INSTITUTE OF TRANSPORTATION ENGINEERS

A TOOLBOX FOR ALLEVIATING TRAFFIC CONGESTION AND ENCHANCING MOBILITY

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A TOOLBOX FOR ALLEVIATING TRAFFIC CONGESTION AND ENHANCING MOBILITY

Institute of Transportation Engineers

Prepared by
Michael D. Meyer, Ph.D., P.E.
Georgia Institute of Technology

The Institute of Transportation Engineers published the first edition of&e Toolbox in 1989. Thii edition was one of the first efforts to develop a comprehensive summary of all the tools available to "solve" the urban congestion problem. We have learned much since 1989, and much has happened in the way of how we look at the urban transportation system and the types of strategies that can now be considered in a toolbox. Perhaps most dramatically, we are now seeing the initial application of advanced electronic technologies to better manage the transportation system. Known as intelligent transportation system (ITS) technologies, these tools are laying the foundation for the management of system operations that will be the basic component of many urban areas' transportation strategy in the not-too-distant future.

In addition to ITS, there are several other tools discussed in this edition that are not found in the earlier version. These include: nonmotorized transportation, transit-oriented development and urban design, traffic calming, freight movement, congestion pricing, intermodal terminals, and multimodal corridor investment. The remaining sections from the 1989 edition have been greatly expanded and updated. In many cases, the original chapters have been kept largely intact with new material added. The authors of the original chapters were: Chapter 1, Dr. Michael Meyer; Chapter 2, Thomas E Humphrey; Chapter 3, Dr. Michael Walton; Chapter 4, Katherine Hooper and Robert Stanley; Chapter 5 and 6, C. Kenneth Orski; and Chapter 7, Peter A. Peyser Jr. This edition was prepared solely by Dr. Michael Meyer.

A final acknowledgement must be given to Stephen C. Lockwood, whose ideas expressed in a 1988 presentation at the Annual Meeting of the Transportation Research Board entitled, "Kaleidoscope or Map: Suburban Congestion and Institutional Barriers" served as the basis of the "toolbox" analogy developed in this document.

Notice

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Institute of Transportation Engineers
525 School St., S.W., Washington, D.C. 20024-2797 USA
Telephone: +1 (202) 554-8050, Fax: +1 (202) 863-5486
ITE on the Web: http://www.ite.org

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TRAFFIC CONGESTION: AN OVERVIEW

Over 40 years ago, the United States embarked upon the largest public works project in its history--the construction of the Interstate highway system.

The urban portions of this system along with the highways and public transportation services developed by state, county, and local governments, as well as public transportation services offered by other organizations, have provided urban Americans with unprecedented levels of mobility. However, in many communities increasing levels of traffic congestion have turned once easy trips into nightmares. In addition, the lack of accurate and timely public transportation information and services has discouraged drivers from considering options other than driving alone. People are turning to community officials for solutions.

The purpose of A Toolbox for Alleviating Traffic Congestion and Enhancing *Mobility* (Toolbox) is to provide local elected officials, business leaders, and community leaders with information on the congestion phenomenon and on the multimodal transportation strategies that can be used to provide improved mobility and accessibility. There are ways of dealing with traffic congestion problems. Some actions can be used individually, while others require mutually supportive actions implemented cooperatively by several public and private sector groups. Some actions focus exclusively on changes to the transportation system, while others deal with changes to land development procedures. Some actions provide added capacity to highway and transit systems so that passenger demand can be accommodated, while others attempt to change the characteristics of the demand itself (e.g., by encouraging ridesharing). However, no matter what type of action is considered, those who are dealing with transportation problems need to have information on the likely effectiveness of different actions that can be used to deal with these problems. This Toolbox is designed to provide this type of information.

The remainder of this chapter discusses the characteristics of transportation in urban areas, its history, future trends, and the impacts and costs to the community when the transportation system does not provide the level of performance desired. In addition, this chapter presents an overall framework for developing a coordinated program to provide good multimodal transportation service to a community. Chapter 2 discusses actions that can be implemented to enhance the person-carrying capability of the highway system, without adding significantly to the width of the highway. Chapter 3 discusses actions that result in substantial added capacity to the highway system, either through the widening of exist-

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ing roads or by constructing new highways. Chapter 4 discusses public transportation actions that can be used to move people more effectively. Chapter 5 discusses actions for reducing transportation demand either through land use management, regional demand management programs, or site-specific policies like carp001 programs. Chapter 6 presents an overview of new applications for advanced technologies in providing transportation services. Chapter 7 discusses funding and institutional actions that can be used by themselves or in combination with other actions.

To some, congestion IS considered to be one result of economic prosperity Others argue that the consequences of congest/on are much more serious to a community

Chapters 2 through 7 are structured to provide the reader with easily accessed and understood information about specific actions. Sections within each chapter present:

1) a brief description of the action with special attention given to the criteria for success,
2) the costs and benefits/impacts of the action that have been determined from previous experience,
3) steps needed to implement the action successfully, and
4) sources of further information on the action.

WHY WORRY

Put simply, traffic congestion means there are more people trying to use a given transportation facility during a specific period of time than the facility can handle with what are considered to be acceptable levels of delay or inconvenience. In a broader sense, a congested facility is just one element of a transportation system's ability to provide mobility and accessibility. Delays at particular locations in a transportation network are certainly aggravating to those using the system, but these delays are part of a much larger picture of how a transportation system allows people and goods to move around a metropolitan area.

To some, congestion is not a problem. It is considered to be one result of economic prosperity and one that we will have to learn to live with. Proponents of this viewpoint argue that our expectations about convenient travel will simply have to change. Others argue, however, that the consequences of congestion are much more serious to a community. Those holding this viewpoint have often relied on one or more of the following arguments:

Local Traffic Impacts: When faced with congested conditions, many drivers quickly look for ways to bypass the bottleneck. These often include making their way through residential neighborhoods on streets not designed to handle through traffic. Such bypass traffic often becomes the focus of neighborhood complaints. Similar complaints are often heard when overflow parking finds its way into neighborhoods.

Economic Growth: Efficient transportation access to employment and shopping sites is an important consideration to businesses and developers when considering expansion opportunities. A good transportation system is an important selling point to communities that desire to attract development. In addition, good transportation is very important to the movement of goods and services and thus has a direct impact on sound economic growth and productivity (Transportation Research Board 1995).

Community Access: Good access within a community and to other parts of the metropolitan area by drivers and by those using public transportation is an important issue to community residents. Not only is good access important to those looking for places to live, but it can become an important community public safety (e.g., police, fire and emergency medical) issue.

Quality-of-Life: To some people, congested highways are a symptom of deteriorating quality-of-life in a community. In many cases, and in particular in suburban communities, residents moved to their community to escape urban problems like traffic jams. Now, facing this congestion has once again become part of their daily routine. Another aspect of this quality-of-life characteristic is the role transportation plays as a key element of getting and keeping a job. This is particularly important today with the greater emphasis being given to “welfare-to-work,’ programs.

Highway Safety: Whether characterized by stop-and-go traffic along a major road or by traffic trying to get through intersections, congested highways often can result in accidents. Reducing this congestion could reduce the number of accidents and generally produce safer travel conditions.

Environmental Quality: Congested road conditions can have a detrimental effect on the environment, in particular, air quality. Making improvements to the transportation system or trying to change travel behavior has been an important objective of those wanting to improve environmental quality.

These arguments can be important reasons for being concerned about the performance of the transportation system. However, of even more interest to community leaders, addressing the mobility needs of a community has become in several cases a litmus test for effective leadership. Because the public sector is viewed as having the major responsibility for solving transportation problems, community officials are often the focal point for citizen unrest concerning traffic congestion and mobility needs.

Transportation as a Regional Issue: In addition to the local concerns identified above, there are metropolitan-level planning requirements and federal (and often state) environmental laws that require a comprehensive examination of congestion reduction and mobility strategies. For example, the Intermodal Surface Transportation Efficiency Act (ISTEA) passed and amended by Congress requires that all states and metropolitan areas have a transportation planning process that considers these types of strategies. For metropolitan areas over 200,000 population, and especially those not in attainment of air quality standards, a congestion management system is required that identifies strategies for improving the performance of the transportation system

Addressing the mobility needs of a community has become In several cases a litmus test for effective leadership with special consideration given to he pollution-reducing impact of these strategies. The transportation planning and project programming process in non-attainment areas is very much influenced by this assessa-rent. Therefore, understanding what strategies are available in the *Toolbox* and their likely impacts on travel behavior and air quality becomes a critical input into the planning process in many of our major metropolitan areas. This is especially important if one looks at the expected levels of congestion on urban transportation systems in the near future.

TRANSPORTATION TODAY AND TOMORROW

Increasing levels of congestion are common in urban areas throughout the United States. Recent transportation plans for a sample of urban areas and states indicate some of the characteristics associated with future mobility challenges:

Florida: Daily vehicle miles traveled has continued to grow, from 300 million miles1483 million kms in 1990 to 334 million miles / 538 million kms in 1994, an increase of about 11 percent (Florida DOT 1995).

Dallas-Ft.Worth: The growth in vehicle miles of travel and vehicle miles of travel per person in the region represents a significant challenge in addressing mobility needs of the region. By the year 2010, daily vehicle miles traveled is projected to exceed 124 million / 200 million kms representing a 33 percent increase in travel (North Central Texas Council of Governments 1995).

Milwaukee: In 1991, the number of vehicle miles of travel on an average weekday totaled nearly 33 million / 53 million kms. Under a no-build alternative, the growth in vehicle miles traveled would be approximately 35 percent to 44.5 million vehicle miles / 72 million kms of travel in the year 2010 (Southeast Wisconsin Regional Planning Commission 1995).

Boston: Vehicle miles traveled in 2020 are forecast to increase by approximately 25 percent...Vehicle hours of travel are forecast to grow by 35 percent in the base case, evidence of growing systemwide congestion (Central Transportation Planning staff 1993).

Albany: Congestion-related delay will increase significantly for the region as a whole by 2015. This congestion will be experienced disproportionately-suburban areas will experience a growing percentage of the region's congestion (Capital District Transportation Commission 1995).

Atlanta: . ..despite substantial improvements to the highway system, over 53 percent of the vehicle miles traveled in 2010 will be on facilities that are subject to levels of service F (Atlanta Regional Commission 1990).

Texas: Increased congestion on Texas' highways will worsen significantly over the lifetime of the Plan—twice as many miles of major urban facilities will be congested in 2012 than were in 1992, causing delays on more than half of urban Interstate, freeway, and expressway miles (Texas DOT 1994).

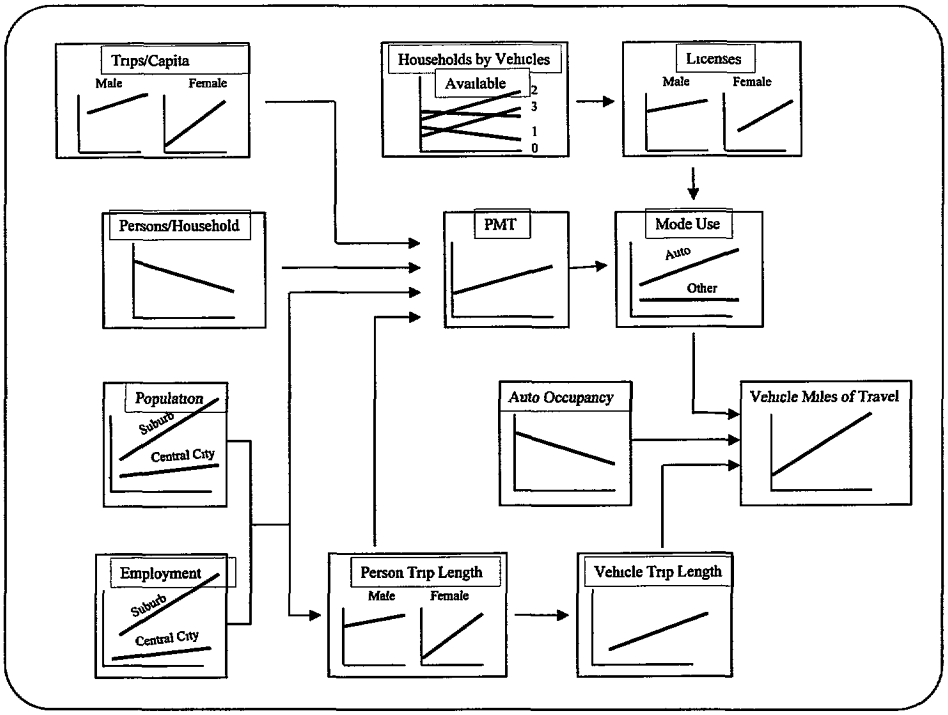
Nationally, the figures are even more staggering. According to a recent national transportation system condition and performance report by the U.S. Department of Transportation, the daily vehicle miles of travel in the 33 most populous urbanized areas is expected to increase by 35 percent from 1994 to 2013 and by 60 percent in small urban areas (U.S. DOT 1996). This increase in travel is expected to continue a trend in increasing congestion on the road system in our largest cities. From 1983 to 1993, for example, the amount of peak hour congestion on urban Interstates increased from 55 percent to 69 percent; and on other freeways and expressways from 49 percent to 59 percent.

What are some of the factors that will contribute to urban mobility needs in the future? Figure 1-1 shows the key factors of growth in personal travel that have in the past and will continue in the future to affect the amount and type of urban travel [For an overview of causes of congestion and case studies of how some metropolitan areas are dealing with it, see (Dunphy 1997; Pisarski 1996)]. Some key considerations:

Population: From 1980 to 1990, U.S. population grew by just less than 10 percent. Importantly, however, much of this growth occurred in major metropolitan areas where growth rates over the same period ranged from 25 to 40 percent. Future population growth will be very different from the past in that different population groups will likely make up the bulk of the growth. For example, growth in the Hispanic population will contribute 32 percent of the nation's growth to the end of the century, and almost 40 percent to 2010.

From 1983 to 1993 the amount of peak hour congestion on urban Interstates increased from 55 percent to 69 percent; and on other freeways and expressways from 49 percent to 59 percent.

Figure 1.1: Factors Contributing to Travel



Source: Federal Highway Administration 1993

Employment: The number of workers in the labor force almost doubled between 1950 and 1990, with women joining the labor force being a major reason for this significant increase. Importantly, the increase in workers by geographic area illustrates the suburbanization that has occurred in every U.S. metropolitan area. From 1980 to 1990, 65 percent of the growth in the labor population occurred in the suburbs, 18 percent in the central city, and 17 percent in non-metropolitan areas. The suburbs in 1990 had 42 percent of the nation's jobs (up from 37 percent in 1980), and suburban areas saw 49 percent of the growth in jobs from 1980 to 1990, whereas central cities represented only 23 percent of the growth.

Households and Persons/Household: Between 1969 and 1990, the number of households grew 49 percent with the largest share of the growth in single-person and single-parent households. The average household size also declined from 3.16 persons in 1969 to 2.56 persons in 1990. This phenomenon has had profound implications on transportation in that each household has a baseline amount of trips and travel associated with it (Federal Highway Administration 1993).

Trips/Capita: Between 1983 and 1990, trips per capita increased by almost 7 percent to 3.04 trips per male and 3.13 trips per female.

Person Trip Length: The average miles for commuting each day in 1983 was approximately 7.9 miles/12.7 kms; in 1990 this number had risen to 9.55 miles/15.4 kms (Federal Highway Administration 1993). This increase can be associated with the tremendous population and employment growth in the suburban areas of our metropolitan regions (86 percent of total U.S. population growth since 1970 had occurred in the suburbs), and in the rising percentage of the adult population who had drivers licenses.

Households by Vehicles Available: Although population and number of households between 1980 and 1990 increased by less than 10 percent and 14 percent, respectively, the total vehicles available to households grew by over 17 percent. Every worker has on average 1.3 vehicles available for the work trip. Over the past decades, the number of households with multiple vehicles grew rapidly.

Licenses: Between 1969 and 1990, the number of licensed drivers in the United States increased by almost 60 percent. For those aged 30 through 49, over 96 percent of the men and roughly 93 percent of the women are licensed. In addition to licensed drivers, the number of automobiles available for trip making increased significantly. Between 1969 and 1990, the average number of vehicles per household rose from 1.1 to 1.77, with only 9.2 percent of U.S. households not having a car available for a trip (one in five households had three or more cars).

Mode Use: Transit's share of all national travel has declined to about 2 percent, although in many urban markets transit retains a strong presence. This decline is associated with increased auto availability to those population groups most likely to use transit and the continued suburbanization of metropolitan regions resulting in land uses difficult to serve with traditional transit services.

Auto Occupancy: Average vehicle occupancy (measured as person miles per vehicle mile) has declined from 1.9 in 1977 to 1.6 in 1990. In many urban highway corridors, the average automobile occupancy for work trips is below 1.1 persons per vehicle.

All of these factors have contributed to a fundamental characteristic of the urban travel phenomenon -the number of person miles traveled and the number of trips made have increased proportionately much faster than the individual factors that influence trip-making.

What does the future hold? A recent report from the Urban Land Institute which examined some of the underlying causes of congestion identified the following trends and observations that could affect future urban travel: (Dunphy 1997)

- Growth in the United States population is slowing, but millions of added travelers will still need to be accommodated.
- Virtually all Americans old enough to drive are already licensed.
- In the U.S. there already is more than one car, van, or light truck for every person age 16 and older.
- Looking ahead to 2010, the number of young adults will return to its 1980 level, from a recent decline.
- Baby boomers will make up a smaller share of the population by 2010.
- The elderly population will be growing more rapidly than the population in prime driving age groups. However, the differences in travel demand between younger people and seniors will be narrowing.
- The image of seniors traveling by bus or on foot to take care of their daily needs is no longer accurate. More seniors will be driving well into their retirement years.
- More people living beyond age 75 will result in more trips taken by younger family members to help in their care.
- There will be a continued divergence in travel behavior between men and women.
- Married men with children, regardless of the age of their youngest child, make the same number of trips as married men without children.
- The use of transit and carpooling is declining more so for women than for men.
- Race and ethnicity further differentiate travel patterns.
- Wealthier households make more trips, use cars more, and travel longer distances.
- Low density development means more automobile trips.
- Nonwork travel will increase as a share of total trips.
- Dispersed development means more shopping trips, while increased catalog and electronic shopping will mitigate against this trend.

The number of person miles traveled and the number of trips made have increased proportionately much faster than the individual factors that influence trip-making

- Cities are capturing a decreasing share of new jobs, resulting in longer work trips and lower public transit ridership.
- During the 1990s cities will not be as successful as they were in the 1980s in slowing the rate of exodus of jobs to the suburbs. The shift of jobs to edge cities means quicker commutes for suburbanites, more travel for lower-income city residents, and lower transit demand.
- The dispersal of employment centers means more commuting between suburbs and across county lines.
- Growth in the labor force is slowing. More people are holding two or more jobs.
- More companies are offering flexible work hours as an employee perk and to reduce peak hour traffic. Telecommuting and working at home are increasingly popular options.

MOBILITY AND ACCESSIBLITY: THE BIGGER PICTURE

The original Toolbox published in 1989 focused on strategies and actions that were aimed at relieving congestion on the transportation system with primary focus on the highway system. Most often, this congestion occurred at specific locations and were, in many ways, just one element of the total trip for people and goods in a metropolitan region. Since passage of the Intermodal Surface Transportation Efficiency Act in 1991, many transportation officials have broadened their perspective on the types of strategies that can be considered in dealing with congestion and mobility. Multimodal transportation system performance more than ever now includes an integrated multimodal perspective for overall mobility and accessibility. The three terms that will be used in this version of the *Toolbox* are defined as: (Meyer, 1996)

Mobility: The ability and knowledge to travel from one location to another using a multimodal approach.

Accessibility: The means by which an individual can accomplish some economic or social activity.

Congestion: The travel demand for a facility or service exceeds the capacity of that facility/service to handle the demand at performance levels considered acceptable to facility/service users.

Note that this definition includes not only highway facilities, but also transit services. Also, in these definitions, "mobility" implies movement, but accessibility does not. For example, modern telecommunications allows one to order goods and/or conduct work without ever leaving home. The activity is accomplished, but the individual does not have to use the transportation system to achieve the objective. In fact, one of the more recent strategies for reducing congestion is to encourage telecommuting so that accessibility to the workplace still occurs, but vehicular travel is reduced. This broader perspective on improving the performance of the transportation by developing a coordinated mobility program for your community system is further illustrated later in this chapter.

CAN ANYTHING BE DONE?

The simple answer to this question is, "yes"! There are proven techniques that can be used to deal with specific congestion problems, as well as transportation and land use strategies that can be implemented to enhance mobility and accessibility. The more difficult answer to this question is, "Yes, but . ..." Many of these techniques and strategies require changes in individual travel behavior, persuasive use of land use management techniques, changes in institutional structure, garnering of political will, and/or increased funding. This is partitularly true for those strategies aimed at a longer term vision of improved mobility and accessibility. Given this perspective, what can be done?

- Recognize that traffic congestion is a more difficult problem than simply too many cars at a particular location. There are institutional and land use dimensions to the problem that make it complex. In addition, congestion is simply a symptom of much larger issues associated with mobility and accessibility in a community.
- Recognize the direct and fundamental relationship between land use and travel patterns. Approving land developments without providing adequate transportation options will result in congested, unsafe, and environmentally damaging conditions.
- Recognize that transportation improvements can be considered from the perspective of enhanced transportation services (i.e., the "supply" of transportation), from the perspective of those who use these services (i.e., better managing the "demand" for the transportation system), from the perspective of influencing where this demand occurs (i.e., the land use dimension), or any combination of the above.
- Consider carefully how individual actions relate to one another and how, when combined into an overall program, they relate to regional and community objectives.
- Implement those actions that through sound engineering and planning analysis are shown to improve congestion problems in a cost effective, multimodal manner. Be realistic in the assessment of what is likely to be accomplished.
- Recognize early on that the implementation of actions that are likely to be controversial will require strong commitments and efforts at developing a constituency for the action from interested organizations that have not traditionally been part of the transportation planning process.
- Incorporate private sector interests (developers, employers, business associations, etc.) into the planning and decision-making process. It is often in their best interest to participate, and they can provide strong support in gaining project or program adoption.
- Cooperate with neighboring governmental jurisdictions, regional transportation agencies, and organizations that provide transporta-

Many of these techniques and strategies [that address congestion problems] require changes in individual travel behavior; persuasive use of land use management techniques, changes in institutional structure, garnering of political will, and/or increased funding.

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tion in those situations where the transportation problem is an areawide phenomenon. In many cases, because of the dispersed nature of travel patterns and the multitude of organizations providing transportation services, solutions to particular problems in a region or corridor will require a multi-jurisdictional approach.

Thus, there are actions that can be taken to deal with mobility, accessibility and congestion issues. In many cases, however, they require a thoughtful approach on how best to implement a coordinated program and a realistic assessment of what is likely to be accomplished. At the very least, they take a commitment that it will be done.

MOBILITY AND CONGESTION AS AN AREAWIDE MULTIMODAL PHENOMENON: DEVELOPMENT OF A COORDINATED PROGRAM

Many communities are facing congestion problems at very specific locations, e.g., intersections and entrances to major shopping centers. Others are struggling to provide transportation options for fast growing sections of their community or for those individuals unable to drive personal vehicles, but who nonetheless need to travel (e.g., the poor, elderly and those with disabilities). These challenges can be addressed with many of the tools discussed in subsequent chapters. However, factors often outside the control of community officials can significantly influence the magnitude of the problem, while also affecting the feasibility of possible solutions. In addition, long term trends in development and travel characteristics imply that no matter what action is taken to solve the immediate problems, they could simply reoccur as these trends catch up to and overwhelm the improved services. In such situations, community officials need to be concerned with not only those actions needed to mitigate existing problems, but also those actions needed to avoid problems in the future.

Although engineers, economists, and planners often have one or two favorite "solutions" to congestion and mobility challenges, there really is no single solution. As stated earlier, the transportation phenomenon is the result of demographic and market forces that are difficult to change. To be effective within this context, one needs to examine how actions complement one another and how over the long run these actions will influence future travel patterns.

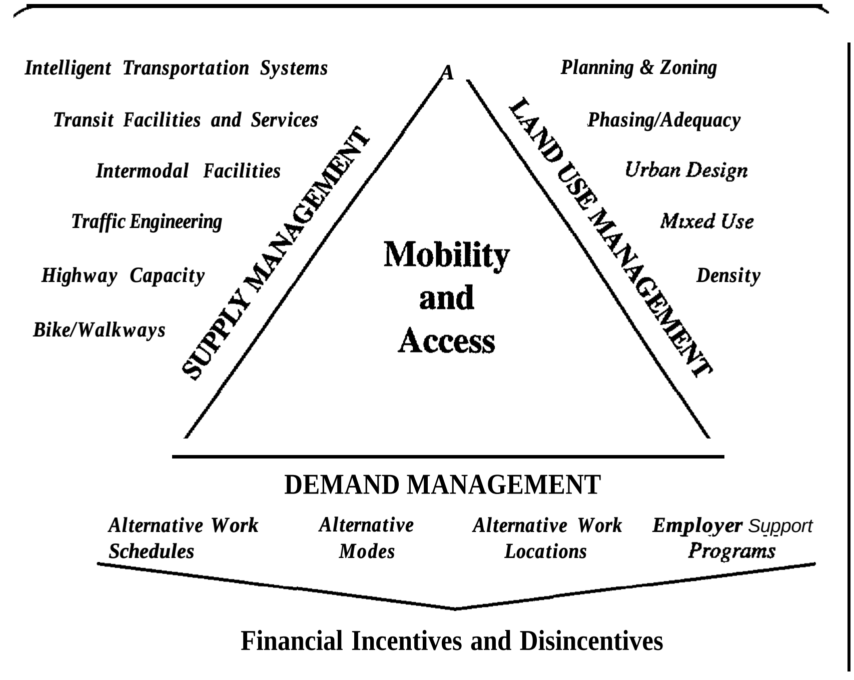
A coordinated mobility and congestion-reduction program should consist of several elements. The specific structure of such a program depends, of course, upon funding and the feasibility of implementing such actions in the local political environment. First, a mobility/congestion program should provide the most cost effective transportation system improvements that enhance mobility and reduce traffic congestion while being consistent with community goals. These improvements can include operational changes to improve the performance of the existing network and services, and physical expansion of the highway system or the addition of transit services.

Second, a mobility/congestion reduction program should examine better ways of managing transportation demand, especially if the opportunity for substantial gains in system mance through expansion or operational improvements is limited. Third, a mobility/congestion reduction program should explicitly consider long-range strategies that will provide the foundation for avoiding similar problems in the future. This implies an important role for considering future land use/development patterns and their impact on travel. Finally, the program needs to deal with institutional arrangements and funding requirements for implementing the program. This is especially important where the transportation services are housed in separate units. In most cases, substantial levels of funding will be necessary to provide the desired levels of mobility and/or congestion relief. However, there are a number of cost-effective improvements that can be implemented at low cost, including improvements using intelligent transportation system (ITS) technologies.

Even though these program components are listed separately, they are really complementary to one another. For example, a ridesharing program (an effort to influence demand) can become more effective if some form of preferential treatment is provided en route (e.g., a high occupancy vehicle lane) or at the destination (e.g., preferential parking), both changes to the transportation system. The effectiveness of the ridesharing program could be even greater if employers were required to incorporate enhanced ridesharing activities into the design and use of the site (a land use/development decision). Similarly, linkages exist between different tools that often work at cross purposes. For example, land development regulations that require high minimum levels of parking as a condition of development work against employer demand management programs. A mobility and congestion reduction program must therefore consider how each action relates to one another.

The important components of a mobility/congestion reduction program are shown in Figure 1-2. Note that a key word that is used to describe each component is "management." Because much of our transportation system is in place, the decisions of what additional capacity to provide, what types of operational improvements to make, how to influence demand for the purpose of

Figure 1.2: Elements of a Mobility/Congestion Reduction Program



Source: Meyer

reducing the impact of traffic, how to develop compatible land use, and how to provide the institutional and funding structure that supports the program are all in essence system management decisions.

Figure l-2 is an important point of departure for developing effective mobility/congestion reduction programs. Significantly, this figure suggests that to be effective, such a program should consist of actions or tools that come from three different categories-managing the supply of the transportation system, managing the demand or travel behavior of those who use transportation, and managing the land use and/or development patterns that influence when and where travel demand occurs. Every community's mobility/congestion reduction program falls somewhere inside the shown triangle. In some cases, a community might rely more on transportation demand and land use actions to provide improved mobility, whereas others might place greater emphasis on expanding the capacity of the transportation system. Each community must decide through its planning and decision-making process where inside the triangle it wants to be.

Managing Transportation System Supply-Managing the transportation system by adding new facilities or by making operational changes to improve system performance has been the most common response to transportation problems for many years. Actions such as the construction of new highways and transit facilities; the provision of improved traffic signalization schemes; the use of traffic engineering improvements such as turn lanes, one-way streets, reversible lanes, and turn prohibitions; the addition of new transit services or improving existing service by adding vehicles, increasing vehicle size, or increasing frequency of service; the provision of preferential treatment to those who use multi-occupant vehicles; and ramp metering are Illustrative of the types of actions that can be used to deal with congestion problems that occur every day. Increasingly, transportation professionals are also becoming interested in those actions such as incident detection programs, motorist information systems, and towing/enforcement efforts that can be used to minimize the effects of accidents and other non-recurring incidents on traffic flow. Advanced transportation technologies, known as intelligent transportation systems (ITS), are also being considered seriously as tools to reduce congestion and enhance mobility.

Because planners and engineers have had many years of experience with the supply side of the transportation system, there is more evidence in the literature on the impact of these types of actions. In the extreme, that is, where new capacity can be continually added to accommodate the demand, these actions can significantly reduce congestion levels. In the long term, however, this additional capacity, if assigned to highway improvements only (e.g., additional lanes), will continue a heavy reliance on the automobile which could have serious implications to some on the urban mobility options available in the region. On the other hand, additional capacity improvements to transit could help alleviate the congestion problem. In heavily urbanized areas, the construction of these actions (especially major highway improvements) can be costly, their implementation met with strong opposition, and even if feasible, they might take a long time to complete. It is for these reasons that other actions need to be considered.

Managing Transportation Demand-In its broadest sense, demand management is any action or set of actions intended to influence the intensity, timing, and spatial distribution of transportation demand for the purpose of reducing the impact of traffic or enhancing mobility options. Such actions can include offering commuters one or more alternative transportation modes and/or services, providing incentives to travel on these modes or at non-congested hours, providing opportunities to better link or "chain" trips together, and/or incorporating growth management or traffic impact policies into local development decisions.

Available evidence suggests that well-conceived and aggressively promoted demand reduction programs can indeed decrease peak period traffic at many sites by as much as 10 to 15 percent. In fact, as will be described in chapter 5, significantly higher demand reduction levels have been achieved at several employment sites. But one should be careful to understand the limitations of this technique. Demand reduction efforts, unless undertaken on a truly massive scale, can have only a local impact. They can relieve spot congestion-for example, at entrances and exits to large employment centers--but they cannot appreciably reduce traffic on freeways and major arterials. The only exception to this seems to be areawide road pricing schemes which at least from a modeling perspective indicate significant influence on travel demand. One should therefore be careful not to raise unrealistic public expectations as to their impact on areawide levels of traffic congestion.

