Chapter 14

Congestion Reduction Strategies

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All road users have experienced traffic congestion, some more than others. Most probably have an intuitive sense of what congestion is and what causes it. Americans know it makes a difference in their lives because it makes them wait in their cars, losing the opportunity to do other things. Congestion also influences where people choose to live and where they work, often limiting the range of feasible choices to households and workers.

The business community also understands congestion. Retailers, manufacturers, and shippers have to adjust their operating practices to compensate for time wasted in traffic. Because of congestion, transporting goods and services to their destinations takes longer.

Allowing for unexpected delays makes congestion even more problematic. Individuals must allow more time to arrive at important appointments. When calculating the time to travel to a given location, they must add a "buffer factor." Often, this means that they arrive early and, once again, must wait. Unreliable travel times can also affect businesses, forcing them to carry larger inventories to guard against delays in deliveries.

Chapter 4 describes the dimensions and magnitude of the congestion problem in U.S. cities, which has grown over time in both its depth and reach across the country. Chapter 13 includes a discussion of the impact that congestion has on freight movement. This chapter describes several strategies and approaches that can be used to reduce congestion on our Nation's highways.

Causes of Congestion

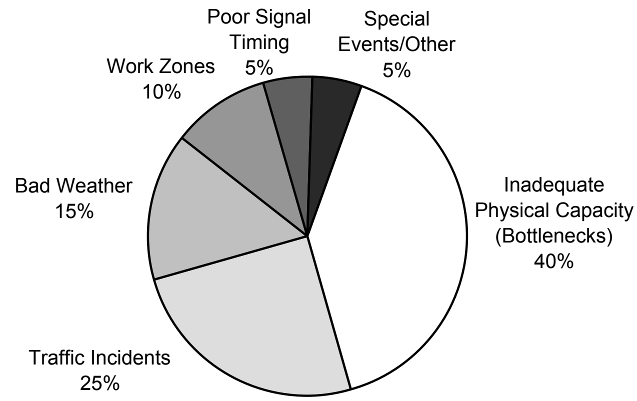
The root causes of congestion have long been understood, and there is now broad consensus that congestion generally reflects a fundamental imbalance of supply and demand. During hours of peak usage of the transportation facilities most desirable to motorists, the supply of roadway capacity is insufficient to meet the demand for those facilities. Economists have long understood that such an imbalance stems from inefficient pricing, where the true costs of usage are not reflected in prices paid by the users. For example, travelers are not generally charged for the impact their trip will have on others using the same facility (e.g., increased levels of congestion) or on other members of society (e.g., increased air pollution). In fact, in this country, access to highway travel, for the most part, is rationed by traveler delay.

The imbalance of supply and demand leading to congestion is also impacted by the absolute volume of traffic (e.g., demand) on a given facility relative to its physical capacity (e.g., supply). Looking at traffic congestion from a demand perspective means considering how many vehicles compete for space on a particular facility at a given time. The demand for a facility is a function of individual decisions as to when, where, how, and even whether highway travel will take place.

On the supply side, congestion is primarily a function of the physical characteristics of the facility and events that limit the availability of this capacity. Congestion driven by supply-side considerations is characterized as either "recurring" or "nonrecurring." This distinction is useful in helping transportation professionals devise strategies that will either mitigate or reduce congestion. Recurring congestion happens in roughly the same time and place on the same days of the week. It results when physical capacity is simply not adequate to accommodate demand during peak periods. On the other hand, nonrecurring congestion is caused by events such as work zones, traffic incidents, and bad weather. Obviously, when these nonrecurring events occur on an already congested facility, the impacts are magnified. *Exhibit 14-1* shows the factors that cause on-the-road congestion.

Exhibit 14-1

Sources of Congestion



Source: Federal Highway Administration.

