Unclogging America's Arteries:

Prescriptions for Healthier Highways

Prepared for:
American Highway Users Alliance
Prepared by:
Cambridge Systematics, Inc.
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About the American Highway Users Alliance

The American Highway Users Alliance is a nonprofit advocacy organization serving as the united voice of the transportation community promoting safe and uncongested highways and enhanced freedom of mobility. Known as The Highway Users, the group works for sound transportation policy in the United States.

Since 1932, we have fought for road and bridge investments that will save lives, clean our air, promote economic growth, improve our quality of life, and protect our freedom of mobility.

Working with Congress, state and local governments, and the media, we promote a favorable climate for highway construction, efficient deliveries of raw materials and finished products, and tourism. Fair highway use taxation, federal highway funding, responsible environmental transportation policy, and highway and bridge investments are the focus of The Highway Users' campaigns.

The Highway Users includes among its 220 members corporations, small businesses, national trade associations, and state and local nonprofit organizations that represent over 45 million highway users.

Cambridge Systematics, Inc.

Cambridge Systematics is an internationally recognized consulting firm providing transportation planning, policy, and management services for a wide variety of clients. Its headquarters is located in Cambridge, Massachusetts with other major offices in Washington, D.C. and Oakland, California. Cambridge Systematics is an employee-owned company and was founded in 1972.

The Context of this Study

Unclogging America's Arteries was prepared by Cambridge Systematics, Inc. for the The Highway Users in conjunction with a national conference on mobility, *Driving America*. Sponsored by The Highway Users on November 30 and December 1 at the National Press Club in Washington, DC, *Driving America* is designed as a forum for examining the problems, pitfalls, and potential solutions to the growing gridlock on our highways. During the conference, some of the top transportation minds in the country will present effective, affordable solutions that can reduce traffic congestion, cut highway crashes that kill and maim tens of thousands each year, improve air quality, and ensure businesses that their products and supplies will reach their destinations on time and in good condition.

The Highway Users publishes studies, reports about transportation trends and developments, as well as other pertinent issues that affect highway safety and mobility. For information about our periodicals and other reports, contact The Highway Users' web site: www.highways.org.

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American Highway Users Alliance
1776 Massachusetts Avenue, NW, Suite 500
Washington, DC 20036

Telephone: 202-857-1200
Facsimile: 202-857-1220
E-mail: GoHighway@aol.com
Internet: www.highways.org

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1. Executive Summary

This first-of-its-kind study examines a significant cause of traffic congestion—America's worst bottlenecks—from three perspectives. First, it examines how much worse the gridlock will become at each of the 18 worst bottlenecks in the United States if no improvements are made. Second, it makes individual, city-specific evaluations of the benefits of improving these locations. In particular, the report evaluates how fixing each bottleneck will

- **Save Lives**—by reducing crashes and their attendant fatalities and injuries;
- **Save the Environment**—by reducing emissions of carbon dioxide (CO_2)—a greenhouse gas—and air pollutants; and
- **Save Time**—by reducing the delays (to motorists and businesses) associated with congestion.

Finally, the report calculates the combined benefits of improving bottlenecks nationwide. Collectively, improvements to these 167 serious bottlenecks would prevent 287,200 crashes (including 1,150 fatalities and 141,000 injuries). CO_2 emissions would drop by an impressive 71 percent at these bottlenecks. Emissions of smog-causing volatile organic compounds would drop by 44 percent, while carbon monoxide would be reduced by 45 percent. And rush hour delays would decline by 71 percent, saving commuters an average of almost 40 minutes each day.

A Comprehensive Examination of the Benefits of *Unclogging America's Arteries*

A full and true estimate of the benefits of congestion relief must include an analysis of lives saved; debilitating injuries averted; cleaner air; affordable products and fresh foods at the market; and more time for family activities, recreation, and work.

Saving Lives. Traffic congestion causes highway crashes that can kill drivers and their passengers. As highway crowding increases and motorists jockey for position at exits and entryways, the potential for crashes increases. Improving bottlenecks saves lives and averts injuries.