Available evidence suggests that well-conceived and aggressively promoted demand reduction programs can indeed decrease peak period traffic at many sites by as much as 10 to 15 percent.

Managing Land Use-One of the fundamental relationships in understanding how and why the transportation system operates is the linkage between land use and transportation. Put simply, trip-making patterns, volumes, and modal distributions are largely a function of the spatial distribution and use of land. Thus, at individual development sites, exercising control over the trip generating characteristics of the land use (e.g., development density) can be used to make the resulting demand consistent with the existing transportation infrastructure and the level of service desired.

Over the long run, the spatial distribution of land use can greatly influence regional travel patterns, and in turn this land use distribution can be influenced by the level of accessibility provided by the transportation system. Changing the economic equation for travel by equalizing subsidies for all modes could also affect location decisions. Avoiding future congestion therefore requires careful attention to zoning and land use plans, in coordination with the strategic provision and pricing of transportation services to influence where development occurs.

Managing the Institutional and Funding Framework-Implementation of individual actions or combinations of actions is often constrained by institutional problems associated with the coordination of many groups in both the public and private sectors. The authority for transportation decision making is dispersed among several levels of government and often between several agencies within each governmental level. The areawide nature of travel requires a regional or subregional framework of decision making.

In some metropolitan areas, the challenge created by today's transportation problems has resulted in transportation agencies re-examining their mission and function. For example, many transit agencies are responding to the new, non-traditional suburban markets with new types of services. Transit agencies are viewing themselves as "managers of mobility" rather than just operators of traditional bus or rail services. In other metropolitan areas, subregional planning groups have been formed to deal with transportation problems.

Given that not much can happen without funding, managing the process of obtaining the required resources and then effectively managing the operating and capital budgets that result, is the most critical aspect of a comprehensive mobility congestion reduction program

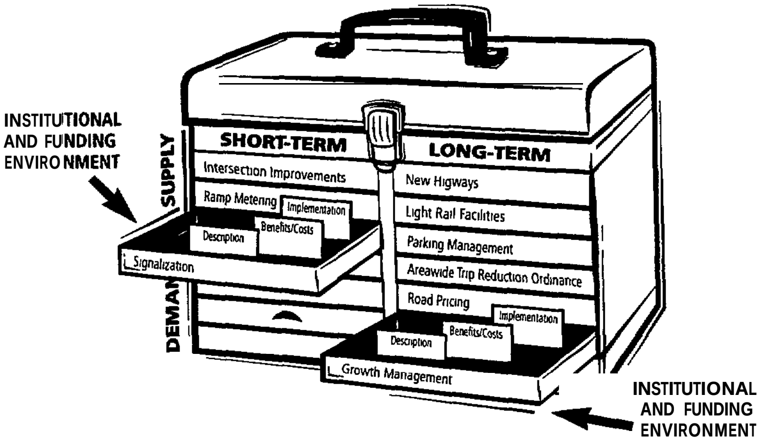
The increased role of the private sector in dealing with transportation issues has often introduced added complexity into the institutional structure for decision making. Diverse perspectives on responsibility, funding, and decision-making authority, combined with differing expectations of project timing and outcomes, can lead to frustration in dealings between the two sectors. However, effective mobility/congestion reduction programs require the active participation and support of private sector groups. Therefore, successful program implementation will be in large part due to the success that project proponents have in managing the institutional characteristics of decision-making and project implementation in the public sector and among public and private sector participants.

Adequate funding is an important aspect of any congestion reduction action or mobility program. In those cases where actions are more local and site-specific, acquiring the necessary funding will be a matter of programming the project in the capital budget of the responsible agency or of getting commitments from other sources (e.g., developers or business associations). In addition, many market-based strategies can generate revenues for use in improving the transportation system. At the regional level, adequate funding could require special assessments or taxes that would be allocated for this purpose. Such funding will most likely require serious political deliberation and voter approval. Given that not much can happen without funding, managing the process of obtaining the required resources and then effectively managing the operating and capital budgets that result, is the most critical aspect of a comprehensive mobility/ congestion reduction program.

A MOBILITY/CONGESTION REDUCTION TOOLBOX

All of the mobility/congestion reduction actions that are presented in the rest of this Toolbox should be considered as "tools" that can be used by local officials to develop a comprehensive program for dealing with the transportation problems they face. Similar in concept to the tools that are used to make repairs around the house, these tools, both individually and in different combinations, can be used to "fix" transportation problems. For purposes of presentation, assume that these tools are available in a toolbox. As shown in Figure l-3, this toolbox has four different compartments. In come cases, the nature of the congestion/mobility problem would require tools that deal with changes to transportation supply and which require a short (one to three years) timeframe to implement. Other drawers in the toolbox contain tools that also deal with transportation supply but which require a longer timeframe to implement. In addition, the toolbox contains tools that try to influence transportation demand over both the short- and long-term.

Figure 1.3: A Toolbox for Reducing Congestion and Enhancing Mobility



The remaining chapters of this book provide the contents of these drawers. Figure l-3 is also an example of how this toolbox (and the remainder of this book) can be used. Note that each drawer contains information on that particular mobility/congestion reduction action, its benefits and costs, and the requirements for successful implementation. Once a drawer is opened, the effectiveness of that particular congestion reduction tool depends on the institutional and funding environment specific to that tool. The challenge to the user of a toolbox of course is to know which tool or combination of tools to use in a particular situation. Effectively HANdling a mobility problem may simply require some combination of highway, transit improvements, and land use/development policies (e.g., higher density levels for new sites) in a specific corridor. In fact, as noted previously, the areawide nature of travel will usually require some combination of tools and thus different sections of this document. What is needed then is a better understanding of the BENEfits and costs of each tool available to community officials and the effect that these tools have when combined into packages.

Once a drawer is opened, the effectiveness of that particular congestion reduction tool depends on the institutional and fundrng environment specific to that tool.

INTELLIGENT TRANSORTATION SYSTEMS

One of the new "tools" in the Toolbox is the application of intelligent transportation technologies to the improved management of the transportation system. Intelligent transportation systems (ITS) are defined as "the application of advanced sensor, computer, electronics, and communications technologies and management strategies-in an integrated manner-to increase the safety and efficiency of the surface transportation system." The basic premise of ITS is that by integrating different system components and technologies in a consistent fashion, great benefits can occur. ITS applications can occur for both highway and transit operations, such as freeway and arterial management, interconnected traffic signals, areawide traveler information services, electronic toll collection, and transit automatic vehicle location. The key vision for ITS is that such technologies will provide a core communications network, transportation system monitoring, and advanced information processing capabilities that can act as a foundation for the coordinated operation of the transportation system.

The appropriate role for ITS in the context of transportation planning includes:

- ITS can represent both direct operational initiatives (e.g. freeway and network traffic control systems and incident management systems) as well as actions that support other strategies (e.g. user services that support ridesharing and transit operations).
- ITS strategies interact with other transportation strategies in impacting traffic congestion and mobility (e.g. an HOV ramp meter bypass system needs to interact and coordinate with the provision of transit service and ridesharing efforts).
- ITS may sometimes need to be considered as a competing alternative with other transportation strategies.
- In a planning environment with constrained resources, ITS needs to be considered for its investment merits along with other strategies.
- There are elements of ITS that are unique and that need to be considered at a regional level independent of other transportation strategies in establishing cost-effective systems. For example, a communications system or traveler information system should be thought through at a regional level to provide for economies of scale, consistency among geographic areas, and coordination among agencies.

Given the operational focus of many ITS actions, the consideration of ITS in transportation planning might very well provide an important operations orientation to the transportation plans and programs that result from the planning process.

Nine key ITS infrastructure components have been identified as being essential to traffic management and traveler information services within a metropolitan area.

1. *Regional Multimodal Traveler Information Systems*
2. *Traffic Signal Control Systems*
3. *Freeway Management Systems*
4. *Transit Management Systems*
5. *Incident Management Programs*
6. *Electronic Toll Collection Systems*
7. *Electronic Fare Payment Systems*
8. *Railroad Grade Crossing Warning Systems*
9. *Emergency Management Systems*

BENEFITS AND COSTS

The benefits and costs associated with transportation improvements can vary by type of improvement being implemented, the context in which the project is being placed, and who is defining the benefits and costs. There are three major categories of benefits and costs that should be kept in mind when considering particular projects or program implementation: (Apogee 1994)

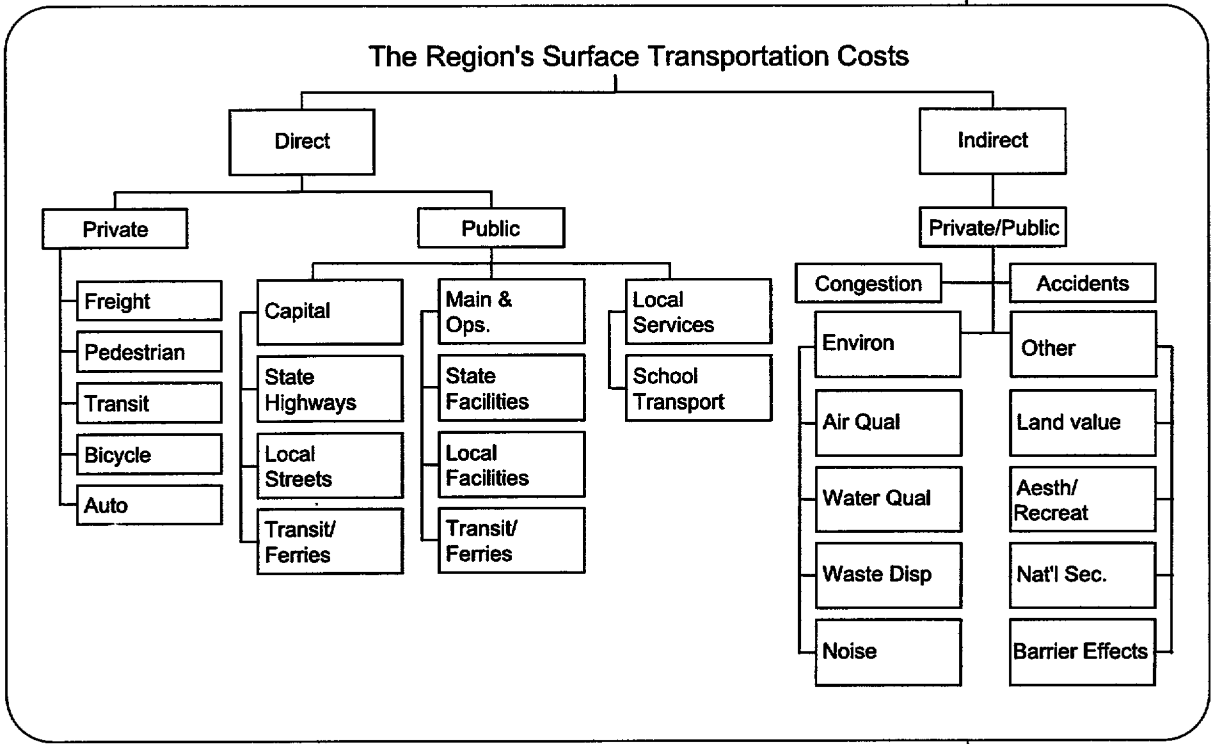
Private benefits or costs: Benefits or costs experienced by persons or private firms using facilities.

Social benefits or costs: The sum of benefits or costs to persons.

Societal accounting: Taking account of private benefits or costs in such a way that all impacts on individuals are captured, not just the impacts on those directly involved in some activity.

Another way of looking at benefits and costs is shown in Figure 1-4 (Puget Sound Regional Council 1996). In this example from Seattle, direct costs are out-of-pocket expenditures directly for transportation—the costs of cars, insurance, building and maintaining roads, paying police officers to provide traffic enforcement, operating transit service, transportation planning, and so on. These costs are paid by private individuals and businesses as well as by governments. Indirect costs include costs that occur as a result of transportation—congestion, accidents, air pollution, water impacts, solid waste disposal and noise. The Seattle report estimated that direct annual private costs totaled $18.3 billion, direct public costs were $1.7 billion, and indirect costs were conservatively

Figure 1.4: Transportation Cost Accounting In Seattle



Source Puget Sound Regional Council 1996 estimated at $1 .l billion. The study concluded:

- The Seattle region spends a "staggering" amount of money on transportation, about 25 percent of the region's personal income.
- Public expenditures on roads, transit, and ferries represent only 8 percent of all transportation expenditures
- Even without considering gas taxes, licensing, and excise taxes, auto-related expenditures by individuals and businesses represent 62 percent of all expenditures.
- Less than 3 percent of the region's direct public and private transportation expenditures go toward transit, ferries, and non-motorized transportation.

These distinctions on how one estimates benefits and costs are important in that many debates on the cost effectiveness of individual projects depend on what type of benefit or cost is being considered. Some methods only take into consideration those benefits and costs that are linked to those directly affected by a project. Others argue that a fair accounting of benefits and costs should consider all direct and indirect impacts and take into consideration the total costs to society of implementing a particular project.

Some methods only take into consideration those benefits and costs that are linked to those directly affected by a project Others argue that a fair accounting of benefits and costs should consider all direct and indirect impacts and take into consideration the total costs to society of inplementing a particular project

The traditional benefits relating to such improvements usually reflect the cost savings to users and to society of reductions in travel time, vehicle operating costs, fleet management costs, ease and convenience of use, and accidents. However, more recently, a great deal of professional attention has been paid to the economic benefits of improvements in transportation services. These benefits can be associated with additional business or industry attracted to a location, increased tourism, and expansion of existing businesses due to decreased transportation costs (Weisbrod and Beckwith 1992; Wilbur Smith and Assocs. 1993). For transit services, benefits have been. defined along many different dimensions-those improvements to transit riders in the form of reductions in time, cost and inconvenience; changes in well-being and security, changes in lifestyle, and improvements to the natural environment (Beimbom and Horowitz 1993).

The estimation of costs is often more complex than simply adding the amount of dollars needed to construct a project. Importantly, monetary costs should be considered over the entire life cycle of a project to obtain a better picture of how much a project will cost when considering not only actual construction, but also operations, maintenance, and rehabilitation. Total societal costs of a project might include costs associated with congestion, air pollution, noise and water pollution, loss of biological diversity, accidents, and energy consumption. In this document, the costs reported for typical application of the tools are primarily construction or purchase costs. Users of the Toolbox, however, when considering the implementation of different actions should carefully weigh a full cost accounting of a project's impacts.

COMMITMENT, PROCESS AND PUBLIC INVOLVEMENT

Tools are not very helpful if one does not know how or is unwilling to use them. Many of the tools in this Toolbox, especially those that attempt to influence demand, require time for their full effect to occur. For example, a major purpose of preferential lanes for high occupancy vehicles on major freeways is to encourage the increased use of transit and ridesharing. For this to happen in any significant way might have to await land use and travel behavior changes that could take years. In the meantime, inconvenience to existing users of the freeway could result in political pressure to remove the lane. Officials must have a strong commitment to the implementation of these types of techniques if they are ever to be effective.

One of the ways of gaining support for these actions is to involve the public in the discussion and debate that precedes adoption. Some of the most successful efforts at adopting transportation programs have exhibited the following characteristics:

- Waging an aggressive campaign to inform the public of what is likely to occur if something is not done.
- Clearly stating what the average citizen will gain from these actions.
- Providing opportunities for citizens and interest groups to participate in the planning and decision-making process.
- Actively pursuing business support for the proposed actions.
- Seeking media support in editorials and news reporting.
- Developing a cost effective program that appeals to as broad a political base as possible.

There are many examples from around the country where good ideas and projects have languished for years. In some sense then the process of implementing mobility/congestion reduction actions is as important as the actions themselves. It is for this reason that a focus on implementation is provided for each tool described in this Toolbox.

Officials must have a strong commitment to the implementation of these types of techniques if they are ever to be effective.

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IN THIS CHAPTER . . .

Urban Freeways

- *Freeway Incident Detection and Management Systems*
- *Ramp Metering*
- *Highway Information Systems*
- *Freeway Corridor Traffic Management (including Arterial Surveillance and control)*
- *Providing Additional Lanes without Widening the Freeway*
- *High Occupancy Vehicle (HOV) Facilities*
- *Park-and-Ride Facilities*
- *Highway Pricing Strategies*

Arterials and Local Streets: Design

- *Super Street Arterials*
- *Intersection Improvements*
- *One-Way Streets*
- *Reversible Traffic Lanes*
- *Arterial Access Management*
- *Traffic Calming and Street Space Management*

Arterials and Local Streets: Operations

- *Traffic Signal Improvements*
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- *High Occupancy Vehicle (HOV) Facilities on Arterials*
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- *Freight Movement Management*
- *Bicycle and Pedestrian Networks*

Enforcement

HIGHWAYS: GETTING THE MOST OUT OF THE EXISTING SYSTEM

This chapter is organized in five major sections. The first focuses on those actions that are primarily oriented to better managing urban freeways or expressways.. The second, third and fourth sections describe actions that relate to the design, operations, and system management of arterial and local streets. The last section in the chapter discusses the important role of enforcement.

As indicated in Chapter 1, highway congestion will grow substantially worse in the years ahead unless the total transportation system is improved to handle mobility demands. In some cities, these improvements will include the construction of new highways. However, in these and other cities, local officials will be greatly interested in what improvements to the existing highway system can be made before more costly and potentially more disruptive highway construction might occur. This chapter thus focuses on the highway element of transportation systems management. This chapter presents cost effective improvements that can be made to existing freeways and arterials in a relatively short timeframe, and in many cases, at a relatively low cost.

(URBAN FREEWAYS)

Although urban freeways make up less than 2.4 percent of the total urban highway mileage, they carry approximately 20 percent of the traffic nationwide. Congestion on this roadway system can occur under recurring conditions (i.e., due to capacity or operational problems) or can be caused by accidents or breakdowns, known as non-recurring congestion. By some estimates, as much as 60 percent of all freeway congestion is considered to be non-recurring. Thus, a key strategy for reducing congestion in major urban areas is to handle accidents’ and incidents as quickly as possible to keep traffic flowing.

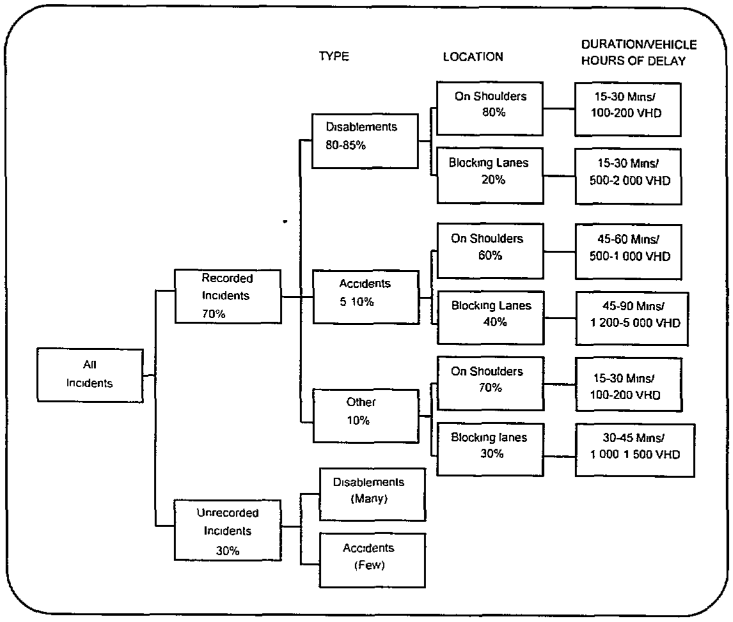
The approaches discussed in the following sections will describe the potential of reducing one or both types of congestion.

Highway congestion will grow substantially worse in the years ahead unless the total transportation system is improved to handle mobility demands.

Freeway Incident Detection and Management Systems

Description: Accidents (and other incidents) are a common occurrence on urban freeways. As shown in Figure 2-1, between 80 to 85 percent of recorded incidents are vehicle disablements, 5 to 10 percent are accidents, and the remaining percentage includes emergency maintenance work, debris on the road, etc. (Cambridge Systematics and The ATA Foundation 1996). There are three major stages to an incident management program: 1) detection/verification, 2) response/clearance, and 3) recovery/information.

Figure 2.1: Composite Profile of Reported Incidents By Type



Source Cambridge Systematics and The ATA Foundation 1996

There are three major stages to an incident management program·

1) detection/ verification,

2) response/clearance, and

3) recovery/information.

Detection/Verification: Currently, about one-half of all incidents are reported to police from cellular phone and roadside callboxes. However, more recent advancements in intelligent transportation systems (ITS) technologies have resulted in areawide surveillance systems consisting of such things as cameras and on-road sensors.

Response/Clearance: Response to incidents is often coordinated by local police. However, regional traffic management centers in many cities are now coordinating the response to incidents. Clearance strategies differ by type of incident and are often guided by police estimation of public safety risk.

Recovery/Information: The recovery to normal traffic operation has traditionally been left to on-site police and agency standard operating procedures for handling traffic. Today, many cities use traffic management centers to warn motorists upstream from an accident of the delays that will be encountered and to recommend alternative routes. This communication can occur through many means, including variable message signs, in-vehicle communications, and highway advisory radio.

Table 2.1 shows selected incident management programs in U.S. cities.

A freeway incident detection system consists of one or some combination of roving tow or service vehicles, motorist aid call boxes, citizen band radios and cellular phones, incident teams, detectors in mainline lanes to monitor volume, bridge/tunnel surveillance systems, motorist information systems, video surveillance, traffic diversion, and alternate route identification. The surveillance system itself normally consists of highway and ramp traffic detectors, changeable message signs, closed circuit television surveillance on particular trouble spots, a communications system, and some type of central management control (Institute of Transportation Engineers 1992). A system of detectors connected to a central command center allows monitoring of conditions throughout the freeway system. Pertinent driver information is provided through a changeable message sign system, radio traffic reports, highway advisory radio, and in-vehicle displays to alert drivers to congested conditions and allow diversion to alternate routes if necessary. A good example of a regional surveillance system is found in Minneapolis/St. Paul where over 3,000 in-pavement loop detectors provide online monitoring to a central traffic management center, 156 video cameras are mounted on 50-foot poles

Table 2.1: Incident Management Programs in the U.S.

	Formal Program?	Year Started	Service Patrols	Cellular Phones	Automatic Detectors	Closed Circuit TV	Traffic Operations Center	Incident Management Teams	Wrecker Agreement	Quick Clearance Policy	Highway Advisory Radio	Variable Message Signs	Alternate Routes	Media Partnership
Statewide														
Arizona	Yes	1993	○		○	○	●	●	●			●	●	●
California	Yes	1970s	●	●	●	●	●	●	●	●	●	●	●	●
Connecticut	Yes	1992	○	●	●	●	●	○	●	●	○	●	●	●
Florida	Yes	1980s	●	●	●	●	●	●	●	●	●	●	●	●
Maryland	Yes	1980s	●	●	●	●	●	●		●	●	●	●	●
Missouri	In development	1990s	●	●	○	●	○	○	●	○	●	●	○	●
New Jersey	In development	1976	●	●	●	●	●	●	●	●	●	●	●	●
Virginia	Yes	1980s	●	●	●	●	●	●	●	●	●	●	●	●
Metropolitan														
Atlanta	Yes	1990	●	●	○	○	●	●	○	●	○	○	●	●
Boston	Yes	1991	●	●	○	●	○	●	●	●	●	●	●	●
Charlotte	Yes	1991	●	●	○	○	●	●	●	●	●	●	●	
Chicago	Yes	1960	●	●	●	●	●	●		●	●	●	●	●
Dallas/Ft Worth	Yes	1970s	●	●	○	●	●	●	●	●	○	●	●	●
Denver	Yes	1991	●	●	●	●	●	●		●	●	○	●	○
Detroit	Yes	1992	●	●	●	●	●	●	●	●	●	●	●	●
Los Angeles	Yes	1970s	●	●	●	●	●	●	●	●	●	●	●	●
Minneapolis	Yes	1974	●	●	●	●	●	●	●		●	●	●	●
New York City	Yes	1985	●	●	○	●	●	●	●		●	●	●	●
Sacramento	Yes	1993	●	●	●	●	●	●	●	●	●	●	●	○
Salt Lake City	Yes	1994	●	●				●	●			○		●
Seattle	Yes	1990s	●	●	●	●	●	●	●		●	●	○	●
Washington, DC	Yes	1989	●	●	●	●	●	●	●	●	●	●	●	●

● Current ○ Planned

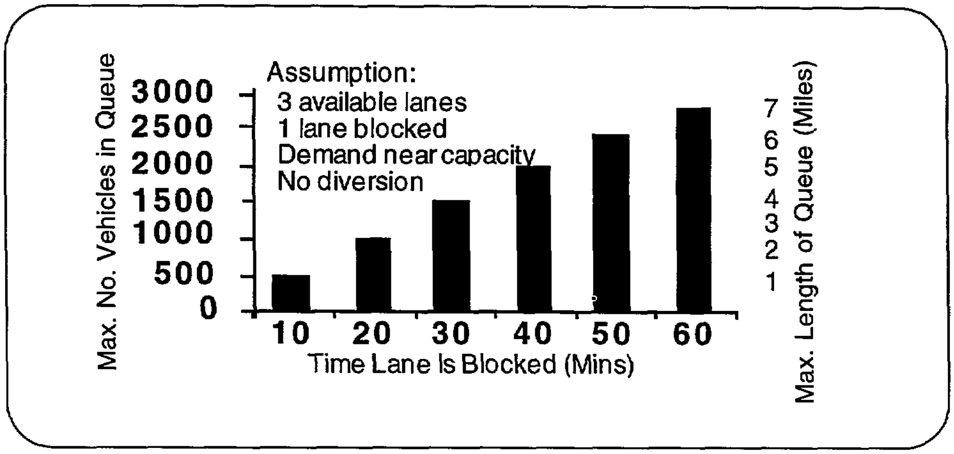
Source: Cambridge Systematics and The ATA Foundation 1996

at one mile spacing, drivers are encouraged to use cellular phones and transit operators their radios to report incidents, and the state DOT freeway operations section has formed a partnership with several commercial traffic information services for aerial surveillance (Minnesota DOT 1996). Another example is found in northern Virginia where 48 cameras positioned at strategic locations along three Interstates, along with 100 variable message signs, provide motorists with advanced warning of congestion on the roadways.

Benefits/Costs: The major benefit of incident detection and management systems is that they will reduce the amount of delay time for traffic affected by an incident. Figure 2-2 shows an estimate from Connecticut of the number of vehicles being delayed and the length of queue for different amounts of time a lane is blocked for the given assumptions. As shown, significant savings in travel time can occur if incident duration can be reduced (Connecticut DOT 1990). A new freeway patrol service response strategy in the San Francisco Bay area resulted in a reduced incident response time of 57 percent, which when combined with estimated reductions in fuel consumption of delayed vehicles, resulted in a benefit/cost ratio of 3.4 to 1 [in addition, 93 percent of motorists assisted by the service rated it as excellent] (Skabardonis et al

The major benefit of incident detection and management systems is that they will reduce the amount of delay time for traffic affected by an incident.

Figure 2.2: Effects of Rush-Hour Lane Blockage on Queue Length



Source: ConnDOT 1990

1995). An evaluation of a Massachusetts cellular phone call-in campaign which included road signs, information brochures mailed to phone subscribers, public service announcements, a special *SP number statewide, and installation of mile markers/overpass street names on state highways resulted in a significant increase in calls (Collura et al 1995). In 1989, just over 61,000 calls were received by the state police; by 1994 this number had increased to 250,000 with almost half reporting accidents, motor vehicle violations and operating-under-the-influence incidents. The use of *SP is estimated to reduce incident waiting time by 30 to 40 percent.

Variable Message Sign

A recent study of the benefits of incident management systems in Houston estimated that a 232 mile/373 km traffic monitoring system in 1995 would have reduced daily incident delay by 4,500 vehicle-hours per day which is equivalent to an additional 40 freeway lane-miles (Schrank and Lomax 1996). The Illinois DOT Emergency Traffic Patrol has provided assistance to expressway motorists in the Chicago area for many years. This effort consists of 35 roving vehicles and 50 people covering approximately 100 miles/161 kms of freeways. This service provides assistance to well over 100,000 motorists each year which is estimated to save over 10 million hours of delay [as reported in (Urban Land Institute 1991)]. Certain nonpriceable benefits which add to the effectiveness of the patrol are: motorist sense of security, improved public relations, reduced requests that require no police function, and improved safety in minimizing secondary accident potential.

A study of a freeway service patrol in the San Francisco Bay area concluded that the proportion of tow truck assisted incidents increased from 9 percent “before” to 24 percent after implementation with 80 percent of these assists provided by the patrol (Skabardonis et al 1995). About 30 percent of these incidents required the vehicle to be removed from the highway. The response times of the service patrol assists were reduced by 57 percent, and the response times of all assisted incidents were cut by 35 percent. This service had an estimated benefit/cost ratio of 3.4:1 and an estimated annual reduction of 77 tons of carbon monoxide, 19 tons of oxides of nitrogen, and 7.6 tons of hydrocarbons. A survey of motorists assisted by this service not surprisingly showed overwhelming approval with 93 percent rating the service “excellent.”

A 1986 Federal Highway Administration study revealed that incident management systems could reduce congestion on approximately 30 percent of the major urban area freeway mileage, returning a benefit/cost ratio of approximately 4: 1, where benefits are measured as the aggregate value of time saved by the motorists (Federal Highway Administration 1986). Other studies have produced the following benefit/cost ratios for specific types of actions:

Developing a comprehensive freeway incident management strategy is one of the most cost effective strategies that can be implemented as part of a transportation system management program. As shown in Figure 2-3, the different types of actions that can be undertaken to provide better incident management capabilities can vary in potential benefits and costs.

Implementation: The documented impacts of freeway incident management improvements have been impressive. As freeways become more congested, incident detection and management systems will become even more important. The process from conceptual planning to completed system in an urban area can take five years. Marketing efforts, in particular, are needed early in the process to assure that the public and elected officials will understand the impacts of these traffic management efforts. Table 2.2 shows the different constituencies for incident management and key “selling points” for each. Some metropolitan areas have established “Congestion Management Teams,” with specific responsibilities for planning, implementing, monitoring and identifying these activities. Of particular interest is the use of advanced technologies in the development of incident detection and

Location	Program	Benefit/Cost Ratio	Year
Charlotte	Motorist Assistance Patrol	7 6:l	1993
Chicago	Emergency Traffic Control	171	1990
Denver	Mile-High Courtesy Patrol	135.1 to 184.1	1993
Houston	Motorist Assistance Patrol	19 1	1993
Houston	Motorist Assistance Patrol	71to361	1991
Houston	Freeway Courtesy Patrol	*2.1*	*1973*

Source Cambridge Systematics and The ATA Foundation 1996 management systems. Intelligent transportation system (ITS) technologies can provide a significant capability in the use of such systems. However, incident management strategies should be undertaken in the context of a corridor demand management program that provides incentives/disincentives to reduce the overall motor vehicle demand.

See Chapter 6 on ITS for more information on freeway management strategies.