In considering solutions to the congestion problem, it might be useful to think of transportation as a resource that is incrementally distributed to customers. At present, the resource is limited; there is not enough to meet everyone's requirements. Society has several options: make more of it (add new capacity), use it more productively (operate the system at peak condition and performance), provide alternatives to highway travel (encourage travel demand management strategies), and create an efficient transportation market (use congestion pricing to balance supply and demand).

Making More of It: Strategic Addition of Capacity

The traditional approach to dealing with congestion is to expand the capacity of the road network. At the beginning of the Interstate era, Federal funding provided incentives to build new highways that offered significant improvements in speed, safety, and traffic-carrying capabilities. As traffic levels increased over time, many of these roads have been widened or rebuilt with higher capacity. Today, however, concerns about air pollution, noise, and urban sprawl often stand in the way of capacity additions. Equally significant, adding new capacity can be enormously expensive and physically challenging.

The demand for new highway capacity is not only increasing but also is dynamic in nature and location. For example, locations that were rural communities in the early 1960s are now major metropolitan areas. Increases and shifts in international trade have created new trade routes and have expanded freight access requirements at seaports and major cargo hubs. The investment analyses of Part II of this report include significant discussion of future system expansion and performance.

Many capacity expansion projects are aimed at relieving bottlenecks. Traffic bottlenecks are specific roadway locations that routinely and predictably experience congestion because traffic volumes exceed capacity during periods of heavy demand. Bottlenecks are characterized by queues upstream and freely flowing traffic downstream. They may be compared to a storm pipe that can carry only so much water—during floods the excess water just backs up behind it, much the same as traffic at bottleneck locations. However, the situation is even worse for traffic. Once the traffic flow breaks down to stop-and-go conditions, capacity is actually reduced—fewer cars can get through the bottleneck because of the extra turbulence.

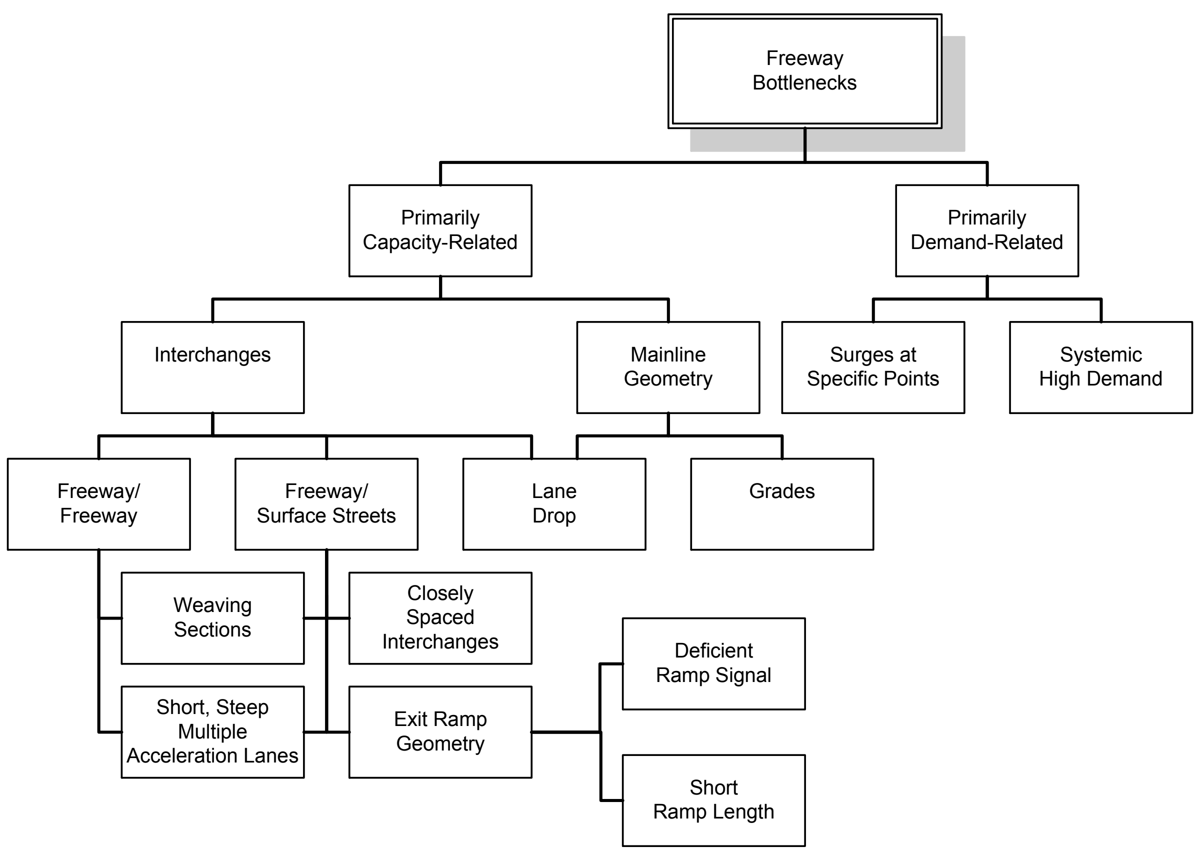
The severity of congestion at a bottleneck is related to its physical design. Some bottlenecks were originally constructed many years ago using designs that are now considered to be antiquated. Others that have been built to extremely high design specifications are simply overwhelmed by high traffic volumes. Whatever the root cause, operational conflicts can occur at lane drops (where one or more traffic lanes are lost), weaving areas (where traffic must merge across one or more lanes to access entry or exit ramps), freeway on-ramps, freeway-to-freeway interchanges, and abrupt changes in highway alignment (such as sharp curves and hills).