Saving the Environment. Bottlenecks retard the nation's otherwise impressive progress in improving air quality. Vehicles caught in stop-and-go traffic emit far more pollutants—carbon monoxide, volatile organic compounds, and nitrogen oxides—than they do when operating *without* frequent braking and accelerations. Improving bottlenecks reduces tailpipe pollutants.

Reducing Greenhouse Gas Emissions. Vehicles emit CO_2, a greenhouse gas, as fuel is consumed. The longer they are delayed in traffic, the more fuel they consume and the more CO_2 they emit. Nationwide, 6.7 billion gallons of fuel are wasted annually because of urban congestion. Reducing delays has a direct effect on reducing greenhouse gases.

Saving Time. Traffic congestion is a major source of frustration for American travelers, adding stress and inciting road rage. Reducing road delays eases that frustration and gives motorists more time for families, errands, work, and play.

Enhancing Productivity. Bottlenecks also delay product deliveries, inhibiting productivity and raising costs. Businesses suffer direct economic consequences because of congestion: In the world of "just-in-time" deliveries, time really is money. Congested roadways can also discourage businesses from bringing their business and jobs to urban areas. Improving bottlenecks boosts productivity and economic health.

Prescriptions for Healthier Highways

There seems to be a growing sentiment that gridlock is an unavoidable part of modern life. Transportation officials, the media, and even motorists seem resigned to the "fact" that congestion can only get worse—certainly never better.

While past experience shows that no single strategy can adequately address the problems of metropolitan congestion, the good news is that there *are* effective solutions that can reduce traffic congestion, cut the number of fatalities and injuries from crashes, improve air quality, curb greenhouse gas emissions, and give us more time with our family and friends. This study shows that these benefits can be realized at high congestion locations throughout the country. However, these benefits must be weighed against implementation costs on a case-by-case basis.

To help accomplish these benefits, a balanced, comprehensive approach to traffic congestion that uses all the tools at our disposal can lessen the stifling gridlock found on many of our highways. This approach needs to include improving the convenience and safety of transit. At the same time, we need to use the roads we already have in the most efficient way possible. Investing in smart road technologies—such as synchronized traffic lights, computerized systems to route traffic around congested areas, and options like reversible commuter lanes and movable barriers that add road capacity during peak hours of travel—will help. By tailoring and scaling improvement packages to individual situations, implementation costs can be minimized.

But in many instances, as highlighted by the bottlenecks discussed in this study, our overstressed road system needs additional capacity at key points. Providing that capacity by removing strategic bottlenecks, as part of an overall program of congestion relief, will reduce the amount of time commuters have to spend on the road, save hundreds of lives, prevent thousands of injuries, and help us safeguard the environment.

2. Introduction

What This Study Is About

Highway traffic congestion is a major source of frustration for American travelers, causing an estimated 4.6 billion hours of delays per year.[1] Put another way, in the largest metropolitan areas, trips during rush hours take an average of 35 percent longer than if they occurred when no congestion was present. Besides adding to the frustration and stress levels of American drivers, traffic congestion also has strong economic, environmental, and safety consequences as well. When vehicles are delayed in traffic, they emit far more pollutants and consume far more fuel than if traffic congestion did not exist: An estimated 6.7 billion gallons are wasted because of metropolitan congestion.[2] In addition, as highway crowding increases, so does the potential for crashes. Businesses also suffer direct economic consequences because of congestion: In the world of "just-in-time" delivery services, time really is money. Finally, businesses and individuals often decide where to locate based on congestion patterns in a metropolitan area. When dollar values are assigned to the value of travel time and excess fuel consumed, the cost of congestion is staggering: $74 billion in 1996.[3] If environmental, safety, and relocation costs had been included, this figure would be much higher.