Figure 2.3: Different Incident Management Strategies

Options to Reduce Detection and Verification Time

Type of Program	Potential Benefits	Potential Costs	Comments
Peak Period Motorcycle Patrols	++++	$$ to $$$	Roving motorcycle patrols can provide added surveillance along high incident segments
Dedicated Freeway Service Patrols	++ to ++++	$$ to $$$$	Roving patrols on high incident segments of the freeway can reduce detection time
Motorist Aid Call Boxes/Telephones	++	$$$	May incur added costs or complications because of required utility work
Incident Phone Lines	+	$$	Requires an initial publicity effort and continued cooperation with media
Cellular Telephones	++++	$	Information should be distributed to users describing proper reporting techniques
Citizen Band Radio	++	$	Information should be distributed to operators with proper reporting techniques
Volunteer Watch	+	$	Training efforts may be wasted on short term volunteers
Ties With Transit/ Taxi Companies	+++	$	Can be expensive to cover all routes or limited to those who travel in high incident areas
Aircraft Patrol	+ to ++++	$ to $$$$	May be limited by noise or density *restrictions*
Electronic Loop Detection	++	$$$$	Can also serve other operations functions, but may give false calls in incident detection
Central Information Control Center	+++	$$$	Centralization of information allows for better detection
Video/Closed Circuit TV	++++	$$$$	Can also serve many other operations functions such as volume & speed data collection

+ = Minor Benefits
++ = Moderate Benefits
+++ = Substantial Benefits
++++ = Very Substantial Benefits

$ = Minor Costs
$$ = Moderate Costs
$$$ = Substantial Costs
$$$$ = Very Substantial Costs

Source: Koehne et al 1991

Figure 2.3: Continued

Options to Improve Response Time

Type of Program	Potential Benefits	Potential Costs	Comments
Personnel Resource List	+++	$	Can save time in locating specially trained personnel
Equipment and Materials Resource List	+++	$	Can save time in locating special equipment or personnel if list is frequently updated
Peak Period Motor Cycle Patrols	++++	$$ to $$$	Roving motorcycle patrols can provide added surveillance on high iincident segments
Dedicated Freeway or Service Patrols	++ to ++++	$$ to $$$$	Roving patrols can reduce response time required by response vehicles
Personnel Training Program	+++	$$	An emphasis on training through knowledge and repetition can reduce response times
Tow Truck/ Removal Crane Contracts	++	$	Provides faster access to equipment, but may be problematic with competing firms
Improved Inter-agency Radio Communications	+++	$ to $$	Adequate communication can help to insure closest response vehicle is dispatched
Ordinances Governing Travel on Shoulders	+	$	Can provide additional travel lane for response vehicles
Emergency vehicle Access	++	$$	Requires iidentification of those freeway links which suffer from poor access
Alternative Route Planning	++	$	If properly planned, can allow quicker access
Equipment Storage Sites	++	$ to $$	Provides faster access to equipment or materials
Administrative Traffic Management Teams	+	$	Provides forum to discuss and provide funding for area incident management programs
Public Education Program	+++	$	Can educate drivers regarding disabled vehicle removal and help resolve incidents without need for actual response
Central Information Processing and Control	+++	$$$	Provides a single location for monitoring incidents and allows coordination of response from many different agencies
Closely Spaced Milepost Markers	++	$	Fast, accurate, easy location of incidents Improves response speed

+ = Minor Benefits
++ = Moderate Benefits
+++ = Substantial Benefits
++++ = Very Substantial Benefits

$ = Minor Costs
$$ = Moderate Costs
$$$ = Substantial Costs
$$$$ = Very Substantial Costs

Figure 2.3: Continued

Options for Improving Site Management

Type of Program	Potential Benefits	Potential Costs	Comments
Incident Response Teams	++ to ++++	$ to $$$	Highly trained response teams can greatly reduce site management delays
Personnel Training	+++	$$	Highly trained personnel can speed the management process as well as reduce conflicts
Peak Period Motorcycle Patrols	++++	$$ to $$$	Motorcycle patrols have more maneuverability in congested areas and can carry out vital tasks
Improved Inter-agency Radio Communications	+++	$ to $$	Direct communication between various agencies can reduce repetition and confusion
Command Posts	++	$	Allows information and instruction to disseminate from single source
Identification Arm Bands	+	$	Allows quick differentiation between respondents, public and media
Properly Defined Traffic Control Techniques	+++	$	Provides greater safety for motoring public as well as for respondents
Properly Defined Parking for Response Vehicles	++	$	Ensures that excess lanes are not blocked by response vehicles
Flashing Lights Policy	+	$	Need to consider safety of respondents, liability and impacts on normal traffic flow
Administrative Traffic Management Team	+	$	Provides forum to discuss and provide funding for area incident management programs
Central Information Processing and Control	+++	$$$	Central collection and analysis of information allows better coordination
Alternative Route Planning	++	$	Serves to improve response and clearance
Incident Response Manual	+++	$	Predetermined chain of command and response can facilitate decision making

Options for Improving Motorist Information

Type of Program	Potential Benefits	Potential Costs	Comments
Improved Media Ties	++	$	Information disseminated by the media must be effective and accurate and must therefore come from a single and central point
Highway Advisory Radio	+ to ++	$ to $$	Variations include mobile and truck mounted, but in each case, must be kept current and accurate to be utilized by motoring public
Variable Message Signs	++	$ to $$	Variations include flap, matrix, drum, permanent, and portable, but each must be kept current and accurate
Radio Data Systems	+++	$$$$	Provides information to motorists when they want it, but is still in the early implementation stage

Options for improving Motorist Information, Continued

Type of Program	Potential Benefits	Potential Costs	Comments
Externally Linked Route Guidance Systems	++++	$$$$	Provides the most comprehensive information concerning traffic situations, but is still in development stage
Central Information Processing and Control	+++	$$$	A central location can collect data from multiple sources and provide a more accurate picture of existing traffic conditions

Options for Reducing Clearance Time

Type of Program	Potential Benefits	Potential Costs	Comments
Policy Requiring Fast vehicle Removal	++++	$	Serves to quickly restore the capacity of the roadway but may require ordinance
Accident Investigation Sites	++	$$ to $$$	Serves to improve safety of the motoring public as well as that for respondents
Dedicated Freeway Service Patrol	++ to ++++	$$ to $$$$	Specially equipped patrol vehicles can clear most minor incidents without other assistance
Push Bumpers	++	$	Allows minor accidents to be cleared
Inflatable Air Bag Systems	++	$$	Improves clearance times for incidents involving overturned trucks, limited by truck type
Responsive Traffic Control Systems	++	$$$$	Can improve clearance efforts by limiting congestion in immediate area
Variable Lane Closure	++	$	Can speed clearance efforts by allowing the interruption of flowing traffic
Ordinances Governing Shoulder Travel	+	$	Can provide additional travel lane for removing vehicles by may be limited by space
Emergency Vehicle Access	++	$$	Requires identification of those freeway links which suffer from poor access
Alternative Route Planning	++	$	If implemented with information systems, can serve to reduce congestion and Improve mobility by rerouting uninvolved vehicles
Identification of Fire Hydrant Locations	++	$	Can greatly speed clearance efforts by allowing quick locating of utilities in incidents with fire
Incident Response Teams	++ to ++++	$ to $$$	Coordinated response teams should be trained in a variety of equipment use
Incident Response Manual	+++	$	Once developed, should be Included in regular training procedures for clearance efforts
Hazardous Materials Manual	+++	$	Once developed, should be included in regular training procedures for clearance efforts
Administrative Traffic Management Teams	+	$	Provides a forum to discuss and provide funding for area incident management
Public Education Program	+++	$	Can educate drivers regarding disabled vehicle removal policies
Total Station Surveying Equipment	++++	$	Can reduce time required for accident investigation by nearly half

+ = Minor Benefits
++ = Moderate Benefits
+++ = Substantial Benefits
++++ = Very Substantial Benefits

$ = Minor Costs
$$ = Moderate Costs
$$$ = Substantial Costs
$$$$ = Very Substantial Costs

Table 2.2: Key Incident Management Constituencies

	State/Local DOTs	MPOs	State/Local Police	Fire Departments	Health Agencies	Environmental Protection Agencies	Emergency Mgmt. Authorities	Toll Authorities	Emergency Service Providers	Tow Truck Operators	Insurers	Motorist Associations	Motor Carriers	Private Businesses	Traffic Reporting Media
Improves public relations	●	●	●	●				●			●	●	●	●	
Improves highway safety	●		●					●			●	●	●	●	
Enables more efficient use of equipment, personnel	●		●	●			●		●	●					
Reduces risk of injury to on-site personnel	●		●	●					●	●					
Provides better, more timely information	●		●			●					●				●
Reduces delay times for all highway users	●										●	●	●	●	
Improves freight mobility	●										●		●	●	
Reduces vehicle maintenance and fuel costs											●	●	●		
Reduces congestion cost-effectively	●	●						●							
Saves lives by reducing response time					●				●						
Increases revenue or prevents loss in revenue								●		●					
Improves contracts with jurisdictions									●	●					
Lends balance to regional transportation plan	●	●													
Improves air quality		●													
Enhances interjurisdictional cooperation		●													
Provides premium service to customers								●							
Prevents loss in economic competitiveness														●	

Source: Cambridge Systematics and The ATA Foundation 1996

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Ramp Metering

Description: Ramp metering is a cost-effective technique for improving traffic flow on freeways. Using a modified traffic signal placed at the end of a ramp, ramp metering allows traffic to enter the highway traffic either at pre-timed intervals or at times determined by traffic volume on the ramp or on the main highway. Although delays are often incurred by ramp traffic, mainline capacities are protected and the overall operational efficiency, usually measured in terms of travel time or speed, is improved. HOV bypass lanes on metered ramps have been used to provide time savings for carpools, van pools, and buses. Minneapolis / St. Paul has 380 ramp meters on the region's freeways, 350 of which are centrally controlled by a traffic management center. In a new twist to the concept of ramp metering, the Minnesota DOT is metering 70 freeway-to-freeway ramps that have been severely congested over the past 10 years (Minnesota DOT 1995). Figure 2-4 shows the basic concept of how ramp meters work.

Benefits/Costs: Ramp metering is primarily a tool for increasing traffic throughput on a freeway. However, ramp metering also can be used to discourage drivers from using the freeway for very short trips and to provide incentives for bus riders and carpools by bypassing ramp congestion (often a one to four minute time savings). A survey made for the Federal Highway Administration of seven ramp metering systems in the United States and Canada revealed that average highway speeds increased by 29 percent after ramp metering was installed. When delays on ramps are included, average speeds still increased 20 percent and travel times decreased 16.5 percent. An analysis of the FLOW system in Seattle (ramp metering and HOV lanes) revealed that in addition to similar improvements in speed and travel time, highway volumes increased by about 60 percent as a result of ramp metering. An additional benefit from ramp metering is a decrease in the accident rate. Reductions from 5 to 50 percent have been achieved through improved merging operations (Piotrowicz and Robinson 1995). The following is a summary of ramp metering impacts from five locations in the United States: (Connecticut DOT 1990)

			Change in:		
	"Before Speed"	"After Speed"	Travel Time	Accidents	Volumes
Portland, OR	16mph	41 mph	-61%	-43%	NA
Minneapolis	34 mph	46 mph	NA	-27%	+32%
Seattle	NA	NA	-48%	-39%	+62%
Denver	43 mph	50 mph	-37%	-5%	+19%
Long Island, NY	29 mph	35 mph	-20%	NA	0

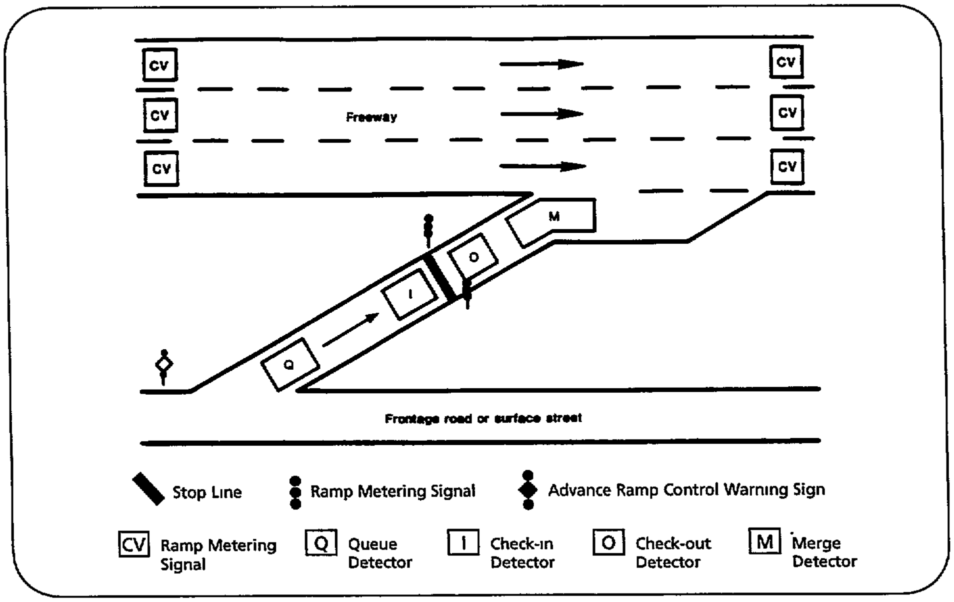
Ramp metering is a cost-effective technique for improving traffic flow on freeways.

Various levels of entrance ramp control have been implemented across the country. Some are used simply to improve the conditions at specific problem merge areas. Two ramp metered locations in Detroit resulted in increases on the freeway mainline of traffic volume and speed (27 mph to 60 mph) at one location and increases of traffic volume and speed (35 mph to 58 mph) at another. A few states have focused attention on longer sections of routes in urban areas and are now attempting system-wide applications, notably in California and Texas. Average speed increases of 30 percent commonly result, while reducing mainline congestion by between 20 percent and 60 percent. In addition, Minnesota recently compared conditions on one freeway prior to system activation to conditions during 14 years of system operation. They showed a 16 percent increase in average peak hour freeway speeds (37 to 43 mph) and a 25 percent increase in average peak period volumes.

Traffic-responsive metering often produces results that are generally 5 to 10 percent greater than those of pre-timed metering. A traffic-responsive ramp control experiment in Los Angeles obtained a 100 percent increase in average speed (25 to 52 mph), a 20 percent decrease in ramp wait times, and a 3 percent increase in freeway volumes. Although this is probably a "best" case example, it points to the greater flexibility of traffic-responsive control and the impacts possible.

A special type of metering system was installed in 1974 at the Oakland-Bay Bridge approaching San Francisco. The system consists of stop-and-go traffic signals located over each of the 15 lanes about 1000 feet downstream from the toll booths. The metering system allows all multi-occupant vehicles to proceed nonstop under a green light, while other vehicles are allowed to proceed at preselected time intervals. The result is a more flexible system accommodating the variations in buses and carpools while at the same time allowing the bridge to carry vehicles at its peak efficiency. Prior to constructing the metering project only 7 percent of the morning commute periods were incident-free. After metering, 20 percent were incident-free. Travel time savings averaged from 2.5 to 3.5 minutes per vehicle. Tow services, incident detection equipment, motorist call boxes, changeable message signs, and closed circuit television are additional elements implemented in the Bay Bridge computerized traffic management system.

Figure 2.4: Example Ramp Meter Installation



Source Federal Highway Administration 1995

The common increase in freeway speed and flow rate that results from ramp metering must be considered from the perspective of latent demand. Over time, significant increases in freeway capacity will lead to large growth in traffic volume, possibly encouraging travelers to switch to auto use from transit services. Therefore, ramp metering should be implemented in conjunction with corridor transportation demand management strategies that will encourage high-occupancy vehicle use.

Implementation: A substantial amount of time is needed to plan and implement a ramp metering system. The engineering aspects of ramp metering are fairly wellknown. However, ramp meters can often create significant controversy regarding the perceived inconvenience to motorists, and importantly the equity issue of providing improved freeway traffic flow for those using the freeway (e.g., suburban commuters) to the inconvenience of those trying to access it (e.g., center city residents). The implementation of a ramp metering system must therefore include a process where a variety of government and public groups are actively involved in the conceptual planning and implementation.

The following implementation strategy was recommended for incorporating ramp meters into the Hartford, CT freeway system (Connecticut DOT 1990).

- Involve all affected agencies and institutions in the process from the very beginning.
- Institute a proactive public relations program.
- Discuss with local governments how the metering will be operated, e.g., diversion strategies and how to minimize impacts on local streets.
- Perform ramp control experiments to demonstrate the effectiveness of metering.
- Install ramp meters in conjunction with freeway rehabilitation and resurfacing.
- Provide updates on meter operations at frequent intervals.

The implementation of a ramp metering system must include a process where a variety of government and public groups are actively involved in the conceptual planning and Implementation.

Although ramp metering can provide some important improvements to the flow of freeway traffic, it is not always an appropriate solution for a number of reasons. Ramps selected for this technique must be at locations where arterials feeding the ramps will not become severely congested as a consequence of such action. Improvements to freeway flows could be made at the expense of transferring a more severe congestion problem to local streets. Possible mitigation measures for such an occurrence include:

- Increasing ramp storage, e.g., widening/increasing number of lanes.
- Creating an areawide system control of metering such that backups are distributed among many different ramps.
- Installing a queue detector at the top of the ramp that will increase the metering rate to clear out the vehicles in the queue.

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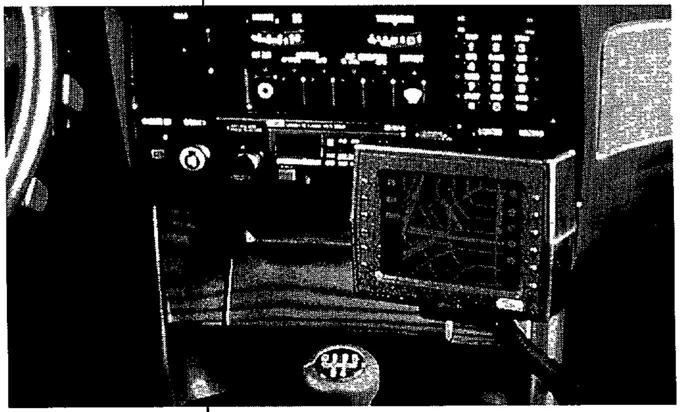
Highway Information Systems

(See also Regional Multimodal Traveler Information Systems, Chapter 6)

Description: Highway information systems represent an important element of a freeway management system in that they provide the means of communicating to those traveling on the road system. Such information systems can consist of one or more of the following: changeable message signs, highway advisory radio, and/or in-vehicle navigation and information systems. The intent of these information systems is to provide dynamic information regarding existing traffic conditions so that travelers can make intelligent route choices if already on the road network, or even mode choice if the trip has not yet started. Information that could be conveyed includes: (Connecticut DOT 1990)

- Delays due to recurring congestion
- Delays from non-recurring congestion
- Speed limits
- Weather conditions
- Construction activities
- Evacuation information
- Implementation of new devices (e.g., ramp meters)

Highway Information Systems can consist of the following: changeable message signs, highway advisory radio, and/or in-vehicle navigation and information systems.



Invehicle Navigation System

More recently, the Internet has been used to provide real-time freeway condition information in a number of cities in the United States. Local cable TV channels could also provide real-time video of traffic conditions to the public as is being done in Montgomery County, Maryland. The state-of-the-art of this technology was demonstrated in the Atlanta Traveler Information Showcase that was put in place for the 1996 Olympics (see Chapter 6 for a more detailed description of this program).

Benefits/Costs: The benefits of improved traveler information systems include:

Early warning reduces the speeds of vehicles approaching a queue, resulting in fewer secondary accidents and associated delays. Decelerations have been found to be less severe in congested locations when advanced warn.ing was given.

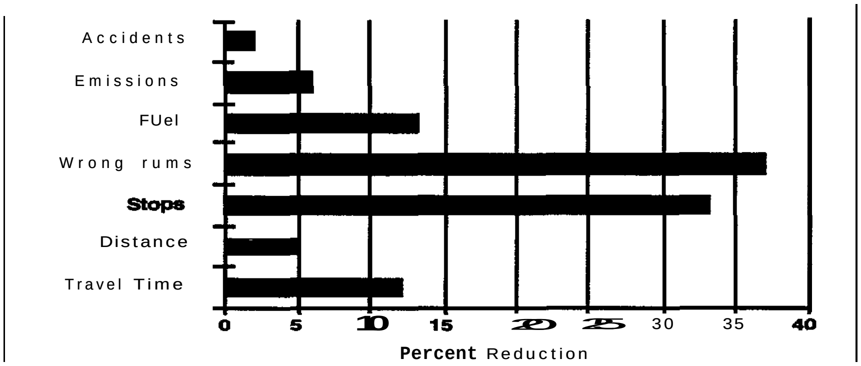
- Vehicles can divert to alternate routes when informed of an incident that is blocking the road ahead.
- Information on lane blockages induces lane changing away from that lane.

Motorist diversions will generally contribute to overall savings in travel time over the delays likely to be experienced on the mainline. This assumes, of course, that there are alternative routes available to divert to and that these routes themselves are not greatly congested. However, every effort should be made to keep diverting motorists from using residential streets.

Highway information systems can also be used at locations where heavy congestion occurs. Highway advisory radio, for example, is often used at approaches to airport parking facilities, near construction sites on freeways, and in mobile units by incident management teams. The transmitters have a range of approximately 2 miles/3.2 kms in each direction. The messages are changed remotely to reflect actual conditions. Other information dissemination tools can also be used including in-vehicle displays (Federal Highway Administration 1995).

One of the more recent demonstrations of in-vehicle traveler information was the TravTek program in Orlando, Florida (Federal Highway Administration 1996). This demonstration consisted of 100 vehicles equipped with in-vehicle information displays, a traffic management center and a TravTek information and services center. The majority of the vehicles were rented to Orlando visitors. Figure 2-5 shows the results of improved information to drivers. Note in this figure that the reduction in the different parameters were the result of tests with local drivers as well as out-of-town visitors.

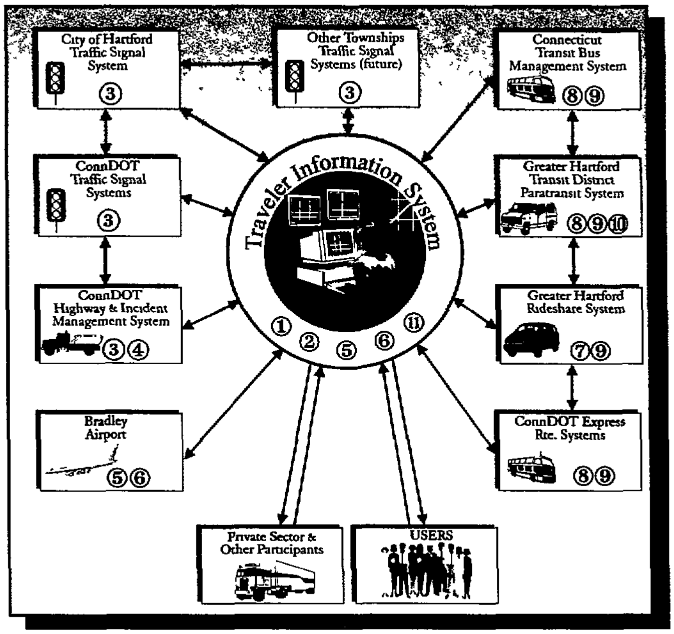
Figure 2.5: Summary of TravTek In-Vehicle Information Demonstration



Source: FHWA 1996

Implementation: A substantial amount of time is needed to plan and implement a highway traveler information system. Implementation requires the design and construction of the system, using the steps required for a typical highway construction project. However, the nature of this system is such that experts in the areas of electronics and information systems must be involved in addition to highway and traffic engineers. Local communication media should be included in the planning and possibly in the implementation stage. Ideally, the system should be designed as an integral part of an areawide freeway management program, as described previously. An example of a coordinated freeway corridor management system that relies on traveler information systems is shown in Figure 2-6. This approach has been

Figure 2.6: Example of Coordinated Traveler Information System in Hartford, CT



Legend: ITS services included in core infrastructure

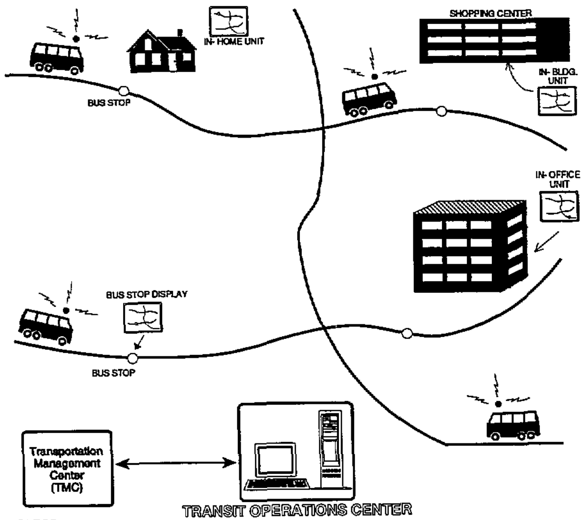
① En-route Driver Information	⑦ Ride-Matching & Reservation
② Route Guidance	⑧ Electronic Payment (Fare) System
③ Traffic Control	⑨ Public Transportation Management
④ Incident Management	⑩ Personalized Public Transit
⑤ Pre-trip Travel Information	⑪ En-Route Transit Information
⑥ Traveler Services Information	

Source ConnDOT 1990

Figure 2.7: Information System Application In An Urban Area

REAL-TIME BUS POSITION AND ARRIVAL INFORMATION

GOAL To facilitate transit use by providing real-time vehicle position information to users



SCENARIO

1 Bus transmits real-time position information to Transit Operations Center

2 Transit Operations Center transmits real-time location and arrival information to homes and businesses

3 Users can alter schedules if bus is seriously delayed

Source: Federal Highway Administration, 1995

adopted in Hartford, Connecticut and shows the strong linkage between data input (surveillance) from the many users of the transportation system and the information feedback to these users so that informed travel decisions can be made concerning mode and route (Connecticut DOT 1995). One of the more likely scenarios for the use of advanced technologies in traveler information will be their application in the context of access to large traffic attractors, such as sports stadia, ports, airports, and convention halls. Figure 2-7 shows an application of real-time information systems for bus routes.

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Freeway Corridor Traffic Management *(Including Arterial Surveillance and Control)*

Description: Freeway corridor traffic management consists of a coordinated application of the strategies discussed earlier on both a freeway and on the adjacent arterials. The important element of a corridor traffic management strategy is that additional mobility enhancements can occur by combining the control and surveillance of nearby arterial roads with adjoining freeway control and surveillance activities. Motorists seeking to avoid the congested freeway could use parallel arterial routes or other freeways, which in turn increases congestion on these facilities. Traffic waiting to enter the congested freeway may spill onto adjacent surface streets, further aggravating congestion. An integrated freeway and arterial network surveillance system consists of incident surveillance and management, entrance ramp control, exit ramp control, freeway mainline control [which includes driver information systems, variable-speed control, mainline metering, lane control, and reversible lane control], and corridor control [which includes coordination of traffic signals on frontage roads and on parallel arterials, coordination of ramp control and frontage road operations to provide alternate routes during emergencies, coordination of turning traffic signal phases, and coordination of traffic signals at freeway interchanges with arterial cross streets] (Institute of Transportation Engineers 1992).

The Important element of a corridor traffic management strategy is that additional mobility enhancements can occur by combining the control and surveillance of nearby arterial roads with adjoining freeway control and surveillance activities

Benefits/Costs: A good example of an operationally integrated freeway and arterial road project is in New York State. The Information for Motorists (INFORM) project was conceived to optimize traffic flow through a 35 mile/56 km long and 5 mile/8 km wide corridor of freeways and arterials in Long Island by integrating ramp metering, coordinated traffic signal control, and variable message signing into one comprehensive system sharing the same software and database. INFORM consists of the following elements: (Domjan and Han 1994)

- 2069 roadway embedded vehicle sensors
- 101 variable message signs
- 75 ramp meters
- 34 closed circuit TVs
- 22 Citizen Band radio receivers
- central control center
- 133 centrally controlled signalized intersections

Both California and Texas have embarked on similar ventures. An integrated corridor concept is found on the Santa Monica freeway corridor in Los Angeles, 12 miles/l9 kms long and 5 miles/8 kms wide with five arterial alternative routes. A common database has been developed for roadway management and motorist information. Personal computer and telephone information access and in-vehicle navigation information are part of the state-of-the-art activities. One of the few studies that have estimated the benefits of freeway management focused on the existing and projected (in the year 2000) freeway traffic management (FTM) systems in Houston. This study estimated that the 48-mile/77-kilometer FTM system in 1995 reduced daily recurrent delay by 6,300 vehicle-hours which is the equivalent of an additional 56 freeway lane-miles. For the projected 110 mile/l 77-km FTM system in 2000, the reduction in daily recurrent delay would be 21,100 vehicle-hours which is the equivalent of an additional 153 freeway lane-miles (Schrank and Lomax 1996).

The most important benefits associated with these types of projects is the reduction in delay that occurs with improved traffic flow in the corridor.

The most important benefits associated with these types of projects is the reduction in delay that occurs with improved traffic flow in the corridor. A sophisticated surveillance and control program in a corridor could increase average vehicle throughput by 12 to 20 percent and produce benefit/cost ratios of between 10 and 12 to 1 (Henk,) Poe, and Lomas 1991). A recent case study of TRANSCOM a regional institutional structure for coordinating a large number of transportation and enforcement agencies in the New York City area, illustrates the benefits of such an approach (Wilson 1996). A consortium of 15 transportation and traffic enforcement agencies created TRANSCOM, an incident management and communications clearinghouse. TRANSCOM receives updated information on roadway emergency situations, special events, and any other incidents that require immediate attention. TRANSCOM staff evaluate this information and transmit it to all member agencies via encoded pagers, giving them real-time information on events affecting traffic conditions. This ensures quick response. One of the important activities of this effort is the transmission of digitized pictures of incident scenes by cellular telephone to a personal computer at the TRANSCOM center. To minimize disruptions and improve the efficiency of the highway system, TRANSCOM has developed a regional database of all scheduled construction and maintenance projections, and has prepared prearranged diversionary plans for the major highways in the region (Federal Highway Administration 1987). Some benefits associated with TRANSCOM include daily coordination among the operating agencies in a major metropolitan area, longer term coordination of construction scheduling on the regional highway network, and sharing of new transportation management technologies. For example, TRANSMIT, the TRANSCOM System for Managing Incidents and Traffic, uses vehicles equipped with transponders for electronic toll collection as probes to monitor traffic. Although the original purpose of this project was to monitor for incidents, implementing agencies have found great use with the collected data for determining travel times between key points which has been used for scheduling staffing levels at toll plazas.

Of some importance to regional transportation, the TRANSCOM program was one of the major foundations for a much larger effort called the I-95 Coalition which has expanded TRANSCOM's impact from Maine to Virginia (see Chapter 6 for a more detailed description of the I-95 Coalition).

Implementation: Integrated corridor solutions are in the early stages of implementation in several cities. ITS technologies are being used as the foundation of many of these efforts. The barrier to further efforts (large or small, simple or sophisticated) is largely institutional and financial. Only by working side by side, as part of the whole solution, can regional improvements result. The TRANSCOM example above illustrates this point quite well. As noted in (Wilson 1996), there are several general principles that are inherent in regional cooperative efforts:

- Lack of authority should not deter a coalition from pursuing its mission with confidence.
- Even if the coalition has a uniform set of goals and objectives, the motivations among the member agencies for participating or not participating in the coalition can be highly variable.
- Even if the executive management of a constituent agency supports a regional coalition, this may not necessarily translate into support for regionalism at all levels and all sectors of the agency.
- While uniform procedures among the member agencies may be desirable in making a coalition effective, that is an unlikely situation for a coalition that has no authority over its members.
- There should be no inconsistency between the self-interest of each agency and the collective, regional interest of the coalition.
- Coalitions should focus on things that truly are better done collectively.
- To develop from an abstract ideal into a going concern, a coalition has to provide a valuable service-it has to help its constituent agencies do their business and serve their customers more effectively.