Exhibit 14-2 summarizes various root causes of freeway bottlenecks by category. Factors contributing to bottlenecks can be classified as being primarily demand-related or primarily capacity-related. Demand-related causes include both localized surges in traffic volumes at specific points and systemic high demand across an entire facility, corridor, or region. Capacity-related causes include items associated with mainline roadway geometry (grades, lane drops) and interchange design (lane drops, weaving sections, acceleration lanes, interchange spacing, ramp geometry, ramp signals, and ramp lengths). Multiple factors may contribute to causing a bottleneck at a particular location.

Bottlenecks have been the focus of transportation improvements—and of travelers' concerns—for many years. On much of the urban highway system, there are specific points that are notorious for causing congestion on a daily basis. These locations—which can be a single interchange (usually freeway-to-

Exhibit 14-2

Fault Tree for Freeway Bottlenecks



Source: Federal Highway Administration.

freeway), a series of closely spaced interchanges, or lane drops—are focal points for congestion in corridors. Major bottlenecks tend to dominate congestion in corridors where they exist. Many bottlenecks have become so notorious that they have acquired colorful nicknames from local motorists, such as the Mixing Bowl, the Hillside Strangler, or Malfunction Junction.

Some of these major bottlenecks, particularly those involving large freeway-to-freeway interchanges, can be addressed through major multiyear construction projects. While costly, such projects can provide congestion relief to motorists. For most other bottlenecks, however, applying operational and low-cost infrastructure solutions also may relieve congestion at much lower cost. Such strategies may include the following:

- Using a short section of shoulder as an additional travel lane during peak periods
- Restriping merge or diverge areas to better match demand
- Reducing lane widths to add a travel and/or auxiliary lane through restriping
- Modifying weaving areas (e.g., adding collector/distributor or through lanes)
- Metering or closing entrance ramps
- Adjusting speed limits when congestion thresholds are exceeded and congestion and queue formation is impending (known as "speed harmonization")
- Encouraging "zippering" to promote fair and smooth merges
- Designating reversible lanes to accommodate the prevailing direction of traffic flow during morning and evening peaks

Using It More Productively: System Operations and Management

Capacity constraints arise when physical capacity is insufficient and when capacity is temporarily reduced due to traffic incidents, work zones, inclement weather, or special events. As traffic volumes have grown over time relative to physical capacity, the system has become less able to absorb "surprise"—or nonrecurring—

Q&A

How are transportation agencies transitioning to focus on operational considerations?