This study was undertaken to examine a major cause of traffic congestion: the highway bottleneck. In nearly every American city, there are one or more highway locations that have notorious reputations among travelers—heavy traffic congestion occurs in these areas every weekday, and sometimes on weekends, for several hours during the morning and afternoon rush periods. For our purposes, a bottleneck is a specific, physical location on the highway that routinely experiences traffic backups. We have focused on bottlenecks because they are easily recognized and because their removal can lead to immediate and positive improvements in traffic flow. Also, average national statistics, such as those reported above, can mask the most serious problems experienced by many travelers; considering bottleneck locations draws attention to these extreme conditions. Specifically, we have set three objectives for this study:

1. Identify the worst traffic bottlenecks in the United States, recognizing that some cities may have more than one. We have focused in detail on those bottlenecks that create the longest delays for travelers, and we limited our consideration to interstate highways and other freeways.
2. Estimate the benefits to travelers and the environment by removing the bottlenecks, based on the actual improvement plans if they exist. The benefit estimation is driven by a set of assumptions and analysis methods, as detailed in Appendix A.
3. Estimate the benefits to be derived from removing bottlenecks nationwide. There are many more bottlenecks in the country than those identified in this report. These bottlenecks occur not only in the major metropolitan areas but in smaller ones as well. We examine the effects of removing these bottlenecks.

[1] Lomax, Tim, and Schrank, David, *Urban Mobility Study—1996*, Texas Transportation Institute, Texas A&M University, 1998.
[2] Lomax and Schrank, 1998.
[3] Lomax and Schrank, 1998.

Highway Travel in Metropolitan Areas: Is It Getting Better or Worse?

We begin with an examination of recent trends in congestion. The best single source for monitoring congestion trends is produced annually by the Texas Transportation Institute (TTI). In their 1998 report,[4] TTI's researchers found that congestion levels have grown throughout the 1990s. Between 1990 and 1996,

- The percentage of travel on congested metropolitan freeways increased from 51 to 61 percent.
- The percentage of congested travel on other major metropolitan highways increased from 56 to 65 percent.
- Annual hours of delay per eligible driver rose from 27 to 40.

Given these statistics, an economic expansion that is likely to persist for the foreseeable future, and continued population growth, we can expect further increases in traffic congestion.

What Can We Do About Traffic Congestion?

Transportation engineers and planners have developed a variety of strategies to deal with congestion. These fall into several general categories:

1. **Increasing the Number of Highways.** Adding more lanes to existing highways and building new ones has been the traditional response to congestion. In some metropolitan areas, however, it is becoming increasingly difficult to undertake major highway expansions because of funding constraints, increased right-of-way and construction costs, and opposition from local and national groups. Many metropolitan areas now have plans limiting new highway expansion.
2. **Getting More Out of What We Have.** In recent years, transportation engineers have applied advanced technologies based on using real-time information about highway conditions to implement control strategies. Referred to as Intelligent Transportation Systems (ITS), real-time control of highway operations has become a major activity undertaken by transportation agencies. ITS control strategies take many forms: metering flow onto freeways, dynamically retiming traffic signals, managing traffic incidents, and providing travelers with alternative routes and modes. In addition to ITS technologies, other strategies to improve the efficiency of the existing road system have been implemented, including reversible commuter lanes, movable median barriers to add capacity during peak periods, and restricting turns at key intersections. The idea behind nonexpansion strategies is to increase the efficiency of the *existing* transportation infrastructure. ITS deployments—as well as other efficiency-oriented nonexpansion projects—are increasing, but their uses are limited. First, a sound base infrastructure must already exist before ITS is used. Second, only so much extra efficiency can be squeezed out of an already-stressed highway system. Third, these projects compete with other transportation improvements for funding.
3. **Minimizing Vehicle Miles of Travel—Travel Demand Management (TDM) and Nonautomotive Travel Modes.** Other approaches to the problem of congestion involve managing the demand for highway travel. These strategies include putting more people into fewer vehicles (through ridesharing or dedicated highway lanes for high-occupancy vehicles), shifting the time of travel (through staggered work hours), and eliminating the need for travel altogether (through telecommuting). The major barrier to the success of TDM strategies is that they require an adjustment in the lifestyles of travelers and the requirements of employers. Flexible scheduling is simply not possible for a large number of American workers, which limits the effectiveness of TDM strategies. Investing in nonautomotive modes of travel—such as rail and bus transit systems and bikeways—is another strategy for reducing the number of personal use vehicles on the highway system. These

[4] Lomax and Schrank, 1998.

What Is a Traffic Bottleneck?