Another example of integrated freeway/arterial systems is the concept of Traffic Management Teams in Texas. There are currently 12 teams operating in the state, covering the seven largest metropolitan areas and the nine largest cities as well as other smaller areas. Each team brings together professionals from various traffic-related agencies in the area, and works cooperatively to solve the

The barrier to further efforts in integrated corridor solutions is largely institutional and financial. Only by working side by side, as part of the whole solution, can regional improvements result.

area's traffic problems. The rapid spread of the team concept and their wide acceptance among the larger cities in Texas is evidence that effective interagency communications can often lead to cooperation. The Texas Department of Transportation has also sponsored an aggressive education program for both highway/traffic professionals and the general public. The viability of coordinated traffic management schemes is demonstrated through workshops, seminars, and training courses.

Integrated freeway and arterial network surveillance/control programs are important tools for better managing the existing road system. These programs should be integrated with multimodal traveler information systems so that corridor transportation improvements benefit not only auto users, but all travelers. As noted in Chapter 1, the management of transportation supply should be integrated with transportation demand management and land use policies.

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Providing Additional Lanes Without Widening the Freeway

Description: Using freeway shoulders as travel lanes has occurred in some cities since the late 1960s, with many of these lanes being devoted to HOV use. These modifications include, 1) using one or more shoulders as travel lanes (this is often done only during peak hours and in the peak direction), and 2) reducing lane widths to provide additional lanes within the existing pavement.

Benefits/Costs: Significant increases in capacity (up to as much as 30 percent and more) are possible. These capacity increases, however, have often been achieved with some increase in accident rates. Thus, the design of such lanes must clearly take into consideration the safety aspects of the particular freeway section. Even though such treatments should be considered temporary, an FHWA staff study found that in cities with populations over one million, almost 32 percent of the urban freeway mileage could experience reduced congestion through such low-cost measures (Federal Highway Administration 1987).

A recent study of freeway shoulder lanes found: (Curren 1995)

- Freeway capacity in excess of 2,200 passenger car per hour per lane were observed at these sites.
- Modified sites have a greater tendency to fall into more congested conditions at high volumes than unmodified sites.
- The range of observed speeds along an unmodified freeway section will be somewhat greater than along a comparable modified section.
- Accident rates at modified freeway sections are somewhat higher than rates for unmodified sections.
- Truck accident rates are almost always higher on modified sections.

Another study examined the northern Virginia I-95 use of shoulder lanes for the entire day (Chen 1995). This 8-mile/1 2.9~km section of Interstate has a left lane designated for 3+ HOV vehicles, two general purpose lanes, and a right shoulder lane which is used as a conventional travel lane. This study concluded:

- The use of shoulder lanes increased freeway capacity significantly. Analysis indicated that removing the shoulder lanes from general purpose use would increase queue lengths by 140 percent and system delays by 929 percent. The HOV and shoulder lanes carried 47 percent of total vehicles and 63 percent of total travelers on the freeway.
- No adverse impacts on general traffic accident frequency was found. Fatality rates were lower than the "before" situation.

Importantly, in keeping with the concern mentioned earlier about safety, several modifications were made in the corridor to maintain operational and enforcement activities. In particular, emergency pullouts were built and signed to allow for safe storage of disabled vehicles.

Costs will normally vary depending on the individual circumstances and the condition of the existing

Modifications to provide additional lanes without widening the freeway include:

I) using one or more shoulders as travel lanes;

2) reducing lane widths to provide additional lanes within the existing pavement.

freeway, but in general, costs per mile will be $1.5 million for construction and engineering, and $12,000 per year for maintenance. Overall, low-cost improvements have the potential of returning a benefit/cost ratio of up to 7:1

The primary advantages and disadvantages in implementing this tool are:

there are no other less-than-standard features; however combined with shoulder width reductions, substandard sight distance, and other features, (these) lanes may not provide the same operation."

This means that when shoulder use is being considered for traffic flow, careful planning and design should occur to avoid any potential safety problems. In addition, structural capacity of a highway varies across the cross section. The shoulder is not often constructed to accommodate traffic loads. Pavement failure and subsequent repair under traffic conditions will have an effect on both capacity and safety. Changes in traffic and operational patterns often have an impact that goes beyond the immediate facility that is being affected. Thus, additional capacity provided in one corridor could very well influence demand on adjacent arterials or on nearby freeways. Such issues must be considered in the

Design Alternative	Advantages	Disadvantages
Use of Left Shoulder	Left shoulder not used as much for emergency stop or emergency enforcement Least expensive if width is available Trucks often restricted from left lane	Usually requires restriping sight distance problem with some median treatments
Use of Right Shoulder	Often the easiest to Implement	Right shoulder is preferred area for emergency stops and enforcement Sight distance changes at merge and diverge areas of ramps
Use of Both Shoulders	Not recommended Use ONLY in extreme cases	Requires restriping Safety concerns Enforcement difficult Incident response longer Manintenance more difficult and expensive

Source current 1995

When shoulder use is being considered for traffic flow careful planning and design should occur to avoid any potential safety problems.

Implementation: Whenever improvements are made to a highway the level of safety should be improved. As noted in (AASHTO 1997):

> "The need to *accommodate* more *traffic within existing or limited additional* right-of-way on *high volume urban* freeways has led some agencies to increase capacity by exchanging full-lane or shoulder widths for additional travel lanes with reduced widths. Any proposed use of less-than-full-atandard cross-sections must be *analyzed carefully on a case-by-case basis. Experience indicates* that 12ft/3.3m lanes can operate safely if

analysis that precedes a decision to use shoulder lanes.

The state transportation agency would most likely plan and design these improvements as a typical highway project, and enter into a construction or lane striping contract in the usual manner. Cooperation and coordination between the state highway agency and the traffic enforcement officials responsible for enforcement (e.g., the state police) is essential. Because the use of breakdown lanes is not consistent with federal design criteria, federal approval will be required if the highway facility is on the federal-aid system.

When this action is being considered, it typically generates opposition from traffic enforcement agencies and motorists who are mainly concerned about safety (i.e., the emergency lane is used for traffic flow rather than by emergency vehicles or breakdowns). Also, there is concern that the flow from entrance ramps will be adversely affected. These are all legitimate concerns which should be addressed. The response to these concerns include the following (AASHTO 1997):

- Where shoulders are converted to travel lanes, removing the left-side shoulder is preferable.
- Where a highway with a narrow median and median barrier is being considered for using the median shoulder for a travel lane, curves should be checked for adequate stopping sight distance.
- Comprehensive incident detection and response systems should be considered for sections with substandard lane and shoulder widths.
- If both shoulders are removed, mitigating measures should include: adequate advisory and regulatory signing, constructing frequent emergency pullouts, active overhead and side-mounted changeable message signs and signals, continuous lighting, truck lane-use restrictions, dedicated service patrols, and continuous enforcement.
- For sections greater than 1.5 kms where inadequate shoulders are provided, emergency pullouts should be considered where feasible.

The state transportation agency would most likely plan and design the improvements as a typical highway project, and enter into a construction or lane striping contract in the usual manner: Cooperation and coordination between the state highway agency and the traffic enforcement officials responsible for enforcement is essential.

Given that the major reason for implementing this action is to increase the vehicle-carrying capacity of a freeway, the planning for this action should consider the likely impact of induced traffic demand that will now be generated on air quality, environmental issues, and eventually on the long-term operation of the freeway.

A complete guide for the implementation of this tool is found in (Current 1995).

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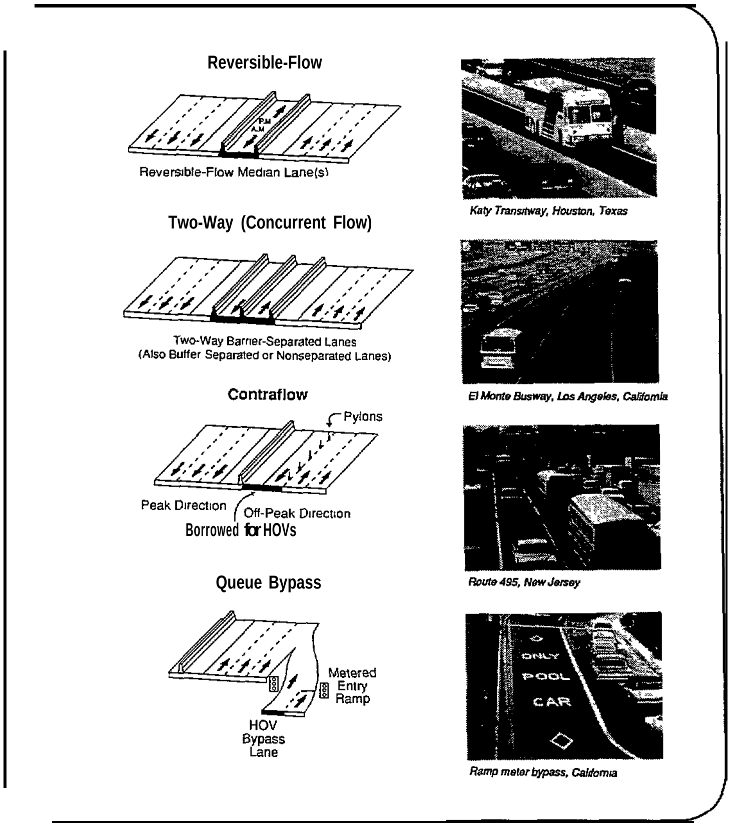
High Occupancy Vehicle (HOV) Facilities

HOV lanes bypass serious congestion points thus decreasing travel times and increasing travel time reliability for HOV lane users which can be a strong Inducement to use transit or ridesharing

Description: An increasingly popular method for increasing the person-carrying capacity of a freeway is to designate some portion of the roadway for use solely by those using high occupancy vehicles (HOVs). HOVs are usually defined as including buses, vanpools, and carpools. HOV lanes bypass serious congestion points thus decreasing travel times and increasing travel time reliability for HOV lane users which can be a strong inducement to use transit or ridesharing. In addition, HOV facilities allow transit operators to provide a more reliable transit service given that buses are not now subject to the unpredictable conditions of freeway operation. Several types of HOV facilities are found in the United States, including: (see Figure 2-8)

Figure 2.8: Freeway HOV Lane Applications



Source. Texas Transportation Institute *1992*

Exclusive HOV Facility, Separate Right-Of-Way. A roadway or lane(s) developed in a separate right-of-way and designated for the exclusive use of high occupancy vehicles (usually defined as vehicles carrying at least two or three persons per vehicle).

Exclusive HOV Facility, Freeway Right-Of-Way. Roadways or lanes built withii the freeway right-of-way that are physically separated from other freeway lanes and are designed for the exclusive use of high occupancy vehicles for some portion of the day.

Concurrent Flow Lane. A freeway lane in the peak direction of travel (commonly the inside lane), not physically separated from the other general traffic lanes, and designated for the exclusive use by high occupancy vehicles during some portion of the day.

Contraflow Lane. A freeway lane (commonly the inside lane) located in the off-peak direction of travel designated for exclusive use by high occupancy vehicles (usually buses only or buses and Vanpools) traveling in the peak direction during some portion of the day. The lane is typically separated from the off-peak direction travel lanes by plastic posts, pylons, or movable concrete barriers.

Benefits/Costs: The primary purpose of HOV facilities is to increase the people-moving (versus vehicle-moving) capacity of a freeway. As shown in Figure 2-9, the results can be quite dramatic. The peak direction, person volumes per lane are substantially higher than comparable non-HOV freeway lanes. The same can be said for average auto occupancy, the number of 2+ Carpools, and the number of bus passengers (Henk, Morris and Christensen 1994). The I-64 HOV lane in Hampton Roads, Virginia is typical of what one sees with the implementation of an HOV lane. The freeway showed an increase of almost 3,000 persons carried with a corresponding decrease of 711 vehicles after the lane was opened in 1992.

The major reason for using an HOV lane often cited in surveys of HOV lane users is improved travel time. Figure 2-10 shows the amount of time saved for different HOV facilities in the United States. These travel time savings have been an important factor in attracting drivers to ridesharing and transit. For example, the following percentage of HOV lane users previously drove alone:

(Who Previously Drove Alone)

	Car Poolers	Bus Riders
I-10, Katy Freeway, Houston	36%	36%
I-394, Twin Cities	43%	
I-395, Northern Virginia	23%	49%
I-45, Houston	39%	39%
I-10, San Bernadino Freeway, Los Angeles	46%	50%

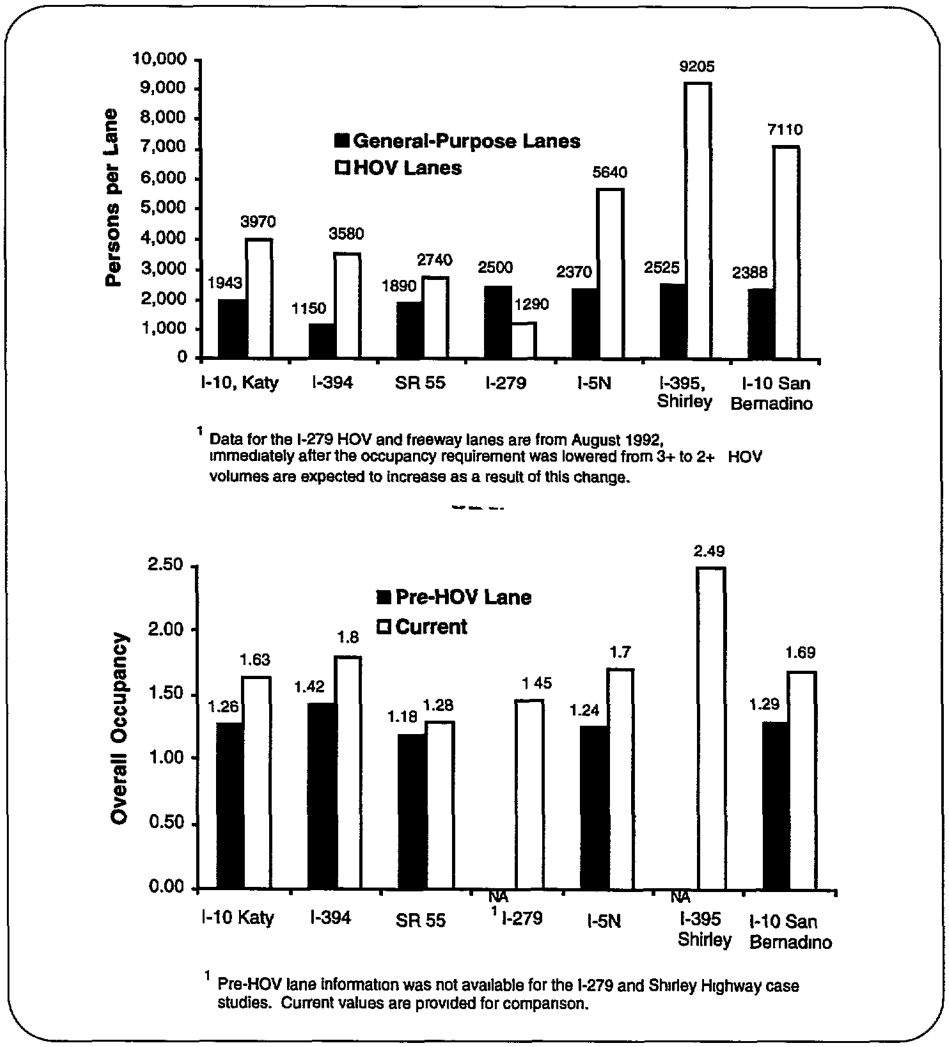
To the extent that HOV lanes can reduce the number of single occupant vehicles on the road, air quality benefits will occur. Some estimates of air quality benefits include a 21 percent reduction in pollutant emissions in the I-395 corridor in Washington D.C.; and a 10 to 20 percent reduction in emissions during the peak hour on the San Bernadino Freeway in Los Angeles.

Improvements in transit operations have also been shown to be significant. In Houston, the peak hour bus operating speeds on the four major freeways with HOV lanes have almost doubled from 26 mph to 54 mph, reducing the revenue bus-hours needed to provide service by 31,000 hours and saving the transit authority approximately $4.8 million annually (Henk, Morris, Christensen 1994). In Pittsburgh, the East Busway has reduced bus travel times by 40 to 50 percent. In Ottawa, Ontario, where a

The major ***reason*** *for using an HOV lane often cited in surveys of HOV* ***lane*** *users is improved travel time.*

Contraflow Lanes for High Occupancy Vehicles

Figure 2.9: Comparison of HOV Lanes With Non-HOV Lanes



[1] Data for the I-279 HOV and freeway lanes are from August 1992, immediately after the occupancy requirement was lowered from 3+ to 2+ HOV volumes are expected to increase as a result of this change.

[1] Pre-HOV lane information was not available for the I-279 and Shirley Highway case studies. Current values are provided for comparison.

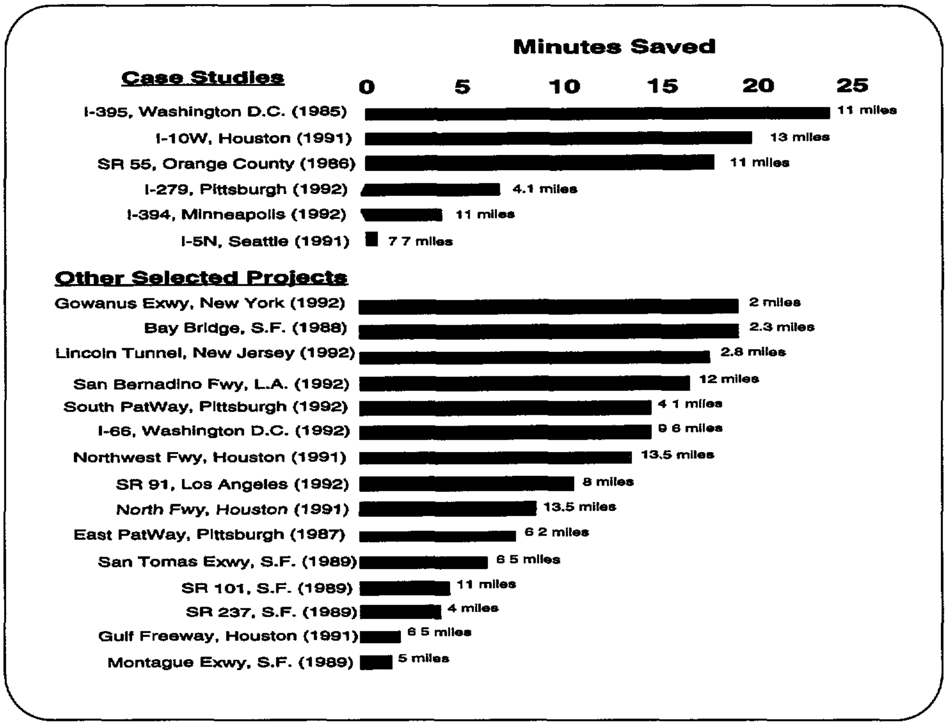
Source Henk et al 1994

comprehensive busway system has been in place since 1986, the transit authority estimates that the transitway system has saved the authority the cost of buying 220 buses and 40 articulated buses that would have been needed to provide comparable service.

Other examples of HOV facilities and their impacts include: (Transportation Research Board 1995)

- There are approximately 70 miles/113 kms of HOV freeway lanes in Los Angeles County. The HOV facilities on average carry 1,250 vehicles per hour and have an average vehicle occupancy of 2.3 persons.
- The Houston transitway system (planned to include 105 miles/169 kms when finished) currently carries over 80,000 riders daily. Bus transit accounts for 40 percent of this volume and carpools/vanpools for the other 60 percent. A comparison of a freeway corridor with an HOV lane to one without showed that the bus ridership was twice as high in the corridor with the transitway.

Figure 2.10: HOV Impact on Time Savings



Source: *Texas Transportation Institute 1992*

- ➤ An HOV lane on I-270 in Maryland has attracted between 400 to 600 vehicles per day. The average travel time on this two-mile segment before the HOV lane was five minutes; after the HOV lane the average travel time was four minutes for the general purpose lanes and two minutes, 17 seconds for the HOV lane.
- ➤ The I-10 and I-5 HOV-only lanes and the State Route 14 mixed HOV/truck bypass lanes in Los Angeles have seen volumes ranging from 2,000 to 2,400 vehicles per peak hour per lane. The overall time savings to HOV users is estimated to be about 20 minutes.
- ➤ A contraflow HOV lane on the Long Island Expressway open to buses, occupied taxis, and authorized vehicles provides service to 130 express buses with over 5,100 riders during the peak hour
- ➤ HOV lanes in Seattle, Minneapolis and Orange County, California showed important contributions to mobility. In Seattle, a poll of residents showed that 85 percent of the respondents had used the HOV lane system with 14 percent using them three to five days a week. In Minneapolis, the I-394 HOV lane has increased the average vehicle occupancy in this corridor from 1.23 to 1.30. Some 1,600 vehicles carrying 4,600 persons use the lane during the morning peak hour. In Orange County, CA, the Route 55 HOV lane had a 1.34 average vehicle occupancy after lane implementation compared to 1.21 before; the I-15 HOV lane in San Diego saw an increase from 1.22 to 1.28 persons per vehicle.

One of the important decisions that must be made early in the HOV lane planning process is the minimum occupancy requirements for those vehicles allowed in the lane. The selection must allow for growth as more commuters choose to switch to ridesharing arrangements to take advantage of the time savings afforded by the lane.

- Two HOV facilities in Hartford, Connecticut have provided a five-minute time savings to express bus users. When a minimum vehicle occupancy requirement was changed from 3+ to 2+ in 1993, lane use increased from 3 15 to 9 13 vehicles.

HOV facilities have been planned, designed and constructed in a three to eight-year time frame. The construction involves well-known highway technology. HOV lanes can be opened as each section is completed thus providing immediate benefits as the entire facility is being finished. The costs of an HOV facility will vary depending upon the type of facility. HOV facilities constructed on separate rights-of-way can cost from $7 to $8 million per lane-mile; barrier-separated facilities constructed in freeway rights-of-way cost from $4 to $6 million per lane-mile; concurrent flow facilities cost from $1 to $2 million per lane-mile; and contraflow lanes cost $0.5 to $1 million per lane-mile (Henk, Poe, and Lomax 1991). The annual operations and enforcement cost will also vary depending on the level of enforcement provided. A study of the Houston HOV lanes, for example, indicated that the annual operating/enforcement cost per HOV lane was between $250,000 and $300,000.

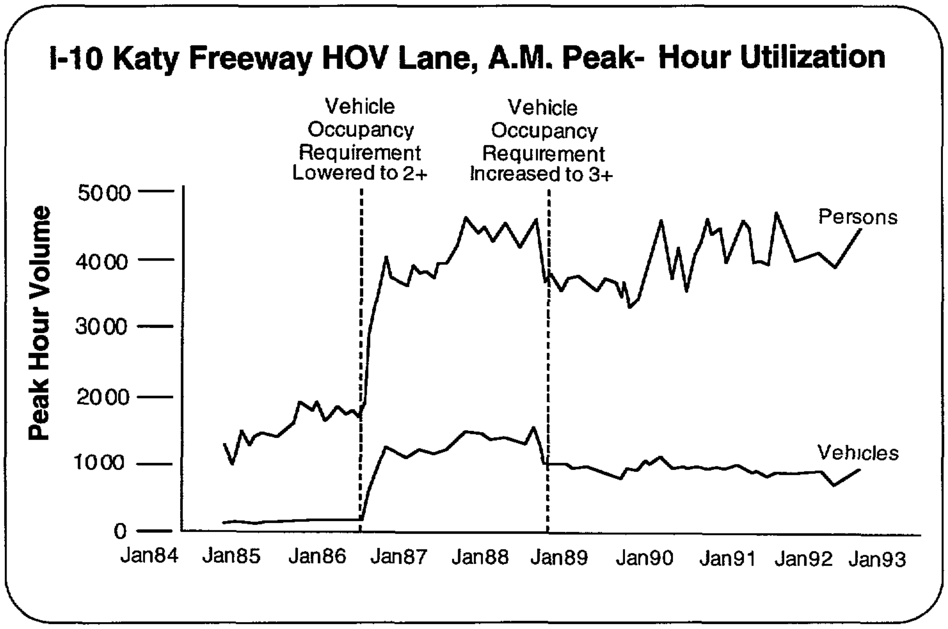
Evaluation of HOV priority lanes has shown that the benefit/cost ratios for such projects are frequently in excess of 6 to 1. Thus, HOV lanes should be considered a very cost effective tool in a region's mobility enhancement program.

Implementation: A recent survey of transportation professionals identified the following concerns in implementing HOV facilities (Tumbull and Capelle 1996).

- Enforcement problems/lack of enforcement
- Converting general purpose lanes to HOV lanes
- 2+ vs. 3+ occupancy requirements/managing demand
- Concern over low utilization levels
- Funding
- Opposition to HOV facilities/lack of political and public acceptance
- Safety issues
- Marketing

As indicated, one of the important decisions that must be made early in the HOV lane planning process is the minimum occupancy requirements for those vehicles allowed in the lane. The selection must allow for growth be more commuters choose to switch to ridesharing arrangements to take advantage of the time savings afforded by the lane. In recent years, a minimum of two persons per vehicle has been the most common occupancy requirement, although a 3+ requirement has also been used. Allowing too small of a minimum occupancy can create excess demand for the facility, thereby negating any time savings and incentives. Figure 2-11 shows the results of lowering the occupancy rate from 3+ to 2+ on the Katy Freeway in Houston and the consequences on the number of vehicles using the lane. In addition to the increase in number of vehicles

Figure 2.11: Impact of Changing HOV Occupancy Requirement in Houston



Source: Turnbull and Capelle 1996

the freeway HOV lane (from about 200 to about 1,200 vehicles), the number of single occupant vehicles also increased (Vuchic et al 1994).

There are several important steps that should be taken to plan and implement HOV lanes which involve many organizations and individuals. Most state transportation agencies having responsibility for freeways in metropolitan areas have design guides which strongly influence the process and ultimate design of an HOV lane [see, for example, (California Department of Transportation 1991)]. The following steps include some of the more important tasks:

1. Planning
   - physical identification and planning the location
   - support facilities, such as fringe parking lots and added bus terminals
   - additional buses required
   - market survey demand analysis
   - induced travel demand and land use impacts
   - air quality impacts
2. Physical Design and Construction of the Facility
   - typical highway design and construction project
3. Operation
   - vehicle occupancy requirement
   - facilities (e.g., buses)
   - enforcement
   - maintenance
4. Marketing and Promotion
   - a major effort is required in order to provide incentives for people to form carpools and vanpools and to utilize express buses.

HOV lanes should be considered a very cost effective tool in a region's mobility enhancement program.

A major innovation in the physical operation of HOV lanes has occurred over the last 10 years with the development of movable barriers. These barriers (which are attached together) are stored at the side of the freeway during off-peak periods and then put in place with a large tractor-type machine that lifts the barriers and places them in predetermined locations while the machine travels down the freeway. This approach is used primarily to create (on a daily basis) a contra flow HOV lane that is physically separated from on-coming traffic. Such systems are found in Boston on I-93 and in Washington D.C. on I-66. They have also been used at locations where limited capacity causes bottlenecks such as bridges.

Most state transportation agencies having responsibilty for freeways In metropolitan areas have design guides which strongly influence the process and ultimate design of an HOV lane.

There are a number of HOV preferential treatments that may be effective in promoting HOV use when implemented as elements of a regional HOV strategy. The following feae tures are very important in planning for a successful HOV facility:

- park and ride lots
- metered ramp by-pass
- preferential parking and pricing
- signal priority
- exclusive access ramps
- turning restrictions
- preferential tolls
- toll preferential lanes
- transit passes

One of the most comprehensive HOV strategies at the metropolitan level is found in Minneapolis/St. Paul. HOV lanes are currently on I-394 and I-35W, with some 55 HOV ramp meter bypasses in operation throughout the metropolitan area. Three parking garages in downtown Minneapolis with direct access to I-394 have been constructed with preference given to HOV users. Remote park-and-ride lots have been constructed and timed transit transfer stations to encourage transit ridership. The metropolitan area has also created a “Team Transit” which identifies low cost enhancements to HOV users (Minnesota DOT 1996). This is the type of comprehensive HOV program that is necessary to produce significant results.

The ITE Traffic Engineering Handbook provides guidelines for the feasibility of different HOV applications on freeways (Institute of Transportation Engineers 1992).

For Separate HOV Facilities: The potential for HOV lanes on controlled access facilities is limited to high-volume urban corridors. Because of the severe right-of-way and construction cost constraints associated with such corridors, consideration of sole-traveled-way HOVs should take place in the planning stage.

- Projected corridor demand during peak periods should indicate potentially serious capacity problems. A heavy peak period directional split of 65-35 percent or 70-30 percent would be typical of such a corridor.

- The corridor should be of sufficient length and should carry a high enough volume of traffic to provide the potential for large time savings to users of the HOV facility. A minimum of 10 minutes time savings is considered significant, with a 15 to 20 minute potential time savings considered desirable.
- Transit bus demand should exist in the corridor.
- HOV lanes on sole-traveled ways should normally be designed with a minimum of two lanes.
- Lane use vehicle occupancy requirements should be carefully considered if an acceptable level of service is to be provided for all users.
- Access to the separate HOV lanes should preferably be restricted to special access ramps from grade-separated roadways.
- In planning and design, maximum operation flexibility should be preserved that will allow changes to the operation of the HOV facility should it become unworkable in practice.

For Concurrent or Contra-Flow HOV Lanes:

- The lane should be physically separated from the remaining freeway lanes.
- Physical modifications to the freeway that reduce lane widths must be approached with extreme caution. Minimum shoulder widths should be maintained.
- Contra-flow priority lanes should be considered only when a considerable flow imbalance prevails during peak traffic periods and if the remaining off-peak direction traffic can flow at an acceptable level of service.
- For safety reasons, contra-flow operations must be at all times clearly and unmistakably identified by opposing traffic.
- Concurrent-flow HOV lanes should be physically separated from the normal lanes by a buffer zone that will safely ensure the desired separation.
- Exclusive connections or bypass ramps should be considered where time savings to the HOV users are greater than the costs when the ramp and through-lane capacities are not adversely affected.

One of the key issues associated with contra-flow or concurrent flow lanes is taking existing highway capacity from general purpose use versus widening the road or restriping the highway lanes to provide additional HOV capacity. Beginning in the mid-1970s with a controversial "take-a-lane" project on the Santa Monica Freeway in Los Angeles, HOV lanes that substantially reduce the vehicle-carrying capacity of the freeway have faced strong opposition from those who argue that such use and impact is unwarranted. For those projects where a "take-a-lane" design is the only feasible alternative or where public policy is designed to

The ITE **Traffic** *Engineering Handbook provides guidelines for the feasibility of different HOV applications on* **freeways.**

restrict automobile use, project implementation should include a comprehensive marketing campaign to influence public attitudes toward the HOV lane. In addition, such an HOV lane might best be implemented during a freeway reconstruction project, or serious consideration be given to allowing non-HOV use of the lane for a price, the so-called high occupancy toll lane or "HOT" lane. Some ITS demonstration projects are doing just this (see Chapter 6).