The transportation community is exploring approaches for bringing management and operations (M&O) into the planning process. Underscoring the move to link planning and operations are provisions in the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) calling for both the congestion management process and the long-range transportation plan to reflect consideration of M&O strategies. The Federal Highway Administration (FHWA) is advancing a comprehensive program that assists State departments of transportation and metropolitan planning organizations in implementing SAFETEA-LU provisions. The program lays out a path for transportation agencies to move from the traditional project-oriented planning approach to an outcome-based approach.

The FHWA has established a robust program providing guidance, technical assistance, and training in performance measurement. Just as outcome-based performance measures provide the means for linking planning and operations, so too can they link transportation agencies directly to their customers. Performance information explains not only an agency's performance in providing transportation services, but also helps guide agencies (and stakeholders) toward investments and strategies with the highest payoffs for reducing congestion. An emphasis on performance outcomes will provide a common platform for transportation agencies to communicate with their customers. When the customer understands the value of M&O strategies (and the associated investment trade-offs), the project-oriented business model can change to one that is more service-oriented.

events. In the realm of managing the highway system, the margin for error is very small and continues to decline. By operating the system to maximize system performance in the first place, and being prepared to take actions to recover as quickly as possible when disruptions occur, operational strategies can make a major contribution to effective performance of the highway system at a much lower cost than capacity expansion.

Such strategies include managing temporary disruptions in a way that will return the system to full capacity quickly; ensuring more effective day-to-day operations through coordinated and up-to-date traffic signal timing and operational improvements to relieve bottlenecks; and providing real-time information about the system so that travelers can decide immediately when, where, and how to travel and transportation agencies can adjust immediately to improve system operations.

Real-Time Traveler Information

Real-time traveler information enables travelers to decide how they will use (or not use) the transportation system, influencing the choices that people make about how, when, where, whether, and which way they travel to their destinations. Real-time information enables motorists to manage the uncertainty of travel during congested conditions by leaving earlier or later, taking an alternative route, or even postponing discretionary trips. Transportation agencies also can use the information to better manage and improve the system. Traveler information on traffic conditions, transit service, parking availability, and weather conditions is being delivered through various means, including Web sites, dynamic message signs, e-mail and text message alerts, and highway advisory radio.

The development and establishment of 511 Traveler Information Systems to provide access to highway and travel conditions information in all parts of the Nation have been identified as key elements in implementing a successful national operations strategy. Such systems use the 511 telephone number dedicated by the Federal Communications Commission for relaying information to travelers. As of early 2008, there were 41 active systems in 33 States, providing access to nearly 136 million people, or about 47 percent of the U.S. population.

Real-Time System Management Information Program

Section 1201 of SAFETEA-LU requires the U.S. DOT to "establish a real-time system management information program to provide, in all States, the capability to monitor, in real time, the traffic and travel conditions of the major highways of the United States and to share that information to improve the security of the surface transportation system, to address congestion problems, to support improved response to weather events and surface transportation incidents, and to facilitate national and regional highway traveler information."

Through the Section 1201 program, agencies will be able to anticipate changes and events and take remedial actions, and provide road users with information to make better travel-related decisions. The specific goal of the program is to establish in all States the capability of sharing data on system performance nationwide. Significant opportunities exist for private sector involvement or partnering in implementing this program, including information gathering, data processing, and information dissemination. Toward this end, the FHWA published an interim guidance on data-sharing specifications and data exchange formats in 2007.

In May 2006, FHWA issued a notice in the *Federal Register* requesting comments on the proposed program goals, definitions for various parameters, the current status of related activities in the States, and implementation issues to guide development of the Real-Time System Management Information Program. Based on comments received from State DOTs and other representatives of the private sector and national associations, FHWA is developing a rule to implement the Real-Time System Management Information Program. The FHWA published a notice of proposed rulemaking in the *Federal Register* in January 2009 and anticipates issuing a final rule in late 2009 or early 2010.

