environmental permit reviews, are particularly effective at improving facility reliability, and provide improvements that benefit freight and transit operations as much as the personal automobile.
4. While transit improvements, better operations, adjusted work hours, telecommuting and other efficiency options do not individually seem to offer the promise of large increases in person carrying capacity, they are **absolutely vital** components of an overall solution.

Several policy and operating options, such as value pricing or peak-travel restrictions, present opportunities for improved transportation. They require, however, changes in the way transportation services are viewed and changes in the way we live and travel. In particular, they require a shift in public perception away from the idea that access to government funded transportation services (e.g., roadways) is available equally to all, towards a system that allows purchase of superior levels of service to those willing and able to pay a higher price. It has not been easy to "sell" these changes to the public.

What Will the Future Bring? Increased Demand, Higher Customer Expectations, Environmental Constraints, New Technology?

There are a number of demographic trends that are likely to affect travel patterns and congestion in the future (*10*):

- Rising affluence and increased income— Rising incomes will likely translate into increased auto availability and use, increased number of trips per household, and increased average trip lengths. The rising affluence is partly due to the fact that many households now have multiple workers. When multiple workers reside in a single household, it then becomes more difficult for each to live in close proximity to their work; thus the need to choose some compromise location that meets both workers' needs as well as the needs of other household members (e.g., good schools, nice parks, etc.).
- Democratization of mobility—Privately-owned auto transportation is becoming more accessible to car-less households. This increased access to personal mobility via personal auto is mostly among minority Americans living in center cities. In many instances, this new-found personal mobility carries them to where employment is easy to find— the booming suburban areas that require longer vehicle trips.
- Changing demography—There will be a lack of skilled workers in the future (apparent in some places already), thus industries will desire to employ all that are employable. This means connecting rural populations and inner city residents to suburban jobs. This also means that skilled workers will be more able to select where they live, and employers will follow to high concentrations (such as the San Jose or Austin area).

There is and will continue to be a complex interaction between personal lifestyles and traffic congestion. Recent studies have shown that less than one-half to one-third of all peak period trips are work-related. The other one-half to two-thirds of the trips during the busiest traffic time of the day are typically personal, social, or recreational-based trips. The fact that these trips are made during the peak period indicates that: 1) these trips are more difficult to make at other times of the day; and/or 2) travelers value these trips so much that they are willing to make them during the busiest traffic time of the day. Trip-chaining can explain part of this trend— running several errands on the trip to and from work. This may be more common now as commuters travel increased distances to and from work.

The amount of technology and information available to commuters, travelers, and businesses will continue to increase. The likely repercussion is that travelers will be better informed and will be better able to manage their daily schedules. Recent studies (*11*) have shown that the primary benefit of advanced traveler information is a traveler's ability to manage their daily schedule, rather than the congestion reduction benefits. Travelers will increasingly value their time and ability to control it.

While it is not likely that increased technology or information will reduce the magnitude of congestion, it has potential to improve the reliability of the transportation system. With operational improvements, more integrated technology and information sharing among regional agencies, serious crashes, weather-related problems, or road construction will have less effect on travel time reliability. Information about these serious events will be broadcast to travelers through various information service providers, thus minimizing those unaware of serious events.

Many state and large city transportation agencies are pursuing some of the improvement projects and programs. The mix may be different in each city and the pace of implementation varies according to overall funding, commitment, location of problems, public support and other factors. The agencies should be able to improve the performance and reliability of the transportation system outside of a few congested hours. And the operational systems, policy changes and information improvements can make the congested periods less disruptive. But they probably cannot expand the system or improve the operation enough to eliminate congestion without a significant increase in funding and some significant policy changes.

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