A comprehensive discussion on the design of HOV lanes is found in (AASHTO 1992).

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Park-and-Ride Facilities

Description: The primary purpose of park-and-ride facilities is to provide a common location for individuals to transfer from a low- to high-occupancy travel mode. In the context of freeway corridor management, such facilities become an important component of efforts to encourage HOV use. There are three major types of park-and-ride facilities: (AASHTO 1992)

Remote Park-and-Ride: Facilities that provide a change-of-mode service from a suburban or satellite community to another suburb, a major employment site, central business district (CBD), or major activity center via an established parking facility with express transit service to the destination.

Local Service Park-and-Ride: Facilities located along a local bus route that is served by nonexpress, local transit operations. Demand for these facilities is much smaller than that for remote lots.

Peripheral Park-and-Ride: Located at the edge of the CBD, these facilities are intended to intercept automobiles before they enter congested city streets or downtown areas. The feasibility of these lots depends greatly on the pricing and limited availability of parking in the downtown area.

Users of park-and-ride facilities are very sensitive to the time costs of making a transfer, and thus facility design must be convenient, easily used and safe. Park-and-ride facilities can be built exclusively for such use, or they can be part of some other activity, so-called "shared-use" facilities. Portions of shopping center, church, or school parking lots can be devoted to park-and-ride users by negotiating agreements with the owners of these lots. In addition, park-and-ride facilities should facilitate access to HOV use for non-motorized modes of transportation (e.g., bicycle and walking) where such access modes are likely to be used.

Benefits/Costs: The benefits of park-and-ride facilities relate to user cost and travel time savings, more effective congestion management, lower demand for parking spaces in congested areas, reduced energy consumption and vehicular emissions, enhanced mobility, and improved efficiency of the transit system (Tumbulll995). In almost all cases, the benefits of park-and-ride facilities are tied to those related to transit use (described in Chapter 4). A 1986 study of 305 park-and-ride lots found that the previous mode of work travel for those now using park-and-ride lots in conjunction with some form of HOV use ranged from 11 to 65 percent who drove alone (with an average across all lots of 49 percent); from 5 to 28 percent (with an average of 23 percent) who carpooled; from 5 to 49 percent (with an average of 10 percent) who used transit; and from 0 to 29 percent (with an average of 15 percent) who did not previously make the trip (Bowler et al 1986). Encouraging the use of nonmotorized modes for accessing the park-and-ride lot would further augment the congestion relief and mobility enhancement benefits of these facilities (Replogle and Parcells 1992).

The primary purpose of park-and ride facilities IS to provide a common location for individuals to transfer from a low- to high-occupancy travel mode.

Perhaps the only benefit of formal park-and-ride facilities that is not related directly to the use of alternative modes is the experience in many urban areas of ad hoc parking occurring on highway shoulders or at other nearby locations. Such “informal” parking can create a hazardous traffic situation. Developing park-and-ride facilities can thus provide safety benefits at these locations.

The costs of providing park-and-ride facilities will vary significantly by the type of facility. Shared ride facilities where no additional major capital investment is necessary could be put in place simply through highway signing and pavement marking, with a fee or liability insurance paid by the lot operator. Larger scale lots often built in conjunction with the construction of new interchanges or transit lines could cost significantly more, with the most expensive lots being those that provide parking structures adjacent to major transit lines. Costs can range from $400,000 to $4.$5 million depending on the circumstances.

Users of park-and-ride facilities are very sensitive to the time costs of making a transfer, and thus facility design must be convenient, easily used and safe.

Implementation: The most important considerations in locating park-and-ride facilities include: (Tumbull 1995)

- Locate park-and-ride facilities in congested travel corridors where modal transfer clearly will be perceived by users as having substantial time savings.
- Locate park-and-ride facilities in advance of areas experiencing major traffic congestion which would provide a more convenient and comfortable modal transfer.
- Locate park-and-ride facilities in areas with high levels of travel demand to a major activity center or centers served by the facility.
- Include preferential transit services, either rail or HOV lanes, to enhance park-and-ride facility usage.
- Locate park-and-ride facilities so that commuters do not have to backtrack to reach the lot.
- Orient park-and-ride facilities to ensure good accessibility and visibility to increase awareness of the lots.
- Locate park-and-ride facilities at appropriate distances from one another so that the market service areas do not overlap.
- Consider partnerships to include private services at or near park-and-ride lots.
- Encourage cooperation among agencies in developing, operating, serving, and enforcing park-and-ride facilities.

This latter point is critical. Although there are many successful park-and-ride lots in the United States that only provide the ability to transfer from an automobile to carpools or vanpools, the most successful lots provide some form of direct access to high-speed transit services. In addition, a police presence is important in promoting a safe and secure environment for leaving a car. Planning park-and-ride facilities must therefore include the participation of a large number of agencies and groups; at a minimum, state and local transportation agencies, transit providers, enforcement agencies, local governments, citizens, and the media.

In those cases where existing parking lots are going to be leased for park-and-ride use, agreements must be developed that cover such things as: what types of improvements will be made and by whom? who will perform maintenance? what types of liability insurance are necessary and who will provide it? who will be allowed to use the site?, and other legal issues relating to public use of private property- In addition, lease arrangements often deal with how the spaces will be delineated, how to keep shoppers out of transit spaces, how to handle excess transit parkers who overflow into shopping center parking spaces, and the reduction in parking requirements for the shopping center if spaces are leased for transit purposes.

Intelligent transportation systems (ITS) technologies can play an important role in the operation of park-and-ride facilities. ITS technologies could provide pre-trip and enroute real-time information to commuters on the conditions being faced in the travel corridor and at park-and-ride facilities. In-vehicle navigational aids could guide travelers to parking lots. In addition, travel kiosks at these facilities could provide information on available travel options or on the schedule/likely arrival of the next bus/train.

▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪ ▪

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A pricing strategy for a region's road system would Include charging a premium to motorist who wish to drive during peak travel periods by using tolls, fees for congested areas, or surcharges to parking prices

Highway Pricing Strategies

Description: A pricing strategy for a region's road system would include charging a premium to motorists who wish to drive during peak travel periods by using tolls, fees for congested areas, or surcharges to parking prices. The travel impact of such pricing schemes could vary widely. Travelers could change routes to untolled roads, change time-of-day of travel to avoid tolls, switch transportation modes, change destinations for those trip purposes where such is possible, combine more errands on one trip (so-called trip chaining), telecommute, and in the long run even reduce the number of autos owned. One of the major advances in road pricing is the advent of electronic toll collection (ETC) systems. Tags or smart cards located in a vehicle are "read" electronically as it passes a sensor at a tollgate. A computer deducts the amount of toll from the driver's prepaid tag or is billed monthly. Studies have indicated that ETC can increase conventional toll plaza lane capacity by 50 to 150 percent while permitting free-flow speeds of up to 55 miles per hour. Some issues associated with ETC implementation include using prepayment versus post-payment purchasing schemes, privacy issues associated with the use of ETC collected data, costs and legislative requirements for some types of enforcement (e.g., photos of license plates), and the overall enforcement strategy of ETC-equipped lanes.

Benefits/Costs: Pricing strategies are discussed in great detail in Chapter 5-Managing *Transportation Demand.*

Implementation: The reader is referred to chapter five for further description.

All of the tools described so far have been discussed in light of their application to freeways (except in the section on freeway corridor traffic management). The following sections focus on those tools that are primarily applied to urban arterials

ARTERIALS AND LOCAL STREETS: DESIGN

In 1993, approximately 41 percent of all annual vehicle miles of travel in the United States were on urban arterials (non-freeway) and local streets. Improving travel flow on these roads could thus be an effective means of improving urban mobility. For example, there are approximately 240,000 traffic signals in the United States of which about 54 percent (130,000) are interconnected in traffic signal systems (Henk, Poe, and Lomax 1991). These signalized intersections, together with other improvements on the arterial street system, provide significant opportunities for increasing capacity and making better use of existing arterials without major new construction.

The following sections briefly describe the available procedures that should be considered from the perspective of roadway design.

Super Street Arterials

Description: Super street arterials are wide, multi-laned arterials with limited access provided from intersecting streets. To the degree possible, major intersecting streets are grade-separated in order to minimize the need for traffic signals. Super streets take full advantage of as many traffic operations improvements as possible, including:

- traffic channeliiation
- grade separations
- street widening
- reversible traffic lanes
- intersection widening
- railroadgrade separations
- leftlright turn lanes
- improved traffic control devices
- two-way turn lanes
- removal of parking
- turn prohibitions
- lighting improvements
- one-way streets
- bus turnout bays

These measures generally provide spot or localized reductions in congestion.

Benefits/Costs: Implementation of super arterial streets is similar in concept to the reconstruction and expansion of freeways to increase capacity and to improve traffic flow. However, super arterial streets provide even greater increases in capacity. This approach is beneficial for those suburban highway systems that are based upon arterial networks that will not accommodate freeway facilities. Converting a typical suburban arterial with signalized intersections to a super street could increase capacity by as much as 50 to 70 percent, while the same time significantly reducing delays when at-grade intersections are replaced with grade separations. In addition, accidents have been reduced by up to 20 percent. The cost per mile is estimated to be between $3 and $4 million, resulting in benefit/cost ratios between 2:l and 4:l (Urbanik et al 1990).

Implementation: The design, construction, and operation of a super street arterial will be undertaken by the agency having the administrative jurisdiction for the arterial in question. The design and construction of such a facility will likely be expensive and time-consuming, as it is treated in the same way as any large highway construction project. It is thus not a quick solution to recurring congestion. There are several important constraints that must be addressed in considering this type of improvement, including land acquisition, opposition from abutting land owners, access to existing and future land parcels, and environmental problems (such as wetlands). Importantly, for those areas not in compliance with air quality standards, addition of super arterial capacity will be subject to conformity review to show that additional road capacity will not further deteriorate the quality of the region's air.

implementation of super arterial streets is beneficial for those suburban highway systems that are based upon arterial networks that will not accommodate freeway facilities.

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Intersection Improvements

Intersections often can be designed or redesigned to improve the flow of vehicles and to assure the safe passage of pedestrians and bicycles. The use of traffic control devices such as stop and yield signs can provide significant Improvements in capacity and safety

Description: Intersections often can be designed or redesigned to improve the flow of vehicles and to assure the safe passage of pedestrians and bicycles. Not only will such a design provide better geometries, but the use of traffic control devices such as stop and yield signs can provide significant improvements in capacity and safety. As noted in the section on bicycle and pedestrian networks on page 104, however, not all intersection improvements might be made to facilitate the movement of vehicles. Traffic calming techniques that include intersection modifications are designed to lower the speed of motor vehicles and facilitate the movement of pedestrians and bicycles. Therefore, intersection improvements must be considered from a broad perspective on what a community wants to achieve in enhancing mobility and accessibility.

Benefits/Costs: The costs associated with planning and implementing this technique are modest, and vary depending upon the complexity and the extent of the improvement. The benefits, however, are possibly substantial due to the reduction in traffic conflicts between different vehicle flows and between pedestrians/bicycles and vehicles. There are no readily available data to define the specific costs and benefits of intersection improvements, because there is such a wide range of circumstances that are appropriate for this action.

Implementation: In designing and improving arterial intersections that are at-grade, 11 principles have been established by the Institute of Transportation Engineers (ITE) that should be incorporated wherever possible (Institute of Transportation Engineers 1992; Neuman 1985) They are:

1. Reduce the number of conflict points among vehicular movements.
2. Control the relative speed of vehicles both entering/leaving an intersection.
3. Coordinate the type of traffic control devices used (such as stop signs or traffic signals) with the volume of traffic using an intersection.
4. Select the proper type of intersection to serve the volume of traffic being served. Low volumes can be served with no controls, whereas high levels of traffic may require more expensive and sophisticated treatments such as turning lanes or even at grade separation structures.
5. When traffic volumes are high, separate right turn and/or left turn lanes may be required.
6. Avoid multiple and compound merging and diverging maneuvers. Multiple merging or diverging requires complex driver decisions and creates additional conflicts.
7. Separate conflict points. Intersection hazards and delays are increased when intersection maneuver areas are too close together or when they overlap. These conflicts may be separated to provide drivers with sufficient time (and distance) between successive maneuvers.

8. Favor the heaviest and fastest flows. The heaviest anapplicabled fastest flows should be given preference in intersection design to minimize hazard and delay.

9. Reduce area of conflict. Large intersections cause driver confusion and inefficient operations. When intersections have excessive areas of conflict, use channelization.

10. Segregate nonhomogeneous flows. Separate lanes should be provided where there are volumes of traffic traveling at different speeds. For example, separate turning lanes should be provided for turning vehicles.

- Design for access by pedestrians and bicyclists. For example, when there are pedestrians crossing wide streets, refuge islands should be provided so that a large number of travel lanes have to be crossed at a time (see section on pedestrian and bicycle networks).

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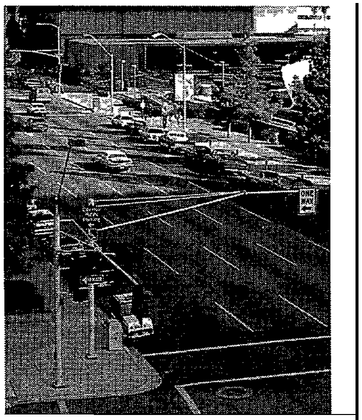
One-Way Streets

Description: Although most streets and highways are designed for use by two-way traffic, high volumes of traffic and vehicle conflicts often lead to consideration of one-way traffic regulations. In major activity centers, such as the central business districts of cities with large traffic volumes and closely spaced intersections, one-way traffic regulations are frequently used because of traffic signal timing considerations and of limited availability of other options to improve street capacity. In the development of new activity centers such as shopping centers, sports arenas, industrial parks, and so on, one-way regulations are frequently incorporated into original street and traffic plans.

In major activity center, such as the central business districts of cities with large traffic volumes and closely spaced intersections, one-way traffic regulations are frequently used

One-way streets are generally operated in one of three ways:

- A street on which traffic moves in one direction at all times.
- A street that is normally one-way, but at certain times may be operated in the reverse direction to provide additional capacity in the predominant direction of flow.
- A street that normally carries two-way traffic, but which during peak traffic hours may be operated as a one-way street usually in the heavier direction of flow. Such a street may be operated in one direction during the morning peak hour and in the opposite direction during the evening peak hour, with two-way traffic during all other hours.



One-Way Street

Benefits/Costs: One-way streets can provid increase capacit or facilitate multimodal improvements as they (Institut of Transportation Engineer 1992)

- Reduce intersection delay caused by vehicle turning-movement conflicts and pedestrian-vehicle conflicts.
- Allow lane-width adjustments that increase the capacity of existing lanes, or provide an additional lane for motor traffic bicycles, or parking.
- Permit improvements in public transit operations such as routings without turnback loops (out on one street and return on the parallel streets).

One-way streets could result /n improved safety as they reduce vehicle-pedestnan and vehicle-vehicle conflrcts at intersections. However, they may also lead to safety problems as they may increase average traffic speeds and lead to wider pedestrian roadway crossings.

- Permit turns from more than one lane and doing so at more intersections than would be possible with two-way operation.
- Redistribute traffic to relieve congestiono on adjacent streets.
- Simplify traffic signal timing by:
    - Permitting improved progressive movement of traffic.
    - Reducing multiphase signal requirements by making minor street one-way away from complex areas or intersections.

The benefits of one-way streets are mixed They could result in improved safety as they reduce vehicle-pedestrian and vehicle-vehicle conflicts at intersection, prevent pedestrian entrapment between opposing traffic streams, and improve a driver's field of vision at intersection approaches. However, they may also lead to safety problems as they may increase average traffic speeds and lead to wider pedestrian roadway crossings One-way streets could also result in more cost-effective operation as they provide additional capacity to satisfy traffic requirements for a substantial period of time without large capital expenditures. And they could also meet other community objectives as they save sidewalks, trees and other valuable frontage assets that could otherwise be lost because of the widening of existing two-way streets. However there is a possible adverse impact on some businesses and commerce in general when one-way streets are initiated.

Implementation: The amount of data to be collected and analyzed in planning for one traffic regulation will depend largely on the size and complexity of the one-way system under donsideration. As a general rule two-way streets should be made one-way only when:

- It can be shown that a specific traffic problem will be alleviated or the overall efficiency of the transportation system will be improved.
- One-way operation is more desdirable and cost-effective than alternative solutions.

- Parallel streets of suitable capacity, preferably not more than a block apart, are available or can be constructed.
- Such streets provide adequate traffic service to the area traversed and carry traffic through and beyond the congested area.
- Safe transition to two-way operation can be provided at the end points of the one-way sections.
- Proper transit service can be maintained.
- The effect on businesses and access to community centers is known and mitigation provided for.
- The impact on nonmotorized transportation is minimal.

One-way streets are sometimes introduced as part of a major detour scheme that is made permanent after the project is constructed.

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Reversible Traffic Lanes

Description Arterial routes that are normally operated as two-way streets, particularly those in urban areas, can experience much greater peak-hour traffic volumes in one direction than in the other. With the reversible lane system, one or more lanes are designated for movement one-way during part of the day and in the opposite direction during another part of the day. On a three-lane road, for example, the center lane might normally operate as a two-way left-turn lane, but during the peak hour operate in the direction of greater flow. One of the outstanding examples of multiple reversible lanes is the eight-lane Cuter Drive in Chicago, which operates a 6-2 lane split during peak traffic periods. The purpose of the reversible lane system is to provide an extra lane or lanes for use by the dominant direction of flow. Two increasingly used methods are to reverse the flow of an entire street during peak-hour periods or to make a two-way street operate one-way during that period.

Benefits/Costs A reversible-lane system is one of the most efficient methods of increasing rush-period capacity of existing streets (Institute of Transportation Engineers 1992). With minimal capital costs, it takes advantage of unused capacity in the direction of lighter traffic flow by making one or more of those lanes available to the heavier traffic flow. The result is that all lanes are better used. The system is particularly effective on bridges and in tunnels, where the cost to provide additional capacity would be high and perhaps impossible. Some disadvantages are:

- Capacity is reduced for minor flows during peak periods.
- Reversible lanes frequently create operational problems at their termini.

With the reversible lane system, one or more lanes are designated for movement one-way during part of the day and In the opposite direction during another part of the day.

- Concentrated enforcement *efforts* may be needed to prevent violations of the lane-use regulations.

Implementation Several factors should be considered in determining whether reversible lanes are justified:

Evidence of congestion. If the level of service during certain periods decreases to a point that it is evident that traffic demand is in excess of actual capacity, the possibility of using reversible lanes should be considered.

A reversible-lane system is one of the most efficient methods of increasing rush-period capacity of existing streets.

Time of congestion. The periods during which congestion occurs should be periodic and predictable. Traffic lanes can usually only be reversed at a fixed time each day.

Ratio of directional traffic volumes. Lane reversal requires that the additional capacity for the heavier direction be taken from the traffic moving in the opposite direction. Traffic counts by lane will determine whether the number of lanes in one direction can be reduced, how many lanes should be allocated to each direction, and when the reversal should begin and end. On major streets, there should be at least two lanes for traffic flowing in the minor direction.

Capacity at access points. There must be adequate capacity at end points of the reversible-lane system, with an easy transition of vehicles between the normal and reversed-lane conditions. Installation of a reversible-lane system with sufficient end-point capacity may simply aggravate or relocate the congestion problem.

Once a reversible system is deemed necessary and feasible, the method of designating lanes to be reversed and the direction of flow must be selected. Three general methods are used: 1) special traffic signals suspended over each lane, 2) permanent signs advising motorist of the changes in traffic regulations and the hours they are in effect, and 3) physical barriers, such as traffic cones, signs on portable pedestals, and movable barriers (see discussion in HOV section).

Although reversible-lane operation is principally used on existing streets and roadways, it can also be designed into new streets, freeways/expressways, bridges, and tunnels. Applications to older limited-access facilities is difficult because most such roadways have fixed medians separating the two directions of traffic. By constructing special median crossing locations and by properly using traffic control devices, however, even these facilities can be used in a reversible manner. Obviously, extreme care must be exercised to maintain safe operation. Another possible application is the use of movable barriers (see HOV discussion).

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Institute of Transportation Engineers. 1992. Traffic Engineetirrg Handbook, Fourth Edition, Washington D.C.

Arterial Access Management

Description: In a general sense, access management is the control of the spacing, location, and design of driveways, medians/median openings, intersections, traffic signals, and freeway interchanges. Access management elements often include one or more of the following:

- physically restricting left turns
- restricting curb cuts and direct access driveways
- separating obvious conflict areas
- eliminating parking
- locating intersections at no less than minimum intervals
- constructing frontage roads to collect local business traffic and fimneling it to nearby intersections

The importance of access management is seen in the following statistics. Fifty-two percent of all accidents in Colorado were access-related; 32 percent of all fatalities. In Oklahoma, 57 percent of the accidents are access-related; in Michigan 55 percent. Better managing arterial access could thus provide significant safety benefits to a community.

A good example of the role that corridor access management can have is found in a corridor plan for a major thoroughfare in suburban Detroit. The access management plan for this corridor was intended to meet the following goals: (Michigan DOT 1995)

- Discourage commercial development along the corridor where lot depth is inadequate to provide turning truck movements
- Discourage additional commercial sprawl and strip development
- Assess the traffic impacts of all proposed developments
- Minimize conflicts between local and through traffic by regulating land uses, building setbacks, driveway openings, and front or rear service drives
- Provide efficient accessibility to retail uses to minimize traffic conflicts
- Establish driveway location and spacing standards such as distance from intersections, joint use of driveways, spacing of driveways to avoid conflicts, etc.
- Incorporate access management concepts into zoning and subdivision regulations

Another example of access management that includes a variety of recommended actions is found in Penfield, a suburb of Rochester, New York (New York State DOT 1996). The different types of actions found in this program are:

Access Management Changes

- Driveway consolidation and sharing
- Driveway spacing and design
- Comer clearance spacing
- Parking consolidation and access
- Alternative parking requirements

Land Use Modifications

- Conditional land uses
- Front setback reductions
- Density and intensity incentives
- Buffers and lot coverage

Access management is the control of the spacing, location, **and** *design of driveways, medians/ median openings, intersections, traffic signals, and freeway interchanges.*

The major benefit of access management occurs with the resulting reduction in accidents.

- Dimensional requirements
- Landscaping
- Use limitations for corner properties

Transportation Improvements

- Raised medians
- Access roads
- Right turn lanes
- Signal location and timing
- Directional signage modifications

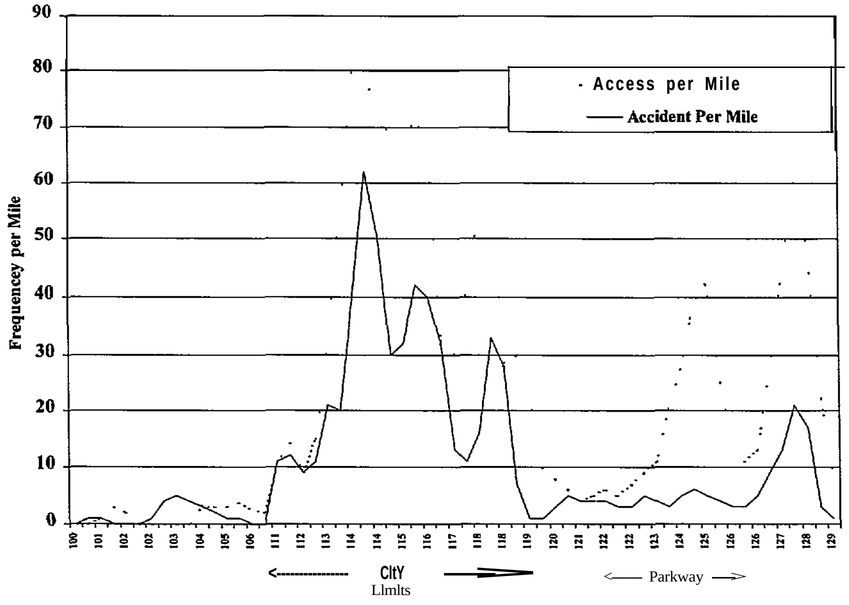
Capital improvements

- Project betterments
- Developer agreements/ mitigation
- Mitigation fees within zone

Benefits/Costs The major benefit of access management occurs with the resulting reduction in accidents. Figure 2-12 shows the relationship between accident rates and the number of curb cuts per mile as determined in two studies (La11 et al 1995; Gluck et al 1996). Figure 2-13 shows the results when median openings are closed. Without an access management program along arterial highways, capital investment for roadway improvements and/or relocation is often required. This cycle relates to satisfying traffic demands that are often a result of increased business activity, which is influenced by improved traffic conditions, which leads to further traffic demands. The number of conflict points among vehicles rises as a result of an increasing number of driveways, causing the capacity at a specific level of service to diminish. Vehicle delay increases, and safety and comfort are reduced.

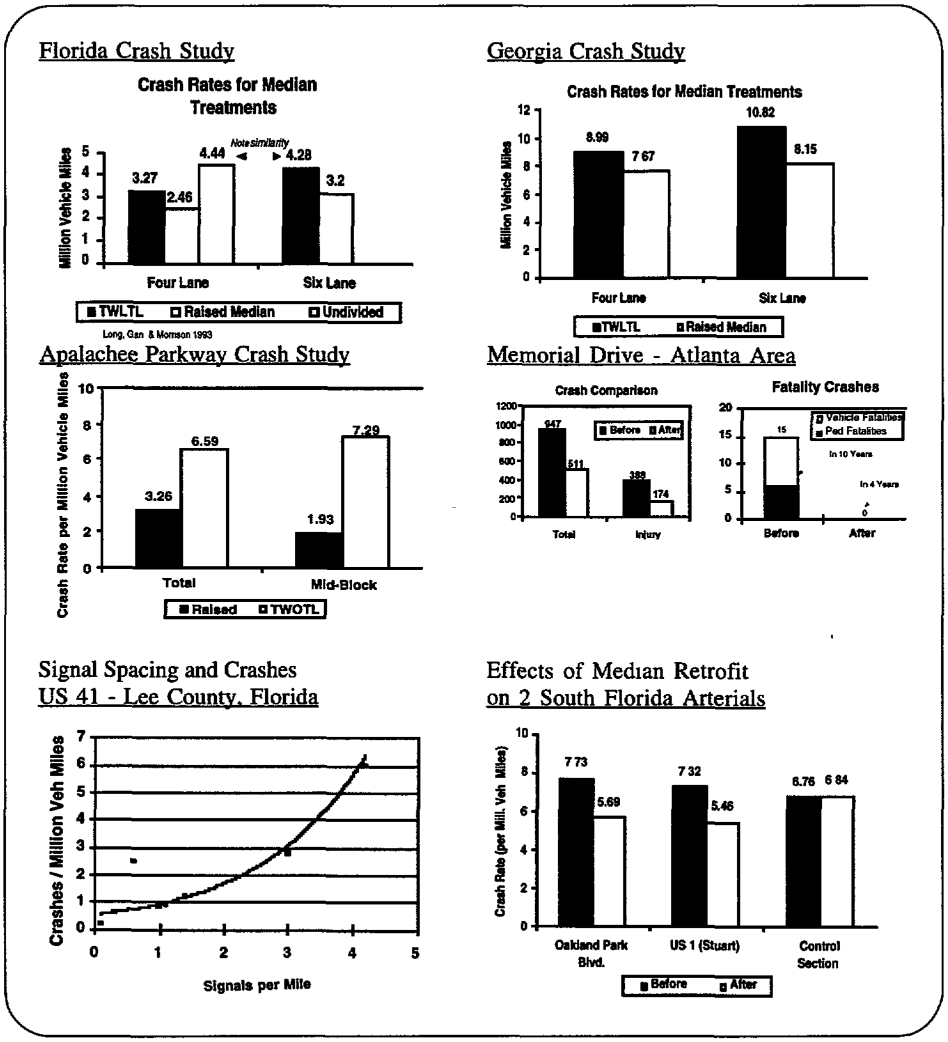
One of the potential consequences of closing medians or not allowing multiple driveways is the negative impact on businesses that are adjacent to the arterial. Several studies have shown that, depending on how access management is implemented, these losses can vary. In one Florida DOT district, for example, 63 percent

Figure 2.12: Accident Rates and Number of Curb Cuts Per Mile



Source. *Lall* et al 1995

Figure 2.13: Effect of Access Management on Accidents



Source: Florida DOT undated

Corridor analyses that assess future demands on the capacity of freeway and parallel arterials and that evaluate major development proposals provide essential information to decision makers.

of businesses along several median controlled arterials saw no loss in business when the medians were closed; 13 percent reported large losses. In another district, 31 percent said that the median closings caused a major impact, 31 percent reported a minor impact and 38 percent said there was no impact.

Implementation: As noted in (Williams and Foster, 1996), "access management is also a congestion management tool, and prevention of excessive congestion has been viewed by the courts as falling within the legitimate purview of police power." Controlling or managing access along arterial highways, however, is perhaps one of the most difficult tasks facing local officials and transportation engineers. This difficulty comes from a time-honored tradition and, in some cases, a legal right for land owners abutting a road to have access to their land. In addition, the process for land development decisions is often very different from that for transportation system planning. There is often very little, if any, coordination between the different decision-making bodies, yet decisions by any one of them can have a significant impact on the region. One approach for providing this coordination is to undertake a corridor-level planning study. Corridor analyses that assess future demands on the capacity of freeway and parallel arterials and that evaluate major development proposals provide essential information to decision makers (Koepke and Levinson 1992).

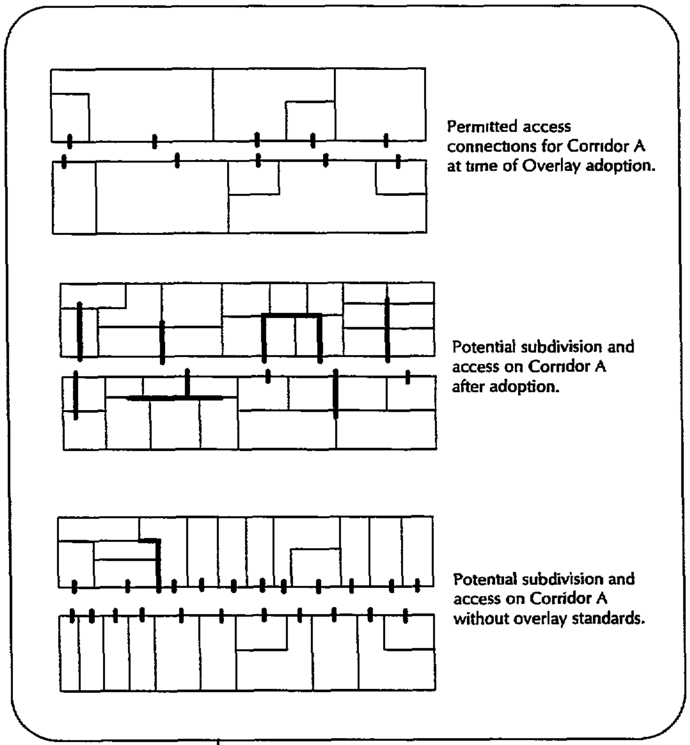
Perhaps the most important strategy for local officials is to incorporate access management principles into land use development decisions.