Traffic Incident Management

Traffic incidents cause approximately 25 percent of all congestion, and each minute of lane blockage creates 4 minutes of congestion after the incident is cleared. Traffic incident management is a planned and coordinated process to detect, respond to, and remove traffic incidents and restore capacity as safely and quickly as possible. Effectively managing traffic incidents requires cooperation among organizations that often have conflicting on-scene priorities and operating cultures. For example, transportation agencies must interact with a variety of public and private sector partners, including law enforcement, fire and rescue, emergency medical services, public safety communications, emergency management, towing and recovery, hazardous materials contractors, traffic information media, and traffic management centers (TMCs). Promoting more aggressive and widespread traffic incident management is an important strategy to lessen the effects of nonrecurring congestion as well as provide a safer driving environment.

Real-time information is particularly critical for effective incident management. Information is necessary for locating and clearing crashes, stalled vehicles, spilled loads, and other highway debris. Efficient and rapid response, effective management of resources at the incident, and area-wide traffic control all depend on the rapid exchange of accurate and clear information among the responding parties. This exchange requires communications standards and institutional coordination among all the parties involved in responding to and clearing traffic incidents.

Work Zone Mobility

Work zones are second only to incidents as a source of delay from temporary capacity loss. Effective work zone management requires fundamental changes in the way reconstruction and maintenance projects are planned, estimated, designed, bid, and implemented. A comprehensive approach to work zone management requires minimizing work zone consequences, serving the customer around the clock, making use of real-time information, and aggressively pursuing public information and outreach.

Road Weather Management

Adverse weather is the third most common source of delay from temporary capacity loss. Although the weather cannot be changed, its effects on highway safety and operations can be reduced. Today, it is possible to predict weather changes and identify threats to the highway system with much greater precision through the use of roadside weather-monitoring equipment linked to TMCs. More precise weather information can be used to adjust speed limits and traffic signal timing; pretreat roads with anti-icing materials; pre-position trucks for deicing, sanding, or plowing; and inform travelers of changing roadway conditions.

Traffic Signal Timing and Coordination

Another source of congestion is outdated or poor signal timing at intersections. When signal timing is not updated to accommodate changes in traffic patterns, drivers may be subjected to unnecessary stops and delays. Outdated signal timing accounts for an estimated 10 percent of the total delay on major roadways, and a far greater percentage on local roadways.

Signal timing can be improved in several ways, with varying levels of complexity. At the most basic level, old signal timing plans can be updated based on more recent traffic counts. Signal controls can be upgraded, from simple signals actuated by traffic to sophisticated adaptive or even predictive computer-based controls. Interconnecting and coordinating traffic signals through a central master control can achieve the maximum benefits from traffic signal optimization.

Q&A

How does technology support the efficient operation and management of the transportation system?

Highway system operations and management strategies often depend on technology to be effective. Advanced technologies can provide system managers with the necessary information about traffic conditions to make decisions, both in responding to real-time events and in devising longer term operations and investment strategies. Technology can also provide managers with the means to control the operations of the system and to convey important information to system users.

The range of technologies used to advance highway system operations are often referred to collectively as Intelligent Transportation Systems (ITS). They include such technologies as electronic toll payment, roadway surveillance systems, and advanced traveler information systems. Such systems are being used around the country to improve the operational efficiency and safety of the transportation system. The impetus to employ ITS is growing as technology improves, congestion increases, and building new roads and bridges becomes more difficult and expensive. Many of these technologies are discussed in the highway investment analyses of Part II.