The layman's definition of a bottleneck as "too many cars trying to use a highway at the same time" is essentially correct. Transportation engineers formalize this idea as capacity—the ability to move vehicles past a point over a given span of time. When the capacity of a highway section is exceeded, traffic flow breaks down, speeds drop, and vehicles crowd together. These actions cause traffic to back up behind the bottleneck.

So, what situations would cause the overload that leads to traffic backups? When traffic volume is high but vehicles are moving at relatively high speeds, it may take only the sudden slowing down of one driver to disrupt traffic flow. However, this sort of bottleneck is short-lived, and unless the slowing vehicle stops in the lane for a significant amount of time, traffic flow will quickly recover. More persistent bottlenecks are caused by either an inefficient design that reduces highway capacity or increasing driver demand for a stretch of highway. Examples of highway-related bottlenecks include

- Areas where a traffic lane is lost
- Restrictive side clearances (such as barriers located very close to the edge of a traffic lane)
- Areas where traffic must merge across several lanes to get to and from entry and exit points (called "weaving areas")
- Traffic signals or tollbooths
- On-ramps

In all cases (except for traffic signals and tollbooths) the actual cause of traffic flow disruption can be traced to vehicles merging into lanes already crowded with other vehicles. Work zones and traffic incidents (vehicle crashes, stalled vehicles) are also considered to be bottlenecks because they induce the same effects. However, for the purposes of this study, *only bottlenecks related to specific highway features and design are considered*. Delays from tollbooths are *not* included in the study because they are not found nationwide and thus are best treated as special cases. Both work zones and incidents, while important to consider as part of an overall program of congestion management, are temporary restrictions of traffic flow.

approaches can be an excellent supplement to the highway system, particularly for commuter trips. However, in most metropolitan areas, the level of investment required to meet transportation demand solely through these means is massive and infeasible. Still, when considered as part of an overall program of transportation investments, TDM and nonautomotive modes of travel can contribute substantially to a metropolitan area's transportation system.

4. **Managing Urban Growth and Form.** The historical cycle of suburban growth has led to an ever-increasing demand for travel. Suburban growth was originally fueled by downtown workers who moved from city centers to the urban fringe to take advantage of lower land prices and greater social amenities. In the past 10 years, businesses have also moved to the suburbs to be closer to their employees. This in turn allows workers to live even further away from city centers, thereby perpetuating suburban expansion. To influence these processes, strategies that attempt to manage and direct urban growth have been used in several metropolitan areas. These include land use controls (zoning), growth management restrictions (urban growth boundaries and higher development densities), and taxation policy (incentives for high-density development). The main problem with many of these strategies is that they often are contrary to market trends, burdening

consumers with extra costs and dampening economic efficiency.

It is clear from past experience that no single strategy can adequately address the problems of metropolitan congestion. However, a balanced, comprehensive approach to traffic congestion can lessen the stifling gridlock found on many of our highways. Such an approach needs to include improving the convenience and safety of transit. At the same time, we need to use the roads we already have in the most efficient way possible. Investing in smart road technologies—such as synchronized traffic lights and computerized systems to route traffic around congested areas—and options such as reversible commuter lanes and movable barriers that add road capacity during peak hours of travel will help.

But in many instances, as highlighted by the projects included in this study, our overstressed road system needs additional capacity at key points. Providing that capacity by removing strategic bottlenecks, as part of an overall program of congestion relief, will reduce the amount of time commuters have to spend on the road, will save hundreds of lives, prevent thousands of injuries, and help us safeguard the environment.

Congestion Caused by Traffic Incidents vs. Congestion Caused by Highway Features

Bottlenecks, for the purposes of this study, are specific highway locations where physical features or designs cause traffic backups. These locations have historically been choke points in the system, and traffic queues there consistently, especially during weekday rush hours. Transportation engineers refer to congestion produced by these bottlenecks as *recurring congestion* because it occurs regularly. Traffic incidents—any abnormal occurrence that causes a temporary blockage or otherwise affects traffic flow—are the other major source of congestion in metropolitan areas. Incident-related congestion is referred to as *nonrecurring congestion* because it does not happen in the same location with the same characteristics with any regularity. Although most people consider traffic crashes to be the predominant type of incident, they in fact comprise only 10 to 15 percent of all incidents; other incident types include vehicular breakdowns and debris in the road. However, traffic crashes are by far the most serious type of incident because they take the longest time to clear and block the most lanes.