Many states and communities have recently begun a comprehensive examination of what is necessary to implement an access management program. Perhaps the most important strategy for local officials is to incorporate access management principles into land use development decisions. Regulatory techniques that support access management include: (Florida DOT 1994)

- Regulate driveway spacing, sight distance and corner clearance
- Restrict number of driveways per existing parcel on developing corridors
- Increase minimum lot frontage along thoroughfares
- Encourage joint access and parking lot cross access
- Review lot splits to prevent access problems
- Regulate flat lots and lot width-to-depth
- Minimize commercial strip zoning and promote mixed use and flexible zoning
- Regulate private roads and require maintenance agreements
- Establish reverse frontage requirements for subdivision and residential lots
- Require measurement of building setbacks from future right-of-way line
- Promote unified circulation and parking plan

One of the means of implementing access management is by overlaying additional development requirements for specific areas (such as an arterial corridor) that add extra constraints on what is permissible in terms of access (see Figure 2-14). In addition, states and local communities should adopt an access classification system that provides developers with clear guidance on allowable access characteristics. Table 2.3 shows an example of such an access classification scheme from Florida.

Figure 2.14: Access Management Overlay District



Source Florida DOT 1994

Site access studies are also an essential part of access management programs. "Site access study" is a term used by transportation/land use planners and traffic engineers to describe an evaluation of how trips generated by new or changing land uses will be served by an existing or future transportation network. The narrower term "traffic impact study" emphasizes the effect of site generated traffic on the road network. A site access study involves technical analyses applied to a distinct study area, which may range from one or two key intersections to the entire transportation network within a mile or several miles of the site. Site access studies are performed both for private developers and public agencies, and may be funded by the developer, the public agency, or even a third party seeking an independent opinion. Sometimes local governments authorize and pay for the study, but require reimbursement from the developer.

An important element of effective access management is linking the type of action to the level of development in the corridor. As noted in (NYSDOT 1995), "in lightly developed areas land-use tools are highly effective in preempting future traffic problems at relatively low cost; particularly minimum spacing and design standards for driveways, alternative access, limiting the number of driveways and provisions for future parking interconnections. As the level of development intensifies, the application of other tools becomes important. Medians, turn restrictions, shared driveways, improved parking circulation, and interconnected parking can be applied to compliment driveway spacing and design standards."

"Site access study" is a term to describe an evaluation of how trips generated by new or changing land uses will be served by an existing or future transportation network. The narrower term "traffic impact study" emphasizes the effect of site generated traffic on the road network.

More detailed information on the characteristics of successful implementation of access management can be found in (Federal Highway Administration 1993).

Table 2.3: Access Classification Scheme In Florida

Functional Class	Access Class	Medians**	Connecting Spacing (feet)		Median OpenSpacing		Signal Spacing
			>45 mph	≤45 mph	directional	full	
Arterials	2	Restrictive w/Service Roads	1320	660	1320	2640	2640
	3	Restrictive	660	440	1320	2640	2640
	4	Non-Restrictive	660	440	▨	▨	2640
Collectors	5	Restrictive	440	245	660	2640/ 1320	2640/ 1320
	6	Non-Restrictive	440	245	▨	▨	1320
Arterials, Collectors, Residential Collectors	7	Both Median Types	125		330	660	1320

Source. Florida DOT 1994

*For roads with posted speed limits ≥ 45mph.

**A "Restrictive" median physically prevents vehicle crossing A "Non-Restrictive" median allows turns across any point

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Traffic Calming and Street Space Management

Traffic calming is a concept that seeks a more harmonious relationship between vehicular traffic and people.

Description: Traffic calming is a concept that seeks a more harmonious relationship between vehicular traffic and people. The definition of traffic calming according to the Institute of Transportation Engineers is as follows: Traffic calming is the combination of mainly *physical* measures that *reduce the negative effects of motor vehicle use,* alter driver behavior and *impose conditions for non-motorized street users* (Lockwood 1997). Comprehensive traffic calming strategies consist of a variety of techniques designed to reallocate trips, either by mode or route, occurring within an urban or suburban street network. Within the United States, traffic calming measures are more focused towards lowering vehicle speeds and reducing traffic volumes, most often with physical or operational changes to the streets themselves (Institute of Transportation Engineers 1993).

With lower speeds and vehicular volumes, the area's living environment becomes more hospitable to residents, pedestrians, and bicyclists. For example, the traffic calming steps that are being considered in Albany, New York include: (Capital District Transportation Commission 1995)

- high visibility crosswalks
- allowing on-street parking
- providing bike lanes
- reducing curb radii at intersections
- lower speed limits
- limiting/prohibiting right turns on red
- sidewalk extensions (both maintaining and reducing number of lanes)
- pavement narrowing (both maintaining and reducing number of lanes)
- speed bumps/tables
- stop signs/all-way stops
- diagonal diverters at intersections (eliminates through movements)
- street closures

In West Palm Beach, Florida, traffic calming actions have been classified into four major groups: (City of West Palm Beach 1996)

Actions Most Effective For Reducing Speeding

- Narrowing the street (choke points)
- Angled slow points (chicanes)
- Bulbouts at intersections
- Roundabouts (or traffic circles)
- Yield points, midblock and intersection
- Speed humps (or speed tables)

Actions Most Effective In Reducing Cut-Through Traffic

- Diagonal road closure (intersection diverters)
- Forced turn barriers
- Partial road closures
- One-way streets
- Rebuild street with reduced pavement width
- Gateways (perimeter treatments)
- Roundabouts (or traffic circles)

Actions Providing the Best Landscape Opportunities

- Roundabouts (or traffic circles)
- Gateways (perimeter treatments)
- Narrowing the street (choke points)
- Angled slow points (chicanes)
- Bulbouts at intersections
- Mid-block single lane points

Low-Cost, Immediate Actions

- STOP signs
- On-street parking
- Turning movement restrictions
- Speed humps

Traffic Circle or Roundabout with Curb Extem-tons

The basic concepts inherent in traffic calming and street space management have been discussed for many years by planners and urban designers [see, for example, (Moudon 1987; Appleyard 1981; Buchanan 1963)]. Recently, traffic calming has received renewed attention in the context of environmental quality and the quality of life in a community (Johnson 1993; Carlson 1995). In addition, traffic calming techniques in the context of neo-traditional neighborhood design have begun to receive serious attention by traffic engineers (Lemer-Lam et al 1992). Issues that must be addressed in the engineering of traffic calming include design speed, use of alleys, intersection geometry, street trees and landscaping, street lighting, sidewalk width and location, building setbacks, superelevation, construction centerline of roads, and trip generation.

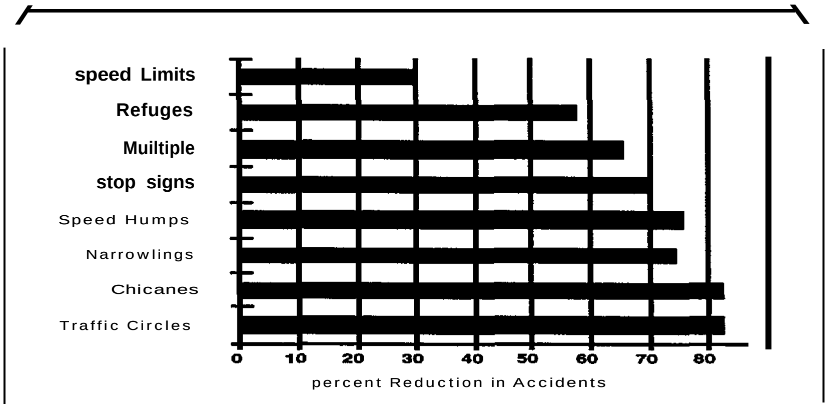
Issues that must be addressed in the engineering of traffic calming include design speed, use of alleys, intersection geometry street trees and landscaping, street lighting, sidewalk width and location, building setbacks, superelevation, construction centerline of roads, and trip generation.

Benefits/Costs: The benefits of traffic calming can vary by the level and scope of the types of techniques that are employed. At a broader level, the impact of such an action on transportation behavior is similar to that found for improved urban design (discussed in Chapter 5)) auto restricted zones (discussed in Chapter 5), and

A study of traffic calming techniques in Germany showed a significant Increase In community interactions when automobile use was *limited and when* a *more friendly pedestrian environment* was *provided*

transit supportive development (discussed in Chapter 4). Generally, transit ridership from such areas will be higher and auto trips will be lower than comparable neighborhoods. Pedestrian/bicycle conflicts with vehicles will also be reduced thus likely decreasing the number of accidents that occur in the area. At the site level, the application of these types of techniques can have an important impact on the community fabric and the interaction among neighbors. A study of traffic calming techniques in Germany showed a significant increase in community interactions when automobile use was limited and when a more friendly pedestrian environment was provided (Eubank-Ahrens 1987). Another study of German traffic calming schemes showed a 20 percent reduction in accidents, a 50 percent decline in serious accidents, through traffic was discouraged, and a "notable decline in the noise level and in the speed of motor traffic"(Hass-Klau 1990). A study of the impacts of traffic calming measures on accident frequency was conducted in Vancouver, British Columbia and the results are shown in Figure 2-15 (Zein et al 1997)

Figure 2.15: Accident Reductions for Traffic Calming Measures in British Columbia



Source Zein et al 1997

Implementation: Traffic calming and street management techniques can provide important benefits to local neighborhoods and shopping areas. However, constraining the use of the automobile and trucks will likely be opposed by those worried about the impact of such constraints on mobility and accessibility to specific activity centers. A study of such techniques in Europe found the following lessons in successfully implemented projects: (Pressman 1987).

- A high degree of public participation in planning is essential.
- Laws and regulations providing enhanced rights for pedestrians and bicyclists were an important foundation for the enforcement of the automobile constraints.
- Public acceptance of the concept will occur over time when the benefits are clearly observable.
- Speed bumps and traffic control devices are being used regularly as a means of controlling vehicle movement.
- Design of the street space (through bricks, paint, street furniture, and fencing) is critical in emphasizing quality and human scale.
- Sophisticated visual guidance systems/kiosks can be used to provide information to visitors.
- Strong political commitment from community leaders is an essential ingredient of success.

- A stable and continuing fund for maintenance is an important element of a financing strategy.

- Traffic calming is integrated with regional and local transit services.

- Zoning should be used to reinforce the types of land uses that are compatible with the pedestrian environment.

- The ability to accommodate changes in use over time is central to the vitality of the area.

The ingredients of a successful traffic calming plan for U.S. application includes not only these items, but also a close relationship between land use plans, transportation plans and programs, and public involvement (Jarvis 1993).

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ARTERIALS AND LOCAL STREETS: OPERATIONS

Similar to the tools discussed under freeway operations, many of the techniques and technologies mentioned in this section are components of intelligent transportation systems (ITS) strategies. Trends in urban traffic management suggest that one of the most important tools in the congestion management toolbox will be improving system operations.

Traffic Signal improvements

Traffic signal improvements generally provide the greatest payoff for reducing congestion on ***surface*** *streets Traffic signal Improvements include:*

- *Equipment update*
- *Timing Plan Improvements*
- *Interconnected Signals*
- ***Traffic*** *Signal Removal*
- *Traffic Signal Maintenance*

Description: Of the approximate 240,000 urban signalized intersections in the United States, about 148,000 need upgrading of physical equipment and signal timing optimization, while another 30,000 are only in need of signal timing optimization (Federal Highway Administration 1987). Traffic signal improvements generally provide the greatest payoff for reducing congestion on surface streets. There are a number of relatively basic improvements that can and should be made to improve traffic flow on arterials. They include:

Equipment update-In this case, an inventory of existing traffic control devices should be made to determine if new, more modem equipment can replace them. This would allow for the planning of a more comprehensive set of strategies to improve traffic flow.

Timing Plan Improvements--This action would require a data collection effort in order to update the traffic signal timing to correspond to current traffic flows. Appropriate pre-timing of signals has been very successful in improving traffic flows.

Interconnected Signals-Specific improvements could include one or more of the following: interconnected pre-timed signals, traffic actuated signals, interconnected actively managed timing plans, and master controls.

Traffic Signal Removal-Many traffic signals are no longer justified in urban areas due to changes in traffic patterns. Many of these intersections can be better controlled by two-way stop control. For those situations where peak traffic flows necessitate continued signalized control, but off-peak traffic does not, conversion of control from full to flashing operation can provide significant reductions in delay and congestion during the off-peak times. Removing traffic signals can reduce vehicle delay and decrease unwarranted stops. However, experience has shown that removing an existing traffic signal will likely be opposed by many groups, especially nearby residents.

Traffic Signal Maintenance-Traffic signals are often installed with little attention given to the cost and procedures required for maintenance. This is a problem that has become particularly critical in recent years as more sophisticated trafhc control devices are installed. Several categories of maintenance should be considered:

- Preventive maintenance, to be performed at regular intervals in order to avoid unnecessary problems;

- Response maintenance, which includes quick response to emergency situations as well as trouble shooting; and
- Design modification, which deals with the need to monitor new equipment as well as signals placed in new locations in order to ensure safe and effective operation.

Benefits/Costs: Improvements to traffic signalization is one of the most cost-effective tools in the Toolbox. Appropriately designed and functioning traffic signals provide for orderly traffic movement, interrupt heavy traffic at intervals to allow pedestrians and connecting-street traffic to cross, increase the traffic-handling capacity of an intersection, and reduce the frequency of accidents. Sometimes traffic signals can have the opposite effect of that intended. Experience has shown that although signals can decrease the number and severity of right-angle collisions, they might increase the number of rear-end collisions (Institute of Transportation Engineers 1992). However, even given such a possibility, the cost effectiveness of improved signal timing is significant primarily due to the reduced delay at intersections. Several studies have indicated the level of such benefits. Texas implemented a statewide signal synchronization program and concluded that after 26 projects, and $1.7 million in expenditure, there was a 19.4 percent reduction in delay, an 8.8 percent reduction in the number of stops, and a 13.3 percent reduction in fuel consumption (Fambro et al 1995). The overall benefit/cost ratio was 38:l. In Tucson, AZ a regional program to improve traffic signals resulted in reductions in average delay per signal cycle from between 14 to 29 seconds (City of Tucson 1991). A similar effort for northern Virginia resulted in benefit/cost ratios in the 2O:l range for signal improvements. The annual user benefits (in terms of travel time savings and fuel costs) were estimated to be just over $7 million (Virginia DOT 1991). An aggressive program of signal timing optimization in California indicated a benefit-cost ratio of 58 to 1. Applied to 3,172 signals in the state, the program resulted in over a 15 percent reduction in vehicular delays and a 16 percent reduction in stops over three years. Overall travel times through these systems dropped by 7.2 percent. The reduction in fuel expenditures (8.6 percent) alone produced savings almost 18 times the total cost of implementing the signal retime program.

Improvements to traffic signalizatron is one of the most cost-effective tools in *the Toolbox.*

Typical costs associated with traffic signalization improvements include: (Environmental Protection Agency 1991)

Equipment or software updating.	**$2,000-$3,000** *per signal*
Timing plan improvements ....,	*$300-$400 per signal*
Signal coordination and inter-connection.	**$5,000-$13,000** *per* **signal**
Signal removal	*$300-$400 per signal*

Implementation: The first action required to improve the traffic signal system in an urban area is to inventory existing signals, the traffic flow conditions being controlled, and the level of service being provided. Traffic and its relationship to the existing traffic signal system must be analyzed to determine if the system is current and still appropriate. Then, a comprehensive policy should be developed to implement the actions described above. Traffic signal locations and timing should be developed in accordance with state and local warrants established for that purpose (ITE 1992). [For more information about these warrants, contact your local traffic engineering department.]

Although the methods available to upgrade traffic signals are relatively straightforward, this action is often overlooked by public officials as an effective way to improve traffic flow. In fact, there are cases where public officials may react to public pressure for installing new traffic signals faster than they will to improve existing signals. Installing new signals could, in fact, further exacerbate the problems of congestion in a particular area. The strategy having the greatest potential for improving system operations is providing better connections or interconnectivity between signals.

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Computerized traffic signal systems usually involve:

1. *Coordinating groups of signals*
2. *Optimizing the signal timing parameters of pre-timed signals*
3. *Incorporating advanced traffic control functions.*

Computerized/Interconnected Signal Systems

Description: Computerized traffic signal systems usually involve three elements: 1) coordinating groups of signals by using either inter-connection or highly accurate timebased coordinators, 2) systematically optimizing the signal timing parameters of pretimed signals or the interval settings of traffic actuated signals, and 3) incorporating advanced traffic control functions by using master computers. This latter includes increased timing plan flexibility, dynamic traffic responsive control features, and on-line traffic petformance monitoring and control system components operation.

Benefits/Costs: Project experience from around the United States indicates that:

- Interconnecting previously uncoordinated signals or pretimed signals, and providing newly optimized timing plans and a central master control system can result in a reduction in travel time ranging from 10 percent to 20 percent.
- Installing advanced computer control has resulted in about a 20 percent reduction in travel time when compared to interconnected pretimed signals operating with old timing plans.
- Installing advanced computer control has resulted in a 10 to 16 percent reduction in travel time when compared to non-interconnected, traffic actuated controls.
- Installing advanced computer control, when compared to interconnected multi-dial pretimed control with relatively active signal timing management, has resulted in an 8 to 10 percent reduction in travel time.
- Optimizing traffic signal timing plans, when compared to previously interconnected signals with various master control forms and varying previous signal timing qualities, has resulted in a 10 to 15 percent reduction in travel time.

Table 2.4 shows the results from a comprehensive signal interconnection effort in Denver. As shown, travel time reduction on the Denver arterial corridors ranged from 7 to 22 percent (Denver Council of Governments 1995). A similar program in Richmond, Virginia saw a reduction in travel time ranging from 9 percent on one corridor to 14 percent on another; a 14 percent to 30 percent reduction in total delay; and a 28 percent to 39 percent reduction in stops (Virginia DOT 1994). A national effort to improve coordinated traffic signalization demonstrated that signal retiming projects can be extremely cost-effective, with benefit/cost ratios conservatively estimated at 10:1 when considering fuel savings only. When the benefits of reduced delay and stops are added, these ratios double to 20:l (Federal Highway Administration 1987).

A national effort to improve coordinated traffic signalization demonstrated that signal retiming projeas can be extremely cost-effective.

Another example of benefits from signal coordination at the regional level is found in a study of a proposed Regional Computerized Traffic Signal System (RCTSS) in Houston. This system will control approximately 2,800 signalized intersections using the latest traffic signal surveillance, control, and communications.

The expected results from different combinations of treatments and existing conditions are shown below: (Schrank and Lomax 1996)

Before Condition	After Condition	Improvement in Speed/Travel Time
Non interconnected pre-timed signals w/ old time plans	Advanced computer based control	25%
Interconnected pre-timed signals w/ old plans	Advanced computer based control	17 5%
Non-interconnected signals w/ traffic-actuated controllers	Advanced computer based control	16%
Interconnected pre-timed signals w/ active timing	Advanced computer based control	8%
Interconnected pre-timed signals, various forms of master control and various quality of timing plans	Optimization of signal timing plans, no changes in hardware	12%

Table 2.4: Impact of Traffic Signal Coordination in Denver

Project	Number of Signals	Length (miles)	Average Daily Traffic	Corridor Travel Time Decreases sec/%	Fuel Use Reduction gals/%	Carbon Monoxide Reductions lbs/%	Daily User Benefits $
Capital Improvement Projects							
US-85	6	3	40,000	89/23%	272/9%	615/16%	3,300
Evans	15	3	45,000	94/18%	415/8%	1,056/14%	5,300
SH-121	6	1 5	35,000	84/32%	300/16%	829/28%	4,000
Wads	17	7	35,000	50/8%	177/2%	367/4%	1,800
Colo	15	6	15,000	147/20%	114/6%	353/15%	1,850
Bowles	111	3	25,000	112/25%	287/10%	772/20%	3,950
Broad.	14	4	30,000	30/7%	207/4%	469/7%	2,400
Signal Timing Coordination Projects							
120th	12	5	40,000	38/7%	67/1%	304/4%	1,800
Arvada	31	8	30,000	60/15%	468/6%	1,218/11%	6,400
Arap	23	8	40,000	162/16%	801/16%	2,112/12%	10,950
Kipling	19	7 5	30,000	99/13%	162/3%	457/6%	2,900
Evans	20	4.3	30,000	168/22%	581/10%	1,575/19%	7,450
Univ	10	2	35,000	27/8%	92/3%	278/6%	1,550

Source. Denver Regional Council of Governments 1995

Additional analysisis of signa improvement in Houston include[see table n next colum (Henk, Poe and Lomax 1991).

Before Condition	After Condition	Effective Increase In Supply
Isolated/uncoordinated	Local coordinated	10%
Isolated/Uncoordinated	Monitored/coordinated	15%
Isolated/uncoordinated	Central coordinated	25%
Local coordinated	Monitored/coordinated	5%
Local coordmated	Central coordmated	15%
Monitored	Central coordmated	10%

Implementation: The implementation of coordinated traffic signal systems should be based on sound analysis of the appropriate charateristics of such a system. Several computer programs are available to develop optimal sisgnal timing strategies. One of the most-used programs is called Transyt-7F and provides useful guidance on optimal signal coordination strategies Another package TRAF-Netsim can be used to assess the benefits of signal coordination Increasingly computerized signal coordination has become an important element of regional traffic management schemes. In these instances, close interjurisdictional cooperation is necessary to assure that technologies are being applied in a consistent manner. Even in the absence of ITS programs, such coop reation is critical for success. The Denver example described previously shows the important role that an agency " convener (in this case the metropolitan planning organization can have in getting different jurisdictions to interconnect signal systems.

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Arterial surveillance and **manage-***ment could include:*

- *Incident detection*
- *intersection surveillance and monitoring*
- *Parking control and management*
- *Integration of freeway and arterial management programs*
- *Traffic surveillance and metering*

Arterial Surveillance and Management

Description: Arterial surveillance and management is very similar in concept to the freeway and integrated freeway/arterial management systems discussed earlier in this chapter. This action could include the following kinds of efforts:

- Incident detection and follow-up action to remove incidents:
  - Service patrols
  - Roving tow vehicles at key sites
  - Motorist information system, including radio announcements, citizen-band radios and cellular phones
  - Incident teams
  - Real time transit passenger information systems at bus stops, kiosks, and via telephone
- Intersection surveillance and monitoring, using:
  - Loop detectors
  - Interconnected signal systems
  - Video monitoring of key intersections
- Parking control and management on key arterials, with greater enforcement of parking regulations on designated through arterials
- Integration of freeway and arterial management programs (as described earlier in this chapter)

➤ Traffic surveillance and metering

The City of Anaheim, California has implemented an integrated traffic management system that is one of the best examples of this action (JHK & Assocs. 1992). One of the most distinctive features of this system is the very extensive use of traffic surveillance data for a variety of traffic management functions. Traffic surveillance data is used in monitoring traffic conditions with computer graphics displays, critical intersection control, traffic responsive control, development of ad hoc timing plans for non-recurring situations, transportation planning, and system performance evaluation. As a general policy, traffic system detectors are placed in each marked approach lane at intersections of arterial streets. Closed circuit television is used to monitor traffic flow, and changeable message signs and highway advisory radios are used to convey important traffic information to motorists. This system has given transportation officials the capability of responding more effectively to short- and long-term changes in traffic demand, developing new signal timing plans, evaluating current timing strategies, and identifying equipment malfunctions.

Benefits/Costs: A major cost of planning and implementing an effective arterial surveillance and management system is associated with intersection control devices and the operational costs of monitoring road performance [described earlier in this chapter]. The benefits to be derived from such a program are significant. The following Boston case study illustrates the possible magnitude of such benefits (Dimino, Bezkorovainy, and Campbell 1987). In August, 1986, Boston initiated Phase I of a Traffic Relief Program (TRP). The program was an interagency effort of the Boston Transportation Department and the Boston Police Department to provide increased enforcement of the city's traffic and parking regulations on congested roadways in downtown Boston (see enforcement section at the end of this Chapter). The TRP was a reaffirmation of the city's philosophy that major arterials primary function is the movement of traffic during periods of heavy traffic flow. A 30.day trial period concentrated on three corridors. The following actions were taken in the corridors:

- No-stopping zones were established along most portions of the three arterials from 7 a.m. to 7 p.m.
- Over 180 parking meters were removed.
- Cab stands, tour bus stops, and handicapped parking spaces were relocated to alternate locations.
- Particular problem areas, such as queuing at large garages, received remedial treatment.
- Enforcement activities featured a close working relationship between the police department (12 motorcycle officers) and the enforcement division of the Transportation Department (20 meter maids). They were instructed to keep traffic moving and not to hand out tickets, unless necessary. The effectiveness of the program was evaluated by collecting travel time data and traffic counts, recording parking violations, and analyzing the collected data.

The most significant increase in travel speeds occurred in the afternoon showing approximately a 28 percent increase. At 7 a.m., these efforts resulted in only a 6 percent increase in speeds. As could have been expected, because average speeds increased, travel times decreased in the range of 28 to 30 percent for three of the routes surveyed, and an 18 percent decrease was noted on another. This resulted in a time savings to motorists of over 1,200 hours per day. An air quality analysis for carbon monoxide showed an overall improvement of 15 percent to 18 percent as measured by eight-hour concentration standards and a 13-33 percent improvement in one-hour concentrations. The program was well received both by the public and the press. The number of parking violations was reduced by nearly 60 percent. Although not sophisticated by City of Anaheim standards, this effort in Boston illustrates what can be achieved when arterial operations are viewed from a systems perspective.

A major cost of planning and implementing an effective arterial surveillance and management system is associated with intersection control devices and the operational costs of monitoring road performance.

Implementation: The planning and implementation of an arterial surveillance and management system can be a major undertaking. The development of such a system must be coordinated with a number of areawide programs. They must be developed in cooperation with all relevant local jurisdictions, property abutters who will be affected, business interests, local elected officials, and citizen groups.

The following keys to successful implementation were associated with the Anaheim project: (JHK & Assocs 1992)

- Incremental implementation which allowed the city to move forward at a reasonable pace

- City officials and officials from all concerned agencies participated directly in all aspects of project implementation
- Flexibility in adjusting to new technologies, funding availability, and actions of other agencies was critical
- Successful interagency cooperation was the most impressive and important lesson
- Risk was recognized as part of the effort to move forward; some degree of risk was needed in exchange for significant opportunities to improve the system
- The lead agency must seek out funding sources and pursue funding directly, and importantly leverage these funds against contributions from other sources

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Turn Prohibitions

The most **cited reasons** *for prohibiting turning movements are:*

- *reduction in accidents*
- *increased intersection efficiency*
- *reduced delay*
- *reduced conflicts*
- *improved traffic flow*

Description: Conflicts between turning vehicles and pedestrians and between turning vehicles from opposing directions can cause congestion delay and safety problems at intersections and driveways. Prohibiting turns is a means of eliminating such conflicts and reducing congestion and accidents. The treatment of turns at an intersection is undertaken with consideration for many concerns, including the following that relate most to turning movements: (Pline 1996)

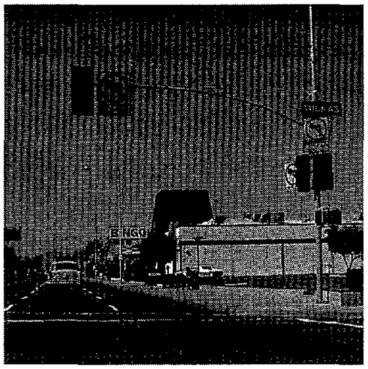
- Undesirable movements should be discouraged or prohibited
- Desirable vehicular paths should be clearly defined, safe speeds encouraged, and points of conflict separated
- High priority traffic movements and desired traffic control schemes should be facilitated; stopped or slow vehicles should be removed from high-speed flows
- Safe refuge should be provided for pedestrians and other nonmotorized travelers.

It is not always necessary to prohibit turning movements at all times in order to alleviate a congestion or accident problem caused by turning vehicles. Turning movements should be prohibited-only during those hours when data indicate that a congestion or accident problem exists and when a suitable alternative route is available. When part-time restrictions are used, signs used to notify motorists of the restrictions must be designed and placed so that the time of the restriction is clearly visible to approaching motorists.

At intersections controlled by traffic signals, turns can be restricted to certain phases of the signal operation by use of separate signal displays and appropriate signs. This type of turn restriction is generally most effective when a separate lane is provided for turning vehicles. The signal phasing techniques can be used to eliminate the conflict between turning vehicles and pedestrians or between turning vehicles and opposing traffic.

Benefits/Costs: The most cited reasons for prohibiting turning movements are: reduction in accidents, increased intersection efficiency, reduced delay, reduced conflicts, and improved traffic flow (Pline 1996). Because turn restrictions cause a change in travel path, reliable data relative to the total impact of turn restrictions on accidents are difficult to obtain. Data compiled in San Francisco indicated that accidents at four intersections with turn restrictions were reduced between 38 percent to 52 percent. All of the intersections were high-volume intersections used by 30,000 to 50,000 motorists on an average day (Institute of Transportation Engineers, 1992).

The prohibition of turning movements at driveways between intersections is frequently accomplished by construction of a median divider. A study in Wichita, Kansas, reported that prohibition of turns between intersections by use of a median reduced accidents between intersections by amounts ranging from 43 percent to 69 percent during the first three years after the median was installed. During the same period, accidents at intersections where turns were not prohibited increased by amounts ranging from 12 percent to 38 percent. However, because accidents between intersections originally represented more than 60 percent of the total accidents on the street section affected by the construction, the median construction resulted in a net accident reduction ranging from 12 percent to 38 percent (see section on Arterial Access Management).



Left-Turn Prohibition

An alternative to turn restrictions is the designation of a separate lane for storage of vehicles waiting to make left turns. This traffic control technique can take the form of "continuous two-way left-turn lanes" which can be used by motorists in either direction. Left-turn storage lanes can also be established with pavement markings for one direction of traffic only on approaches to intersections where left-turning vehicles create accident or congestion problems. Such designation, however, might require that parking be prohibited which could create a need for a study of curb parking supply and demand. The advantages of the turn lane must be compared to the impact of possible parking restrictions.

An alternative to turn restrictions is the designation of a separate lane for storage of vehicles waiting to make left turns. This traffic control technique can take the form of "continuous two-way left-turn lanes" which can be used by motorists in either direction.

One of the critical issues associated with restricting turns is the economic impact on businesses that are now not as accessible as before. The following results came from a study which looked at the economic impacts of restricting left turns: (Cambridge Systematics and JHK & Assocs 1995)

- Gas stations had statistically significant loss of sales
- Retailers of non-durable goods had statistically significant loss of sales
- Service businesses showed patterns of loss of sales although the result was not statistically significant
- Durable goods retailers and hotels showed weak evidence of loss of sales
- Grocery stores and restaurants showed statistically significant evidence of increased sales

The costs associated with different operational strategies are estimated as follows: (Environmental Protection Agency 1991)

Converting two-way streets to one-way	$500-$2,000 *per block*
Two-way street left turn restrictions	*$400 per intenection*
Continuous median strip for left turns	$2,000 *per block*
Channelized roadway and Intersections	$200-$500 *per block*
Roadway and intersection reconstruction	*Varies widely*

Implementation: A modest planning effort is required to identify the locations for possible application of turning prohibitions. A routine design and construction process is then implemented, using appropriate design standards. Turn prohibition studies should consider:

- The amount of congestion and delay caused by turning movements.
- The number of collisions involving vehicles making the turning movement.
- The availability of suitable alternative travel paths if turns are restricted.
- The possible impact of traffic diversion on congestion and accidents at intersections that would be required to accommodate the traffic diverted by the turning restriction.
- Possible adverse environmental impacts caused by re-routed traffic.
- The feasibility of alternative solutions, such as provision of separate storage lanes for the turning movements and, at signalized intersections, the use of special turn-movement phasing.
- The exclusion of buses, taxis, and bicycles from the turn prohibition, depending on circumstances.