Freeway and Arterial Management Technologies. ITS technologies are being deployed to actively manage freeways and arterials in many places around the country. For instance, ramp metering on freeways is used to regulate the flow of traffic entering a facility to increase vehicle throughput and speeds. In the Minneapolis-St. Paul region, ramp metering increased vehicle throughput by 30 percent and average speeds in the peak period by 60 percent. Adaptive signal control is another type of ITS that adjusts traffic signal timing based on current traffic demand. In Los Angeles, where nearly 2,500 of the more than 4,000 traffic signals use adaptive signal control, delay at intersections with these systems is reduced by an average of 10 percent.

Traveler Information Systems. Traveler information systems use a wide variety of ITS technologies to improve highway mobility and safety. These applications are currently being used in many different situations, including road weather information systems and in work zones and during special events. A traveler information system involving traffic cameras, remote traffic microwave sensors, dynamic message signs (DMS), and highway advisory radio is used in work zones on I-30 and I-40 in central Arkansas. In Montana, weather sensors and DMS are being used to warn motorists of high winds on portions of I-90.

Transportation Management Centers. In many places, a TMC coordinates the use of ITS. A TMC is typically a central location for bringing together multiple agencies, jurisdictions, and control systems for managing traffic and transit, incident and emergency response, and traveler information. Transportation management technology includes closed-circuit television cameras, DMS, synchronized traffic signals, vehicle-flow sensors, highway advisory radio, and other high-tech devices. To manage emergencies, Houston TranStar uses a host of technologies in its Road Flood Warning Systems and the Regional Incident Management System.

Integrated Corridor Management. Transportation corridors often contain unused capacity in the form of parallel routes, the counter-peak direction on freeways and arterials, single-occupant vehicles, and transit services that could be leveraged to help reduce congestion. Traffic information is often fragmented, outdated, or not completely useful. Networks are often independently operated, and efforts to date to reduce congestion have focused on optimizing individual networks.

The combined application of technologies and a commitment of network partners to work together may transform the way corridors are operated and managed. Thanks to recent advancements in ITS technologies, a tremendous opportunity exists to integrate operations to manage total corridor capacity.

With integrated corridor management (ICM), the various institutional partner agencies manage the transportation corridor as a system—rather than the more traditional approach of managing individual assets. They manage the corridor as an integrated asset in order to improve travel time reliability and predictability, help manage congestion, and empower travelers through better information and more choices.

In an ICM corridor, because of proactive multimodal management of infrastructure assets by institutional partners, travelers could receive information that encompasses the entire transportation network. They could dynamically shift to alternative transportation options—even during a trip—in response to changing traffic conditions. For example, while driving in a future ICM corridor, a traveler could be informed of congestion ahead on that route and of alternative transportation options such as a nearby transit facility's location, timing of departures, and parking availability.

Vehicle Infrastructure Integration. In the future, vehicle-infrastructure integration (VII) may offer significant crash prevention and congestion relief that could be facilitated through vehicle-vehicle and vehicle-roadside communication. VII envisions a nationwide deployment of a communications infrastructure on the roadways and in all vehicles. Under VII, data transmitted from the roadside to the vehicle could warn a driver that it is not safe to enter an intersection. Vehicles could serve as data collectors and anonymously transmit traffic and road condition information from every major road within the transportation network. Such data would provide transportation agencies with the information needed to implement active strategies to relieve traffic congestion. A VII consortium of public agencies and private companies has been established to determine the feasibility of widespread deployment and to form an implementation strategy.

Providing Better Transportation Choices: Travel Demand Management

In addition to managing the supply of highways, agencies can affect travel demand. One way to reduce the level of demand for highway use is to ensure the availability of high-quality alternatives that meet travelers' transportation needs. Travel demand management (TDM) increases the use of travel alternatives; spreads the timing of travel to less-congested periods; reduces the need for travel; and shifts the routing of vehicles, including trucks and single-occupant vehicles, to less-congested facilities. TDM can provide travelers with choices of location, route, time, and mode.