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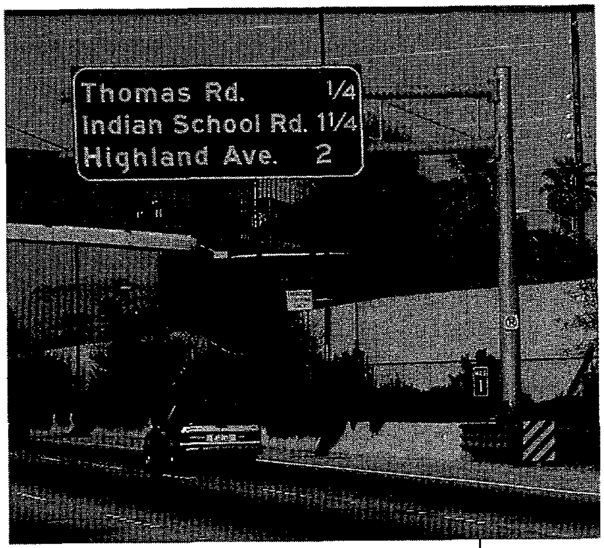
Improved Traffic Control Devices

Description: Traffic control devices which include traffic signs and markings are the primary means of regulating, warning, or guiding traffic on streets and highways. Traffic signs fall into three broad functional classifications:(Institute of Transportation Engineers 1992)

- **Regulatory signs:** used to impose legal restrictions applicable to particular locations and unenforceable without such signs.
- **Warning signs:** used to call attention to hazardous conditions, actual or potential, that would otherwise not be readily apparent.
- **Guide or informational signs:** used to provide directions to motorists, including route designa tions, destinations, available services, points of interest, and other geographic, recreational or cultural sites. Street signs with large, bold letters, both in advance of and at intersections, are extremely helpful to motorists and can improve traffic flow. People looking for a particular street tend to slow down. The provision of easily read cross street signs is relatively cheap and can have great benefit to traffic flow, as well as improve customer satisfaction.

Variable message signs can be used to inform drivers of regulations or instructions that are applicable only during certain periods of the day or under certain traffic conditions. The need for, and use of, variable message signs has increased considerably over the past several years. These variable message signs, which can be changed manually, by remote control, or by automatic controls that can "sense" the conditions that require special messages, have applications for all types of roads.



Street *signs with large, bold letters can improve traffic flow*

Improvements in any type of road signing, the intent of which is to provide better information to the driver, will be beneficial in addressing congestion issues. Improved directional signs, route markers, large street signs, signs on mast arms, etc., are all means of reducing the level of uncertainty (and thus potential indecision) of drivers.

Traffic markings include all traffic lane markings (both longitudinal and transverse), symbols, words, object markers, delineators, cones or other devices except signs, that are applied upon or attached to the pavement or mounted at the side of the road to guide traffic or warn of an obstruction. Traffic markings have certain definite functions to perform in the proper control of vehicular and pedestrian traffic. They serve to regulate, guide, and channel traffic into

improvements in any type of road signing, the *intent of which is to provide better information to the driver, will be beneficial in addressing congestion issues.*

the proper position on the street or highway, and to supplement the regulations or warnings of other traffic control devices. They also serve as a psychological barrier for opposing streams of traffic, as a warning device for restricted sight and passing distances, and provide information for turning movements. As an aid to pedestrians, they channelize movement into locations of safest crossing and, in effect, provide for an extension of the sidewalk across the roadway. Traffic markings aid the vehicle driver in many respects without diverting attention from the roadway.

Transverse marking lines are used for crosswalks, stop lines, railroad crossings, parking space markings, word and symbol markings and curb markings.

Miscellaneous traffic control devices are used to guide traffic in and around work areas, to alert traffic to hazards that are ahead, and to provide a means of identifying specific locations on streets and highways. They include barricades, vertical panels, drums, barricade warning lights, rumble strips and milepost markers.

Benefits/Costs: The costs associated with planning and implementing this technique are modest, and vary depending upon complexity and the number installed. The benefits are substantial, because of the separation of traffic and the enhancement of the safety of operation.

Implementation A modest planning effort is required to identify locations for implementation. A routine design and construction process is implemented, using appropriate design standards. There are five basic factors that must be employed in designing and maintaining traffic control devices: (U.S. DOT 1988)

Five basic factors must be employed in designing **and maintaining traffic** *control devices:*

1. Design
2. **Placement**
3. **Operation**
4. Maintenance
5. Uniformity

Design-the combination of physical features such as size, colors, and shape needed to command attention and convey a message.

Placement-the installation of devices so that they are within the lines of vision of the users, and thus able to command attention and allow time for response.

Operation-the application of devices so that they meet traffic requirements in a uniform and consistent manner, fulfill a need, command respect, and allow time for response.

Maintenance-the upkeep of devices to retain legibility and visibility, or the removal of devices if not needed.

Uniformity-the uniform application of similar devices for similar situations.

In addition, the effectiveness of traffic control devices is greatly enhanced when visible and active enforcement of the related law occurs.

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High Occupancy Vehicle (HOV) Facilities on Arterials

Description: Similar to HOV priority treatments on freeways, HOV preferential treatment on arterials provides for more effective management of scarce highway space during peak periods by moving more people in fewer vehicles. High occupancy vehicles include buses, vanpools and Carpools. Although a variety of HOV facilities have been used in the United States, there are usually one or two types currently being used in urban areas on major arterials: (Levinson et al 1975)

Concurrent Flow-Concurrent flow HOV lanes on surface streets are the most widely applied HOV priority project, found in at least 30 American cities. Most applications have occurred along curb lanes of downtown streets using a minimum of signing and marking. Most concurrent flow HOV lanes in downtown areas are implemented either by taking an existing lane, moving an on-street parking lane, or by narrowing existing lanes to achieve an extra lane. Restricted right-of-way usually prohibits the construction of an added lane.

Contraflow Lanes-Most contraflow applications have occurred on one-way streets, although a few projects have applied the contraflow concept to two-way surface streets, either on the opposite side of a median, or as a reversible center lane. These latter applications are most prevalent on arterial routes outside of the downtown area. Because a contraflow lane is taken from the off-peak direction flow, there are usually no major physical changes required of the roadway; however, good signing is a critical feature. To date, all contraflow lanes in downtown areas have been limited to buses due to the typically high bus volumes and safety concerns arising from the contraflow movements.

Other Downtown HOV Treatment- Apart from the concurrent flow and contraflow lanes, several other sup portive HOV treatments can be found in downtown areas, including:

- Exclusive transit streets
- Priority signals
- Priority parking spaces
- Priority parking rates
- Priority ramp access

Benefits/Costs: If properly implemented, HOV facilities can accomplish the following:

- Induce commuters to shift to higher occupancy travel modes to reduce vehicular demand in peak periods and consequently reduce traffic congestion in the short term, and over the long term reduce energy consumption and air pollution emissions.
- Increase the person-carrying capacity of critically congested highway corridors to provide increased accessibility to important major activity centers, particularly CBDs.
- Reduce total person travel time for given levels of vehicular traffic demand served, i.e., optimize transportation for people.

HOV facilities currently being used in urban areas on major arterials Include.

- *Concurrent Flow HOV Lanes*
- *Contraflow HOV lanes*
- *Other downtown HOV treatments*
  - *- exclusive transit streets*
  - *- prionty signals*
  - *- priority parking spaces and rates*
  - *- priority ramp access*

- ➤ Reduce or defer the need to construct additional highway capacity for general purpose traffic thereby gaining the maximum productivity from financial resources.
- ● Improve the efficiency and economy of public transit operations and enhance transit service schedule reliability.

Several case studies illustrate the costs and benefits that have been experienced in metropolitan areas.

New York City: In an effort to improve user travel times and bus reliability in Manhattan, a comprehensive HOV program for buses only was developed by the New York City DOT Ten concurrent flow bus lanes operating under special regulations were designated between June 1982 and November 1982 for a total of 11 miles. Two of the 10 bus lanes were entirely new. Success has been achieved through emphasis upon a three part approach of engineering treatments, enforcement strategies, and public education programs. "Before and after" results revealed that the average bus saved two to four minutes, representing a 15 to 25 percent increase in speed. Non-bus traffic speeds also increased by 10 to 20 percent due to the separation of buses and autos. Over 3,100 buses and 140,000 riders utilized the lanes on 20 local and 68 express bus routes. These high volumes and time savings translated into large savings in total person-minutes for bus passengers.

Pittsburgh, Pennsylvania: A contraflow right curb bus lane was implemented in June, 1981 along a 0.4 mile length of a downtown arterial. The lane was installed in order to carry buses diverted from a parallel street, which was being reconstructed. The bus lane was implemented by removing curb parking from the arterial, which initially had two westbound lanes plus parking. After the bus lane was implemented, there were still two remaining westbound lanes, one of which is used for short-term parking and loading during off peak hours. The bus lane was so successful that it was made permanent. The bus lane carries approximately 50 to 70 buses in the peak hour. The lane is marked with overhead signs, double yellow line delineation, and the diamond symbol.

Chicago, Illinois: Four contraflow bus lanes were implemented during the early 1980's on streets crossing the State Street transit mall. These right curb lanes operate for seven blocks (0.7 mile). The bus lanes were implemented in response to severe conflicts between buses and right turning vehicles which had occurred at virtually every bus stop in the previous mixed mode operation. The contraflow lanes resulted in a consolidation of bus routes along these four streets. As a result, the lanes are heavily used, each averaging 120 buses per peak period (three hours), and 50 buses per peak hour. These buses accommodate over 3,800 passengers per peak period and 1,700 per peak hour on each street. Buses save from one to four minutes (1.4-5.7 min/mi) during peak periods with an increase bus speeds of 15 to 40 percent. A related benefit has been improved reliability of bus service and greater frequency of service across the Loop due to the consolidation of bus routes. The reliability improvements in the Loop also resulted in improved service along the bus routes outside of the downtown area. The combination of decreased travel time and improved reliability allowed the transit operator to eliminate five buses without decreasing service, thereby yielding an annual operating cost savings of about $400,000.

Houston, Texas: A concurrent right curb HOV lane operates on both sides of Houston's Main Street, a six lane, two-way arterial. The HOV lanes are reserved for buses only on weekdays from 7a.m. to 6p.m. The project was the first HOV treatment implemented in 1971 as a part of a Transit Action Program in Houston. The key feature of the downtown HOV treatment is the prohibition of all turns along the street for 11 blocks (0.7 mile). This restriction was imposed at the same time that the bus lanes were implemented. As a result, once a vehicle enters Main Street within a restricted zone it cannot turn off until it reaches the end of the project. There are virtually no access points on Main Street to parking lots, alleys or hotels. In addition, most off-peak truck loading is performed on cross streets, thus eliminating the obstruction of the bus lanes during the day. Travel time savings were evidenced for both buses and general traffic. Buses saved from 0.4-2.0 minutes; general traffic travel times also improved by 0.2-0.6 minutes due to the elimination of turns and an overall decrease in volume. The specific travel time impacts of the bus lane versus those of the turn restrictions could not be isolated.

San Francisco, California - The experience in San Francisco with HOV lanes on downtown arterials has been mixed. In particular, transit times on city streets after conversion to HOV lane have not significantly declined, especially on those streets where traffic volumes before the conversion were not large. Only in those cases where traffic was continuously congested were there any clear benefits. The Department of Parking and Traffic for the City and County of San Francisco has demonstrated, however, that the distance between bus stops, the placement of bus stops in relation to traffic signals and stop signs, and improved parking and traffic enforcement can have direct impacts on transit speeds (City and County of San Francisco 1989). A recent implementation of an HOV lane on Market Street in the downtown showed other types of benefits to transit operations. Of particular concern in this case was the delay caused by traffic signals to transit vehicles waiting to enter boarding islands. By reducing the number of non-transit vehicles in the nearside lane, it was hoped that all transit vehicles would be able to reach the islands without significant signal delay. The travel time impact of reserving this lane for transit vehicles was limited, a 2 percent reduction in travel time (12 seconds). However, preferential treatment did have a very positive impact on transit vehicle delay. Before such treatment, typically 12 of the 50 buses on Market Street were caught in the signal queue. After the treatment, none of the buses had such delay (City and County of San Francisco 1997).

Implementation: Although every HOV treatment is unique in its setting, there are several guidelines that have been common to most of the projects implemented to date.

- HOV project planning must include various agencies and interest groups such as:
  - Traffic
  - Business groups
  - Enforcement
  - Transit
  - Political leaders
  - Ridesharing
  - Citizen groups
  - Taxi operators
  - Motorist groups
  - Employers and employer associations
  - Environmental groups
- The project must be flexible to meet changing conditions in the downtown area, including different pedestrian flows, construction activities, and transit operations.
- Enforcement is the key to an effective HOV treatment. Adequate enforcement must be in place immediately to establish the credibility of the project.
- Public education (i.e., marketing) must begin before the project is implemented. The high auto, n-an sit, and pedestrian volumes in the downtown can create volatile and potentially confusing travel movements which must be understood by the public.
- The HOV project must be clearly signed and marked to promote understanding of and compliance with the restrictions. These features should be explained as part of the public education.
- Improved travel time reliability and efficient movement of persons should be the primary goals in a downtown area. Many projects do not show a large actual travel time savings due to the large number of buses, frequent bus stops, and other traffic friction; however, improved reliability has been linked to ridership increases and operating cost savings.
- An HOV project should be planned and implemented in the context of other HOV treatments. In a tightly defined downtown area, a combination of HOV treatments (e.g., a network of bus lanes, bus lane plus signal priority) can greatly enhance the effectiveness and visibility of the HOV concept. Coordination with transit and ridesharing incentives should also be provided.
- The effects of an HOV project on non-users as well as users must be analyzed. The implementation of HOV treatments on high volume

downtown streets can result in adverse effects on non-HOV traffic if the project is not well-designed. As a general rule, the traffic flow for non-users should not be degraded more than one level-of-service category (e.g., level of service "C" to "W).

- Projects with unsolvable safety and/or operational problems should be avoided.
- Most downtown HOV treatments (exclusive of transit malls) can be implemented at a low to moderate cost relative to other highway or transit changes. Concurrent flow and contraflow lanes can often be initially implemented at a low cost, with additional funds for final signs and markings expended later, once the project has been established. Thus, major initial capital costs can be avoided.
- HOV treatment can significantly alter the flow of traffic and pedestrian movement on the arterial (and adjacent) streets. Therefore, a study should be done that evaluates the effect on businesses of such a treatment.

In addition to these points, advances in intelligent transportation system technology (ITS) have provided opportunities for improving arterial bus operations. For example, providing preemption of traffic signals for buses in the HOV lanes can be done by linking the oncoming bus to the traffic signal controller. Automated passenger information systems can provide riders with real time information concerning bus arrivals. These innovations can greatly enhance the attractiveness of transit service (Transportation Research Board 1995).

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Parking Management

Description: Parking management is a jurisdictional approach toward the provision, control, regulation, or restriction of parking space. Parking management can consist of actions that fall into six major categories: on-street parking, off-street parking, fringe and corridor parking, pricing, enforcement and adjudication, and marketing. The major types of action in each category are shown in Table 2.5. Although discussed here, parking pricing receives a more detailed discussion in Chapter 5.

Parking management is a jurisdictional approach toward the provision, control, regulation, or restriction of parking space.

Parking management can be undertaken for many reasons. In many cases, communities want to have a comprehensive parking program that provides a sufficient amount of parking space to serve residential, commercial, and retail activities. In other situations, communities use parking policies to achieve different objectives, such as to improve environmental quality, encourage a shift to different modes of transportation, or to preserve sufficient access for local residents. Importantly, parking policies are one of the most effective actions that can be taken to reduce single occupant vehicle use. A study on suburban parking, however, illustrates the challenges facing public officials who wish to use parking policies to meet some of these objectives. This study concluded: (Willson 1992)

- Parking is substantially oversupplied at suburban office worksites.
- Employers and/or commuters rarely receive appropriate price signals about the cost of providing parking.
- Cities often require developers to provide too much parking.
- Parking standards are usually not tailored to the specific use characteristics of office buildings.
- Parking policy is rarely an issue of political importance in suburban cities.
- Transit operators face a daunting task serving low density, overparked employment centers.
- Some suburban areas have matured to the point where they resemble central business districts, and can use urban parking management strategies.
- Suburban parking policy is unlikely to change unless most of the stakeholders involved in parking supply and management are convinced that change is desirable.

Benefits/Costs: The benefits and costs of parking management actions depend upon the specific strategy or strategies to be implemented, as well as the objectives to be achieved [see Chapter 5 for site-specific parking strategies]. Table 2.6 shows the estimated impact of parking management strategies if applied to Portland, Oregon (Portland State University 1995). Not surprisingly, parking pricing strategies have the greatest impact on single occupant vehicle use and transit ridership. This Table also shows an implementation feasibility analysis which indicates the short- and long-term consequences of these types of actions.

Table 2.5: Parking Management Strategies

On-Street Parking Supply	Off-Street Parking Supply	Fringe and Corridor Parking	Pricing	Enforcement and Adjudication	Marketing
Add or remove spaces **Change mix of short and long-term parking** **Parking restrictions** • Peak period • Off-peak • Alternate side parking • Permissible parking durations • Prohibitions on parking before specified hours **Restricted parking permit programs** **Carpool/vanpool preferential parking** **Loading zone regulations**	**Expand or restrict off-street supply in CBD and activity centers** • Zoning requirements - Minimums - Maximums - Joint use • Constrain normal growth in supply - Maximum ceiling - Reduced minimum through HOV and transit incentives • Construct new lots and garages **Change mix of short and long-term parking** **Restrict parking before or during selected hours** **Carpool/vanpool preferential parking**	**Fringe parking** **Park and Ride Parking** **Carpool/vanpool parking**	**Change parking rates** • Increase rates - Parking price increase - Parking rate structure revision - Parking tax - Parking surcharge • Decrease rates • Free parking in CBD • Differential pricing - Short vs long-term - Carpool/vanpool discounts - Vehicle size discounts - Geographically different rates - Monthly contract rates **Merchant shopper discounts** • Stamp programs • Token programs **Employer parking subsidies** • Reduce subsidies • Transit/HOV subsidies	**Enforcement** • Non-police enforcement personnel - Ticketing - Towing - Booting **Adjudication** • Administrative • Judicial	**Advertising** • Brochures • Maps • Media **Convenience Programs** *(monthly contracts)*

Source: DiRenzo 1979

Table 2.6: Estimated ImpactOR, *Source: Portland State University 1995*

Strategy	Winners	Losers	Revenue Implications	Efficiency Implications	Unintended Consequences	Long-Term urban form	Ease	Political Feasibility	SOV Work Trips	Transit Work Tips
Enhanced park and ride	• Employer who can't expand parking • Small benefit due to decrease in congestion for commuters with high time value	• Transit or parking provider if not subsidized • Taxpayer, if paying subsidy • User if paying or inconvenienced	• No excess revenues generated for compensating losers	• Not highly efficient, because it frequently requires subsidy and users to lose time when parking at remote lots	• Very high administrative and operating costs • May increase VMT & emissions under certain conditions	• Encourages centralization of activities and decentralization of population	Difficult	High	0-10% decrease in SOV share	0-10% increase in transit share
Preferential Parking for Carpoolers	• HOV commuters • Low to moderate benefit due to decrease in congestion for all peak hour trips	• SOV auto commuters not able or willing to pay premium prices or to drive HOV	• Some revenues lost difficult to devise means of compensation to losers	• Modestly efficient because although it targets peak commuters, cost of carpool inducements may out-weigh benefits	• SOV spaces will be reduced, possibly reducing revenues and causing SOV auto commuters to spill over onto on-street spaces	Minimal, if any	Moderate to difficult	High	5-10% decrease in SOV share	0 or negative as transit riders may shift to HOV
Transit Incentive Programs • Passes • Free parking • Rides home	• Moderate benefit due to decrease in congestion for all peak hour users • Transit users	• Paying parkers whose supply is reduced • Subsidizers of transit incentive programs	• No revenues generated so not possible to compensate losers	• Slightly efficient because although it targets all peak commuters, it also requires increased transit subsidy	• Parking allowance for transit commuters may deplete supply for paying parkers	Minimal, if any	Moderate to difficult	High	5-10% decrease in SOV share	5-10% increase in transit share
Flat regionwide increase of $3 per parking space	• Moderately high benefit due to decrease in travel congestion for commuters with high time value, commercial operators, transit and nonwork	• Suburban auto commuters • Short distance auto commuters • Low income drivers	• High revenues generated but difficult to devise means of targeting and compensating losers fully	• A "second best" strategy for addressing congestion, however, overprices some commuters while underpricing others	• Spillover parking onto nonemployee and unmetered on street spaces	• Stimulates centralization because suburban parking prices would increase relative to CBD prices	Very difficult	Very low in low density areas	9% decrease in SOV share throughout entire region	10-20% increase in transit share localized in CBD, 0-5% in suburbs
Increase in employee parking price, varying by density	• Moderately high benefit due to decrease in travel congestion as above	• Firms and commuters in high density areas • Short distance commuters • Low income auto commuters to central city	• Moderately high revenues with which to devise means to target and compensate losers	• Well targeted "second best" strategy, but overprices some commuters while underpricing others	• Spillover parking onto non employee and unmetered street spaces	• May stimulate decentralization because suburban communities pay lower prices	Difficult	Low	10-40% SOV decrease *(high density areas)* 8-10% *(moderate)*, 0% *(low)*	5-20% increase in transit share *(high density)* 2-5% *(moderate)*, 0% *(low)*

Table 2.6: Continued

20% increase in off-street parking rates	• Low to moderate to commuters with high time value, commercial vehicles, and through traffic	• CBD firms and auto commuters • Short distance auto commuters • Low income drivers to CBD	• Minimal revenues and difficult to compensate losers	• Not very efficient because it affects only small % of commuters and yields slight reduction in CBD congestion	• Spillover parking onto unmetered on street spaces	• Stimulates decentralization because suburban commuters do not pay	Moderate to easy	Moderate	3-5% decrease in SOV share	2-5% increase in transit share if high transit service
Increase in parking price varying by density	• Moderate/high for commuters with high time value, commercial operators and nonwork trips	• CBD auto commuters • Short distance auto commuters • Low income drivers to CBD	• Moderate to high revenues although difficult to compensate losers	• Fairly broad and inefficient strategy because it is not targeted toward peak travel	• Spillover parking onto unmetered on street spaces	• May stimulate some decentralization because suburban commuters pay lower price	Moderate to difficult	Low because applies to all off street parking	In CBD with good transit, 25-30% decrease in SOV, suburbs 0-5%	In CBD with good transit, 25-30% increase, in suburbs 0-2%
Cashing out employer paid parking; $3/day in CBD $1/day in activity centers	• Recipients of cash out amount • Small benefit due to decrease in congestion to those above	• CBD employers who offer free parking to larger % of employees than those who currently park	• Designed to be revenue neutral	• Moderately efficient, allows commuters to pick most efficient option to them; moderate especially if applied only to leased parking	• Spillover parking onto unmetered on street spaces and spaces reserved for non employees	• May stimulate centralization if applied only to leased CBD parking	Moderate to low for employers	Moderate changes in IRS code	$3/day=2-3% decrease in SOV,$1/day= 1-2% decrease	$3/day=1-3%increase, $1/day-0-1% increase
Expanded meters and residential permits	• Low to moderate benefit due to decrease in CBD congestion to commuters, residents, merchants, nonwork and commercial trips	• Auto travelers priced out of meters • Long term visitors • Merchants who don't place value on turnover	• High revenues are generated to compensate losers	• Efficient because it addresses spillover parking and reduces expansion of parking into high cost areas	• Displacement of spillover into other adjacent areas	• Stimulates some decentralization if on street controls lead to a loss of business or of residents	Moderate to difficult	Moderate to high	2-10% decrease in CBD; 2-5% decrease in business districts; 0-2% in suburbs	1-5% increase in CBD, 0-2% increase in business districts, 0-1% increase in centers
Parking impact fee of $3,000 per space Areas of high growth only	• Small benefit due to decreased congestion for commuters with high time value	• Commuters if supply is set too low • Owners of undeveloped land	• Moderate revenues to invest in alternative modes	• Efficient insofar as existing supply standards are too high	• Spillover parking onto unmetered streets if supply inadequate • May cause congestion from parking search if supply is inadequate	• May stimulate slightly more compact development in areas of new growth	Moderate	Moderate to high	1-5% decrease in SOV in short term, 2-10% in long term	0-2% increase in short term; 0-10% in long term
Development ordinance changes • lower mins and maxs • cond'l use permits Areas of high growth only	• Developers saving on capital investment • Very small benefit to commuters with high time value	• Commuters if supply is set too low • Developers in conditional use agreements supporting alternate modes or paying into city fund	• Difficult to devise means of compensating losers directly	• Efficient insofar as existing supply standards are too high	• Spillover parking onto unmetered streets if supply is inadequate • May cause congestion from parking search if supply is inadequate	• May stimulate slightly more compact development in areas of new growth	Moderate	Moderate to high	0-5% decrease in SOV share in short term, 0-10% decrease in long term	0-2% increase in short term; 0-5% increase in long term

Shared parking means that two or more land uses controlled by one or many owners can share the same parking space over the course of a day, week, or month

Another parking management strategy that is being considered in many communities is the concept of shared parking. Shared parking in essence means that two or more land uses controlled by one or many owners can share the same parking space over the course of a day, week, or month (ITE Committee 6F-52 1995). The basic premise for this strategy is shown in Figure 2-16 which indicates that different activities generate different temporal demands for parking which provide good opportunities for more efficient parking provisions. The advantages of this strategy are:

For developers, shared parking has the potential to:

- ➤ Reduce the amount and cost of parking
- ➤ Have a larger area available for primary uses.

For local governments and the public, shared parking discounts that encourage more efficient parking:

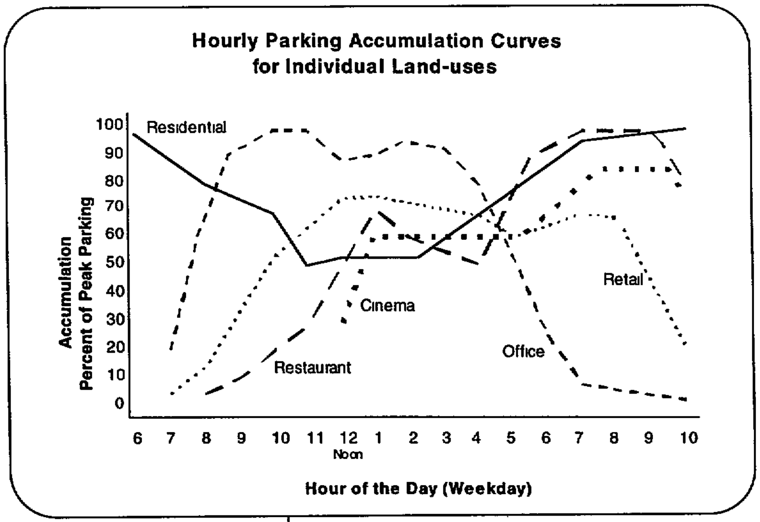
- ➤ Attract mixed-use development projects which tend to promote a more lively urban pattern
- ➤ Require less land area for parking with more land available for tax revenue-generating purposes
- ➤ May reduce traffic access points thereby improving circulation
- ➤ May enhance trip reduction efforts
- ➤ Improves the attractiveness of the cityscape

There are also possible disadvantages to share parking programs. These include: (Regional Transportation Authority 1995)

- ➤ Possible shortage of parking if land uses change
- ➤ Parking generally cannot be reserved for 24 hours for a particular use or time-restricted
- ➤ Due to the need to ensure adequate parking even if land uses change, cities face the complexity of dealing with different developers, monitoring uses, and getting developers to accept convenants or performance bonds

Implementation: Each parking management action requires a different, yet related, set of actions that depend upon the overall program objectives. Table 2.7, for example, shows how different parking management actions should be considered as part of a program of action to deal with different types of problems in an urban community. Both employers and local governments have an important role to play in the implementation of parking strategies (Institute of Transportation Engineers 1995).

Figure 2.16: Shared Parking Use



Source: Edwards 1994

Table 2.7: Illustrative Parking Management Programs

Example 1	Example 2
Problems: • Extensive peak period congestion • Underutilization of transit system • Violation of air quality standards	• Loss of business in CBD • Illegal parking in CBD and residential neighborhood
Objectives: • Improve highway level of service • Increase transit patronage • Reduce energy consumption • Improve air quality	• Encourage downtown development • Reduce illegal parking • Increase parking supply • Improve neighborhood amenities
Potential Tactics: • Reduce/prohibit on-street parking • Provide preferential carpool/vanpool parking • Construct park and ride lots and fringe lots • Parking tax on parkers arriving during A M. peak period • Implement more aggressive ticketing and booting program **Related TSM Tactics** • Provide transit service to fringe and park and ride lots • Provide preferential lanes for transit and HOV • Institute transit, HOV marketing program • Improve traffic signal system • Institute turning lane and lane use restrictions • Institute flexible work hours	• Institute downtown "marketing" programs for retailers, etc. • Provide additional short term parking on and off-street • Implement more aggressive ticketing program • Provide preferential rates for short-term parkers • Implement residential parking permit programs in areas adjacent to CBD impacted by long term parking • Implement joint development projects **Related TSM Tactics** • Widen sidewalks • Pedestrian grade separations • Pedestrian malls • Bus only streets

Source: DiRenzo et al 1979

The following guidelines are offered as a point of departure for developing a good parking management program for a community (Edwards 1994).

A well conceived parking plan includes:

- An assessment of current conditions
- An analysis of current demand
- Projection of future demand
- Recommended changes and systems required to increase the effectiveness of the current parking supply
- A parking development strategy that includes recommendations on the supply and pricing of parking in the community
- Recommended revisions to parking regulations that reinforces flexibility and encourages such things as shared parking, fees in lieu of required parking development, allowances for off-site or satellite parking, incentives for development of ridesharing, and incentives or parking credits for development near transit stations

Securing endorsement for the parking plan means:

- Start early to contact city property owners and business establishments
- Get support for the basics of the costs, possible zoning requirements and participation in the process
- Develop a communications strategy and stick to it
- Secure formal endorsement from city officials

Implementing the plan includes:

- Having qualified staff and a good management structure in place
- Specifying how the effectiveness of parking actions will be assessed
- Formally announcing the adoption of the parking plan
- Modifying the community's comprehensive plan and zoning ordinances
- Conducting an informal assessment of plan effectiveness every 12 to 18 months
- Conducting a thorough update every three or five years

These implementation guidelines suggest that a parking management strategy should be flexible enough to respond to changing conditions. For example, the following elements of a parking system might need fine-tuning after three to five years: time limitations for short- and long-term parking, parking fees, parking fines, adjudication system, parking restrictions, and inclusion of new parking categories (e.g., residential permits, industrial loading/unloading, and monthly parking).