A robust public transportation system can provide the backbone for such choices. Providing exclusive lanes for high occupancy vehicles (HOVs) during peak hours is another means of providing incentives for transportation system users to reduce their use of scarce highway capacity by sharing rides in carpools, vanpools, or buses. Bike lanes and streetscape improvements can encourage the use of non-motorized travel modes. Other tools for enhancing the attractiveness and efficiency of travel alternatives include park-and-ride facilities, guaranteed ride home programs, tax-advantaged transit benefit programs, and transit-supportive local land use controls.

Other TDM strategies are focused on shifting the times of travel or reducing the frequency and distance of trip-making altogether. Flexible work schedules, compressed workweeks, telecommuting, satellite work centers, and encouragement of mixed-use development (combining residential, commercial, and office uses in a single development) are among several options available to employers and public agencies in achieving such goals.

Traveler information systems are increasingly seen as an important tool for encouraging efficient travel choices by consumers. Online travel planning tools can help system users choose the routes and combination of modes that will best meet their travel needs. Online tools can also be used to match carpool drivers and passengers. Real time travel information can be used to notify travelers of parking availability at remote transit stations or even expected travel times on alternative modes.

Creating an Efficient Transportation Market: Road Pricing

Building new facilities and better management and operation of existing roads do not address one of congestion's root causes: that most travelers do not pay the full cost of receiving transportation services. As discussed in the introduction to Part II, when making travel decisions, travelers consider only their own travel times and vehicle operating costs; they do not consider the effects that their trips will have on others using the same facilities. For this reason, congestion often returns to newly constructed facilities, and facilities with state-of-the-art operating practices remain congested as users respond to increases in road supply and efficiency by simply making more trips. In the absence of road pricing mechanisms, highway travel—a notably inefficient market—is distributed according to the amount of time users are willing to wait.

Congestion pricing—charging a cash toll price during peak hours in order to bring supply and demand back into balance—relies on market forces and recognizes that trip values vary by individual, depending on time, location, destination, and cost, and more broadly among individuals, depending on personal preference and access to alternative travel options.

Congestion pricing incorporates both the direct cost to the traveler and the cost of delay that the traveler imposes on others. Travelers are encouraged to eliminate some lower value trips or take them at different times, or to choose alternate routes or modes of transportation, such as transit or carpooling.

Congestion pricing can take many forms. Presently, variable pricing is typically applied on a limited access facility (such as a bridge or freeway) or in a congestion charging zone around a central business district (such as in Singapore or London). In the future, charging systems using global positioning system or dedicated short-range communication technologies may make it feasible to efficiently price entire road networks.

Variable pricing can also be used to make more efficient use of existing transportation infrastructure. This provides users with the benefits of reduced congestion but at a much lower cost than adding new capacity or new technologies. For example, HOV facilities often operate at volumes well below the traffic carrying capacity of such facilities, even during peak hours. Allowing vehicles that fall below the occupancy threshold to use the facility by paying a toll (which may vary to reflect changing levels of demand) enables better use of the facility as a whole without the costly addition of new capacity. Such policies retain the incentive for carpool and transit use while also reducing traffic levels in the general purpose lanesCongestion pricing concepts can also be applied to parking. When parking is made available too cheaply, it can encourage inefficiently high levels of auto use. Underpriced parking can also contribute to localized congestion during high demand periods as motorists search for available parking spaces. Variable pricing of parking can address both of these contributors to congestion.

Conclusion

Various tools are available to policy makers and public agencies to reduce congestion on the Nation's highways. The problems caused by congested roadways call for a more thoughtful and hands-on approach to operating the transportation system to get the most out of existing investments; the United States cannot afford to underutilize the capacity already in place. The challenge to reduce congestion and increase mobility requires public agencies to think and act differently, incorporating proven operational strategies and technologies to provide congestion relief. Through the cooperative efforts of Federal, State, and local transportation agencies, the most beneficial approaches to congestion relief can be identified and adopted, significantly improving the quality of the Nation's surface transportation system.

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