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Freight Movement Management

Description: The effective management of urban arterials and local streets must consider all users of the road network. Companies that pick-up and deliver freight in an urban area are very important system users. Changes in delivery schedules and in the location of terminals and delivery zones could go a long way to minimize unnecessary congestion that occurs because of the mixing of different vehicle types. The movement of goods into and out of urban areas is an essential part of our lives. Consequently, any change in the methods of moving freight must be done with care. Unfortunately, there is little experience or research to help guide actions in this area.

Table 2.8 shows different truck trip rates for urban areas in North America (University of Tennessee 1995). Additional characteristics of urban freight movement that are critical to understanding its importance to transportation system management include:

- Average truck trip lengths vary substantially by type of truck and type of good being transported. For example, in Milwaukee the average truck trip length in 1991 was 8.4 miles/13.5 kms.; whereas in Chicago the average truck trip length was 17.2 miles/27.7 kms.
- Truck trip-making rates have been increasing over the past 20 years. In Chicago, the trips per truck increased from 5.6 in 1970 to 7.1 in 1986; in Milwaukee the rates increased from 5.0 in 1963 to 5.9 in 1991; in San Antonio the rates increased from 8.0 in 1969 to 8.3 in 1990.
- The peak period of truck travel tends to be during mid-day. In Phoenix, for example, the peak

Changes in delivery schedules and in the location of terminals and delivery zones could go a long way to minimize unnecessary congestion that occurs because of the mixing of different vehicle types.

Table 2.8: Truck Trip Rates in Various Urban Areas

Urban Area	No. of Commercial Vehicles	Commercial Vehicle Trips	% of Total Travel	Average Daily Trips Per Truck
Amarillo, TX (1990)				5.2
Brownsville, TX (1991)				8.3
Chicago, IL (1986)	186,769[1]	11,135,914	9.4%	7.1 [2]
		14,800,000[3]		
Minneapolis-St Paul, MN (1981)	25,394[4]			4 02
				6 77 [5]
Ottawa/Hull, Ont./Que (1989)	24,028	153,100	11%	8 7
				12.0 Int.
				3.5 Ext
Phoenix, AZ (1991)				7.7
San Antonio, TX (1990)				8.32
Toronto, Ont. (1987)				9.7
Vancouver, BC (1979)				7.7
Southeast Wis. (1991)	87,500	520,100	11 3%	5.9

[1] Referred to as working vehicles only
[2] Weighted average calculated from data
[3] Total equivalent vehicle-miles of travel in a 24-hour period
[4] Includes only heavy vehicles > 15,000 lbs. gross vehicle weight
[5] Includes only trucks that traveled on a given day

Source: University of Tennessee 1995

Actions to improve goods movement include:

- *Traffic management*
- *Improvements at shipping/ receiving points*
- *Reducing operational and physical constraints*
- *Changes in business operating practices*
- *Changes in public policy*
- *Investment in rail*

period for truck travel is from 12 to 2 p.m.

➤ The largest percentage of truck trips are made by pickup trucks which make half of the truck trips and represent 54 percent of commercial vehicles.

➤ Almost 40 percent of commercial vehicles stop on-street.

➤ A substantial number of vehicle trips in an urban area are truck trips. Table 2.9 shows the daily truck trip summary for the San Francisco Bay Area (California Department of Transportation 1992b).

➤ It is likely that the boom in the use of the Internet, Cable TV-order and phone-order businesses will have a big impact on urban freight movement.

Table 2.9: Daily Truck Trip in the San Francisco Bay Area

	2-Axle Trucks	3-Axle Trucks	4-Axle Trucks	Total	%
Internal-Internal					
Linked	99,521	11,972	22,209	133,702	50%
Garage-Based	72,086	4,730	14,176	90,992	34%
Port	0	1,430	2,779	4,209	2%
Internal-External	13,481	1,852	21,593	36,926	14%
External-External Port	0	167	914	1,081	<0.5
External-External	233	26	1,251	1,510	1%
Total	185,321	20,177	62,922	268,420	100%
Percent	69%	8%	23%	100%	

Source California Department of Transportation 1992b

In addition to the congestion and mobility concerns associated with the movement of goods in an urban area, transportation officials need also to pay close attention to intermodal terminals. Many urban areas have a significant number of freight terminals, and all major U.S. cities have air cargo facilities and a substantial number have seaports. Access to intermodal terminals is often extremely congested, not only causing delays to freight operators, but also causing great inconvenience to other users of the road system (California Department of Transportation 1992a; FHWA 1995).

The types of actions that can be considered to improve goods movement include the following:(Institute of Transportation Engineers 1987; Ogden 1992)

Traffic management—Transportation system management (TSM) measures to improve the flow of freight vehicles include such things as truck-only lanes or roads, providing region-wide traffic information to freight movers, and preferential movements at toll or access points.

Improvements at shipping/receiving points—On-street loading and unloading can be facilitated by designing additional curb space for loading zones and enforcing time restrictions. In addition, intermodal transfer facilities can be developed or enhanced to facilitate truck-rail cargo transfer.

Reducing operational and physical constraints—Traffic signal timing can be changed or demand-actuated signals used at intersections with large volumes of trucks to compensate for the acceleration, deceleration and turning characteristics of trucks. Intersections can be widened and horizontal and vertical obstacles (e.g., islands, lamps and utility poles) can be removed or relocated.

Changes in business operating practices—Business operating practices to reduce the time required for pick-up and delivery will reduce the transport costs of shippers and receivers, and improve the performance of the transportation system. In addition, changes in time of delivery, e.g., at off-peak hours, will provide positive benefits to peak hour travelers.

Changes in public policy—The most commonly considered technique for relief of truck-induced congestion is the separation of trucks from other traffic. Land use planning, zoning and industrial location policies and building regulations requiring off-street loading and unloading facilities can be used to separate freight-oriented activities from other activities. Another policy action is to charge tolls during peak hours to encourage truck movements to shift to non-peak hours, less congested routes, etc.

Investment in rail—Improvements in rail transportation could alleviate heavy truck use of highways leading to ports and freight terminals.

Benefits/Costs: Goods movement management during peak period traffic can effectively reduce overall congestion. The development of the off-peak hour system for urban goods movement through various incentives (tax and otherwise) assists in the reduction of peak period traffic congestion. The development of metropolitan area truck management plans could also be used to spread the commercial demand for truck traffic in the urban core and suburban areas to off-peak hours.

The development of the off-peak hour system for urban goods movement through various incentives (tax and otherwise) assists in the reduction of peak period traffic congestion.

A study conducted for the California Department of Transportation examined possible strategies for reducing the contribution of large trucks to peak-hour freeway congestion (Cambridge Systematics 1988). Four major strategies were examined:

Traffic Management—Modify high-accident freeway locations, provide motorist information on freeway conditions, and enforce safe truck operations.

Incident Management—Aggressive monitoring of and response to truck-involved accidents.

Night Shipping and Receiving—Require business establishments to do most of their shipping and receiving at night.

Peak-period Truck Ban—Exclude large trucks from core area freeways from 7 to 9 a.m. and 4 to 6 p.m.

Freight movement management strategies will require regulatory or legislative authority to be effective. They also involve coordination among the public, political leaders, truck operators, developers, and private businesses.

Table 2.10 presents the estimated impacts of these strategies. Another good example of a freight movement study in an urban area is found in (Capital District Transportation Committee 1995).

Implementation: Any of the above mentioned strategies will require regulatory or legislative authority to be effective. They also involve coordination among the public, political leaders, truck operators, developers, and private businesses. Because urban areas are not alike, the institutional hurdles will vary from one location to another. Institutional strategies require both incentives and penalties to gain compliance. In order to effectively develop a policy on urban goods movement, the following actions are necessary:

- Establish a forum among business, labor, trucking and the government sectors [see, for example, (The American Trucking Associations 1996)] .
- Make changes to local and state government regulations (e.g., local noise abatement ordinances, parking restrictions, and restrictions on deliveries).
- Identify and make modifications to operations (e.g., work hours for both receivers and shippers) or use of street space.
- Focus on changes to infrastructure that will facilitate goods movement, e.g., specialized truck lanes and facilities, improved access, use of advanced technology to expedite truck movements, and provision of off-site docking facilities.

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Table 2.10: Comparison of Freeway/Truck Management Strategies (Millions of Dollars Annually)

			ECONOMIC IMPACTS					
			Direct					
Strategy	Feasible	Freeway Congestion Relief	Motor Carriers[2]	Other Vehicles[3]	Shipper/ Receivers[3]	Indirect: CA Business Sales[4]	Air Quality[5]	Implementation Cost[6]
Traffic Management[7]	Yes	XX	$8	$121	X	$8	X	$20 - 40
Incident Management[7]	Yes	X	$4	$44	X		X	$3.5
Night Shipping and Receiving[8]	Maybe	X	$3	X	-$2,200	-$913	X	$2 - 3
Peak Period Ban Core Freeways[8,9]	Unlikely	X	-$43	$7	--	-$28	--	$2 - 3

Footnotes

[1] 1988 dollars

[2] Time and vehicle operating cost savings (+) or cost increases (-)

[3] Logistics costs savings (+) or cost increases (-)

[4] Changes in volume of business sales (output) in 1988 relative to baseline forecast Traffic and incident strategies were combined because their individual direct motor carrier impacts were too small to modeled reliably

[5] Not quantified

[6] Ten-year annualized implementation costs

[7] Los Angeles, San Francisco, and San Diego

[8] Los Angeles and San Francisco only

[9] Assumes 80 percent of peak period truck miles of travel are diverted to arterials 20 percent are diverted to off-peak periods (midday or night)

Notes

XX	Significant positive impact
X	Modest positive impact
--	Modest negative impact

Source *Cambridge Systematics 1988*

Bicycle and Pedestrian Networks

Description: Arterial transportation corridors not only provide transportation for motor vehicles, they are also often the focus of large numbers of pedestrian and bicycle movements. In some cases, these trips are a significant amount of the trip-making in an urban area. For example, Albany, New York estimates that over 65,000 trips each day are made on bike and foot (Allocco 1995). In most urban areas, even with the renewed interest in bicycle transportation, bicycle networks are not readily available. Some important steps that can be taken to develop better network characteristics for bicycle and pedestrian movements include the provision of continuous and connected sidewalks, marking bicycle lanes in a very clear and visible manner, provide bike racks or other storage facilities at transfer stations, distribute bicycle travel maps, provide clear signage for pedestrian and bicycle movement, and the design of urban streets with non-motorized transportation in mind (Wilkinson et al 1994).

Steps to develop better network characteristics for bicycle and pedestrian movements include:

- *providing of 105 continuous and connected sidewalks,*
- *marking bicycle lanes in a very clear and visible manner,*
- *providing bike racks or other storage facilities at transfer stations,*
- *distributing bicycle travel maps,*
- *providing clear signage for pedestrian and bicycle movement,*
- *designing of urban streets with non-motorized transportation in mind*

Five basic types of facilities are used to accommodate bicyclists:

Shared lane:
: Shared motor vehicle/ bicycle use of a standard traffic lane

Wide outside lane:
: An outside lane with a width of at least 14 feet

Bike lane:
: A portion of the roadway designated by striping, signing, and/or pavement markings for preferential or exclusive use of bicycles

Shoulder:
: A paved portion of the roadway to the right of the edge stripe designed to serve bicyclists

Separate bike path:
: A facility physically separated from the roadway and intended for bicycle use (most often a multi-use path)

The challenge, of course, is to connect these actions in a comprehensive and coordinated fashion to form a nonmotorized transportation network.

Benefits/Costs: The benefits of pedestrian and bicycle networks relate directly to reductions in motor vehicle trips and the associated improvements in congestion reduction and mobility enhancement. An example of the benefits and costs that are typical for this type of action is shown in Table 2.11.

One of the innovative approaches for determining the likely mode share for non-motorized transportation is the application of a so-called pedestrian environmental factor (PEF). This factor quantifies the relative convenience, safety, and level of effort of walking perceived by pedestrians. This is done by evaluating four factors: ease of street crossings, sidewalk continuity, street layout [i.e., grid versus cul de sac], and topography (1,000 Friends of Oregon 1993; NCTCOG 1995). Each factor is given a score with this score relating to non-motorized modal share as shown in Figure 2-17. In Portland, Oregon, one study estimated that a 10 percent reduction in VMT could

Table 2.11: Benefits and Costs of Bicycle/Pedestrian Accommodations, Albany, NY

Benefits

% of Potential Switching	Annual Savings ($M)	"Justified" Investment ($M)	"Justified" Investment per year over 15 years
To Cycling			
0 6 percent (550) of trips <= 5 miles	$44 M	$21M	$1 4 M
2.7 percent (2500) of trips <= 5 miles	$124 M	$102M	$6.8M
To Walking			
0.6 percent (275) of trips <= 2 miles	$16M	$23M	$1.5M
2.7 percent (1250) of trips <= 2 miles	$55 M	$68M	$4.5M

Unit Costs of Bicycle and Pedestrian Accommodations

Major Structural Components (installed prices)

Shoulder construction: $3 86 per square foot

Separate Bikeway Construction: $6.50 per square foot of bikeway

Sidewalks: $9.00 per square foot (ex. $225 for 5' x 5' panel)

Secondary Installations/Accessory Elements

Signs (directional, "bike route", etc.): $200 (including posts)

Bike racks: $10-600 each

Bike lockers: $500 each

Additional right-of-way (for bicycle parking areas, etc.)

$1.10 per square foot

Pavement Treatments

Pavement striping--4" reflectorized (along road); $0.12 per linear foot

Pavement striping--12" crosswalk markings: $0.75 per linear foot

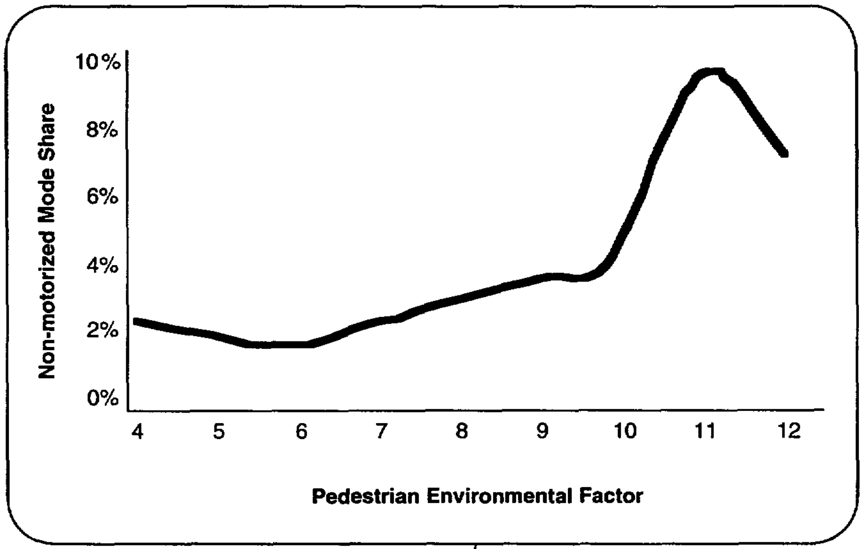
Source: Allocco 1995

be achieved by increasing PEF to peak levels throughout the region.

A more detailed discussion of bicycle and pedestrian improvements is found in Chapter 5 in the section on Nonmotorized Transportation.

Implementation: Because such a large investment has already been made in the existing system of urban streets, bicycle and pedestrian networks would be best developed to utilize these facilities as feeder routes. New construction of multi-use paths, grade separations, etc. would typically function as the trunk lines of the network. With this in mind, the implementation of bicycle and pedestrian networks would most likely be done in an incremental way. For example, in Albany, New York, local officials adopted a four step approach of starting the process: identifying a 353-mile/568 kms. priority bicycle/pedestrian network that the region would like to make more user friendly, listing of known problem locations for early action, listing of sites and areas

Figure 2.17: Pedestrian Environment Factor and Mode Split



Source. As discussed in (NCTCOG 1995)

One of the innovative approaches for determining the likely mode share for non-motorized transportation is the application of a so-called pedestrian environmental factor (PEF) This factor quantifies the relative convenience, safety, and level of effort of walking perceived by pedestrians.

which would be strong candidates for improved bicycle pedestrian access, and an evaluation of the transportation improvement program (TIP) for incorporating possible bicycle/pedestrian elements into programmed projects.

For walking, a good example of implementation guidance comes from the Florida Department of Transportation which has developed a guide for implementing an effective walkable communities program (Florida DOT 1993). The 12 implementation steps included:

- ➤ Provide continuously linked walkways
- ➤ Pedestrianize intersections to accommodate the physical abilities of pedestrians to cross a road
- ➤ Provide special accommodations for mobility impaired individuals
- ➤ Place traffic signals for optimum visibility during critical turning movements
- ➤ Provide clear illumination for pedestrians using sidewalks at night
- ➤ Simplify median crossings to allow pedestrians to cross roads with a sense of safety
- ➤ Provide specific access sites to schools and other important activity centers
- ➤ Minimize pedestrian use and conflicts in parking locations
- ➤ Use access management techniques to control vehicle access
- ➤ Use auto restricted and parking restricted zones
- ➤ Combine walking with transit opportunities
- ➤ Design the community for a walkable scale

Another comprehensive set of recommendations on the implementation of bicycle and pedestrian facilities is found in the North Central Texas Council of Governments' *Bicycle and Pedestrian Facilities Planning and Design Guidelines* (NCTCOG 1995). As discussed in this reference, the following actions provide a framework to improve bicycle and pedestrian mobility:

Planning Policies

- ➤ Establish local development frameworks and planning processes to improve mobility for the purposeful movement of people and goods by the most efficient means possible.
- ➤ Assign a staff member with responsibility for bicycle and pedestrian traffic to coordinate elements of the community's planning, capital improvements programming, budgeting, and maintenance scheduling to ensure improved nonmotorized mobility.
- ➤ Provide transportation opportunities for various types of bicyclists and pedestrians throughout the local transportation system.
- ➤ Establish land-use and community development goals compatible with bicycle and pedestrian traffic through the local comprehensive plan.
- ➤ Establish right-of-way requirements that accommodate the complete bicycle route system, sidewalk, and

multiuse pathway system through the local thoroughfare plan.

- Utilize local development, subdivision, and zoning ordinances to establish block length guidelines, building orientation standards, and other provisions that result in average trip lengths compatible with bicycle and pedestrian mobility.
- Maintain a local capital improvement plan that provides regular funding for the bicycle and pedestrian program to acquire right-of-way, to construct new facilities, to retrofit inadequate facilities, and to refurbish older facilities.
- Include funding for regular facility evaluation, maintenance, and repair, as well as funding to review development and zoning proposals for impact on bicycle and pedestrian mobility in the annual budgets for local staff, operations, and maintenance.

Bicycle Policies

- Link trip origins and destinations with on-street bikeways designed to serve transportation purposes.
- Build and maintain street surfaces to avoid pavement conditions unsafe for bicyclists.
- Accommodate bicycle acceleration, deceleration, and travel speeds in the installation, timing and operation of traffic detection devices and traffic signals.
- Establish a signed on-street bicycle route system over the street grid system to provide bicyclists with a higher level of service than alternate routes.
- Place bicycle route signs at intervals along the route system to identify streets suitable for bicycle traffic.
- Distribute a city bike map that communicates how to safely utilize the on-street bicycle route system.
- Build or retrofit arterials and collectors with wide curb lanes to accommodate bicyclists.
- Utilize structural traffic management facilities along specified on-street bicycle routes to improve bicycle and pedestrian mobility.
- Review sites of collisions and/or bicyclists and pedestrian injuries to identify potential remedial design actions.
- Maintain bicycle routes and other on-street facilities to prevent deterioration or unsafe/impassable conditions.
- Provide off-street routes on separated rights-of-way for nonmotorized transportation that improve bicycle and pedestrian travel times.
- Design all multiuse off-street facilities in urban areas to a minimum width of 12.5 ft/3.8 m.
- Design all multiuse facilities to accommodate bicyclists traveling 20 mph/32 kph or faster.
- Utilize geometric design standards that are appropriate to the average bicyclist for off-street multiuse facilities.
- Design the intersection of off-street routes and streets to provide opportunities for only nonmotorized vehicles to safely enter or exit the facility as well as to provide

Bike Lane

safe and adequate opportunities for bicyclists and pedestrians to cross or merge with traffic.

- Install signs along off-street routes to encourage safety and proper traffic flow.
- Design bridges, overpasses, underpasses, and other structures along off-street paths to accommodate all users.
- Light off-street pathways to ensure the safety and security of those using the facility.
- Design off-street paths along active rail corridors to ensure the safety of those using the facility.
- Develop separate but parallel bicycle and pedestrian facilities to avoid the conflict between user types.
- Maintain pavement quality and facility conditions along off-street routes.
- Where equestrian use of multiuse trails is desired or expected, follow guidelines that accommodate equestrian use.

Pedestrian Policies

- Provide a complete network of pedestrian facilities, designed to accommodate all pedestrians, that serves short trip mobility needs.
- Construct walking facilities to provide an adequate pedestrian level of service for all users.
- Construct sidewalks that meet or exceed Americans with Disabilities Act standards.
- Provide street intersections that encourage safety and ease of crossings for pedestrians.
- Concentrate pedestrian improvements in pedestrian activity centers.
- Maintain pedestrian facilities to ensure the safety and functionality of the pedestrian transportation system.

Terminal Facility Policies

- Provide bicycle terminal facilities to meet the parking, storage, and user support facilities required by bicyclists.
- Install secure, short-term bicycle parking facilities that support the frame of the bicycle at or near visible entrances to public and private buildings at a frequency no less than 2 percent of automobile parking.
- Install secure long-term bicycle parking facilities that protect the bicycle from exposure to weather and potential theft.
- Identify bicycle parking not clearly visible from the street with bicycle parking signs.
- Provide locker rooms with showers and personal storage lockers at public and private buildings where long-term bicycle parking is required.
- Provide bicycle parking and carry-on opportunities at all transit facilities.

An excellent reference for creating bicycle networks is found in (Center for Transportation Studies 1996).

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ENFORCEMENT

Description: All of the actions described in this chapter require strict enforcement in order to achieve success. Enforcement of traffic regulations is a continuing effort of state and local officials, so the typical procedures are well-known. However, whenever individuals are being encouraged to change travel behavior, some reinforcement of the desired change is often necessary. The following actions should be considered as an integral part of the programs described in this chapter.

- ➤ Education: adequate time must be given to fully inform the public of the changes to be made, and of the benefits expected as a result of those changes.
- ➤ Clarity in the description of the new programs.
- ➤ Increased number of enforcement officials in the early stages of implementation.
- ➤ Reasonable fines for failure to comply with the regulations.

A number of different enforcement strategies can be used to enhance the effectiveness of actions described in this chapter. Table 2.12, for example, shows the different types of strategies that are used for HOV facilities in the United States (Federal Highway Administration 1993).

Benefits/Costs: There could be substantial expenses involved when a new program is established, or costs could be relatively minor. For example, the following annual costs are considered typical for the different types of enforcement actions listed (Environmental Protection Agency 1991).

Enforcement of traffic regulations is a continuing effort of state and local officials, so the typical procedures are well-known.

Enforcement for HOV Lane	*$70,000-$100,000 per year**
Enforcement for Downtown Management Plan	*$500,000-$1,000,000 per year**
Freeway Incident Management Systems	*$1,000,000 per mile*
Ramp metering	$50,000 per ramp

** Operating, Maintenance or Labor Cost Only*

Table 2.12: Enforcement Procedures for Selected HOV Projects

HOV Facility	Detection						Apprehension/Citation				
	HOV Code*	Foot Patrol	Line Patrol	Mobile Patrol	Sitting Patrol	Hidden Patrol	Standard Procedure	Sitting Apprehension	Wave Off	Mail	Team
Washington I-395	1A		X		X		X				
Houston I-10 & I-45	1A				X			X	X		
L A I-10 El Monte	1B		X				X				
Miami, 1-95	2		X				X				
Los Angeles Route 91	2		X			X	X	X			
Marin Co US 101	2		X		X		X				
Minneapolis I-394	1.2		X		X		X				
New Jersey Route 495	3				X			X	X		
Minneapolis I-35W	4		X		X	X	X	X		X	X
Los Angeles I-10 Santa Monica	4		X		X		X	X			X
Seattle I-5	5		X	X	X	X	X			X	
Oakland Bay Bridge	6	X	X		X		X	X		X	X

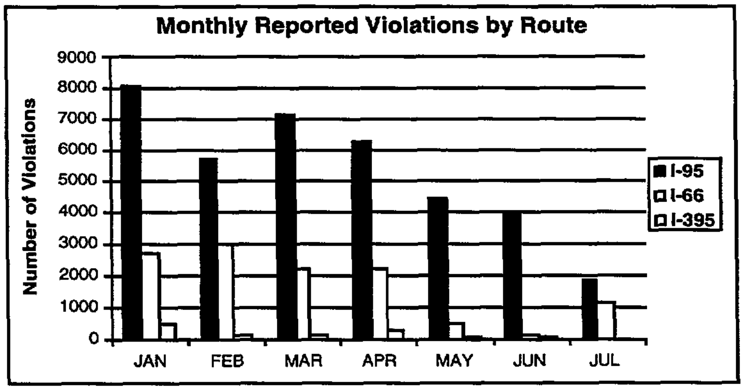
HOV Code

1A Barrier-separated facility (reversible-flow)
1B Barrier-separated facility (two-way)
2 Buffer-separated or non-separated facility (two-way)
3 Contraflow facility
4 Entry ramp with HOV bypass
5 Direct connection access ramp
6 Toll plaza queue bypass lane(s)

Source: FHWA 1993

Enforcement costs must be factored into the overall strategy for planning and implementation. The benefits derived from these costs typically have been substantial. Figure 2-18 shows the reduction in HOV violations that occurred on three HOV facilities in northern Virginia when aggressive enforcement activities were used. Figure 2-19 shows improvements in traffic operations when parking regulations were enforced in Boston (Environmental Protection Agency 1991).

Figure 2.18: Reductions in HOV Violations With Enforcement



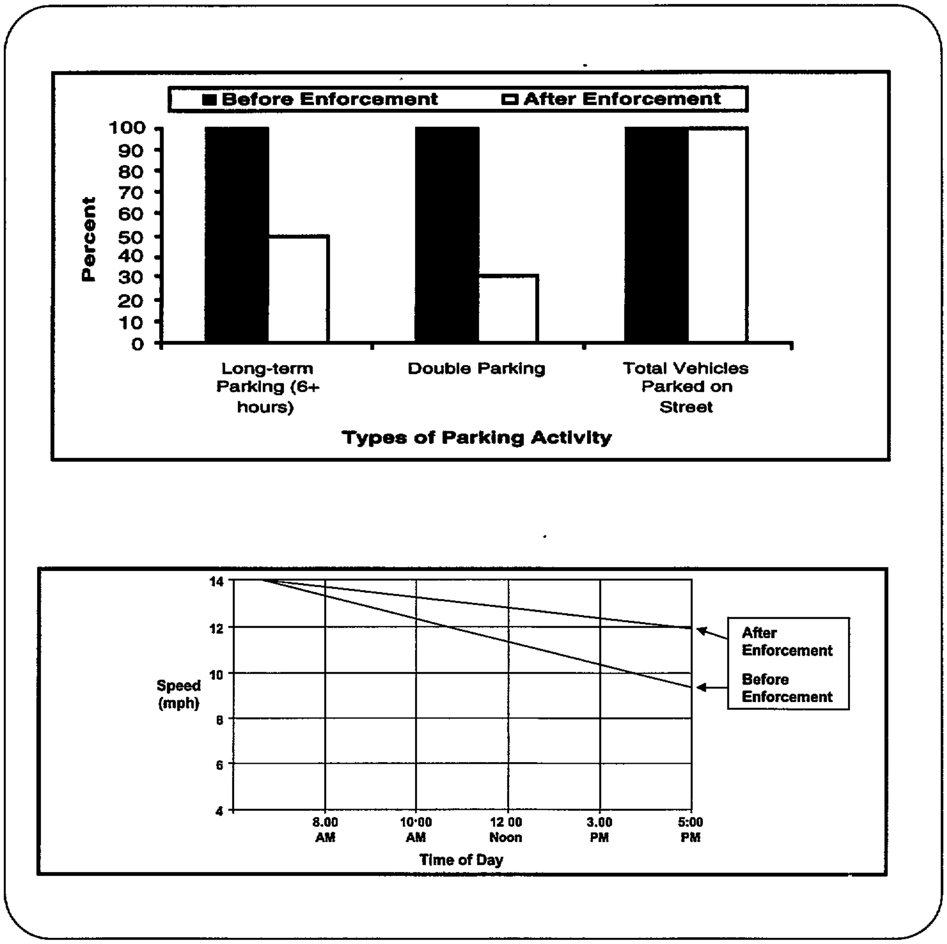
Notes: I-95 lanes are nonseparated without buffers or median shoulder
I-66 is a standard freeway, the peak direction of which is reserved for HOVs during peak periods
I-395 (Shirley) is a two-lane reversible-flow facility that is fully barrier-protected.

Source: FHWA 1993

Implementation: The following steps are considered essential for the success of the actions described in this chapter: (Meyer and Sheldon-Deen 1980)

- ➤ Enforcement is considered an important component of all the tools examined in this chapter. Therefore, substantial advanced planning is essential.
- ➤ Heavy enforcement must occur in the early stages of a project so as to reinforce the need for changes in attitudes or behavior. The enforcement can then taper off with periods of increased enforcement occurring later.

Figure 2.19: Impact of Enforcing Parking Regulations On Boylston Street in Boston



Source. EPA 1991

- Every effort should be made to overcome the technical and institutional barriers to effective enforcement so that such action can be instituted during the initial stages of the project.
- Where possible, the design of the project should provide for self-enforcement. In an auto-restricted zone project, for example, efforts should be made to design the zone so that there is little question that autos do not belong in the area.

A very important aspect of an enforcement strategy is the structure of fines which serves as a deterrent in itself if it is sufficiently onerous. Many transportation officials have pointed to the parking fine structure and relatively small fines as a good example of not discouraging violations at their source. The use of the "Denver Boot" and the resulting heavy penalties have been shown to have a positive effect on payment of past parking fines and on illegal parking.

- Enforcement is not effective unless the concept is generally acceptable to the majority of users. Therefore, a public relations or educational effort is necessary to make sure everyone understands the law and to reinforce the message that violators will be prosecuted.

A very important aspect of an enforcement strategy is the structure of fines which serves as a deterrent in itself if it is sufficiently onerous.

Transportation agencies should recognize the importance of police participation in project plan development and provide formal opportunities for their participation.

Enforcement agencies are often isolated from the transportation agencies in a metropolitan area. Traditionally, they have not held close liaison with planning and implementing agencies, and indeed have often focused resources on other issues perceived to be more important than traffic law enforcement, e.g., serious crime apprehension and prevention. On the other hand, transportation planners often ignore the potentially critical role that police officers have in the design of traffic management projects. Police representatives are often incorporated into the project planning process, but usually late in the process and without full recognition of the contribution that such representatives could make. At the local level, transportation agencies should recognize the importance of police participation in project plan development and provide formal opportunities for their participation. These opportunities should be supplemented with financial support where necessary to allow such participation.

It is important to realize that the most significant benefits of the tools described in this chapter will be achieved when a comprehensive, integrated set of actions is implemented, including enforcement. In many ways, enforcement is just as critical in the overall effectiveness of a project as is the design.

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