Incidents are a major source of total delay in urban areas. In 1996, more than half of the total delay in the 70 largest cities was caused by incidents.[5] Incident delay has been found to be a function of several factors: traffic volume, available highway space (capacity), characteristics of incidents (how frequently they occur and how long and severe they are), and availability of wide shoulders.[6] Many of the same improvements that aim to fix physical bottlenecks can affect these factors as well. For example, additional lanes increase highway capacity, and transit or high-occupancy vehicle alternatives can lower traffic volume. However, these positive effects on reducing incident delay were not assessed in this study.

[5] Lomax and Schrank, 1998.

[6] Cambridge Systematics, *Sketch Methods for Estimating Incident-Related Impacts*, prepared for the Federal Highway Administration, December 1998.

Vehicle Emissions

As vehicles operate, transforming the chemical energy of motor fuel into the kinetic energy of motion, they produce a number of gases that are by-products of internal combustion. The four vehicle emissions examined by this study are the most important from a public policy standpoint.

Criteria Pollutants

The Environmental Protection Agency tracks the emission of six major pollutants, known as criteria pollutants. Three of the six criteria pollutants are found in tailpipe emissions. They are

- *Carbon monoxide*—Carbon monoxide poses a direct health threat to people by entering the bloodstream through the lungs and forming carboxyhemoglobin, a compound that inhibits the blood's capacity to carry oxygen to organs and tissues.
- *Volatile organic compounds*—These emissions mix with nitrogen oxides in the atmosphere and, in the presence of ultraviolet light, form smog.
- *Nitrogen oxides*—Nitrogen oxides are the other half of the smog-forming duo mentioned above.

Greenhouse Gases

Carbon dioxide (CO_2) is a natural by-product of both internal combustion and human respiration. While not a pollutant, increased CO_2 emissions may affect the Earth's climate. Because CO_2 is known to trap heat in the Earth's atmosphere, it is often referred to as a "greenhouse gas."

The Relationships: Why Reducing Congestion Saves Lives, the Environment, and Time

Residents in each of the cities identified as having one of the nation's worst traffic bottlenecks would realize substantial benefits—in terms of lives saved, injuries avoided, tailpipe pollutant and greenhouse gas emissions reduced, and time saved on the average commute—by fixing those chokepoints.

- *Saving Lives*. Popular wisdom often suggests that gridlock can be good for highway safety, based on the assumption that lower travel speeds lead to a lower risk of serious and fatal crashes. However, as highway crowding increases and motorists jockey for position at exits and entryways, the potential for crashes actually increases. Outdated highway design at many bottlenecks also can lead to serious crashes.

- *Saving the Environment*. Congestion is a serious barrier to the nation's otherwise impressive air quality progress. Under most conditions, vehicles caught in stop-and-go traffic emit far more pollutants—carbon monoxide, volatile organic compounds, and nitrogen oxides—than they do when operating *without* frequent braking and acceleration. However, the relationships between average vehicle speed and these pollutants can conflict. Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides (NO_X), however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of NO_X and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve, especially compared with making no improvements at all.

  Vehicles stuck in traffic also increase emissions of carbon dioxide, a greenhouse gas. Vehicles emit CO_2 as fuel is consumed. The longer they are delayed in traffic, the more fuel they consume and thus the more CO_2 they emit.

- *Saving Time*. Traffic congestion is a major source of frustration for American travelers. Reducing road delays eases that frustration and gives motorists more time for families, errands, work, or play. Congestion also has real economic consequences for businesses. Delays in shipments caused by urban congestion can lead to increased costs for transportation that are ultimately passed on to consumers.

  Because reconstruction often causes additional delays by reducing highway capacity, this report takes into account projected construction-period delays when analyzing the time savings attributable to improvements at each bottleneck site. To estimate construction-related delay, we assume that motorists will lose 20 percent of available highway capacity during the entire reconstruction period. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible. Even assuming these construction delays, the time savings produced by the bottleneck improvements outweigh the additional delays caused by road work, based on these assumptions.

Congestion: It's Not Just for Metropolitan Areas Anymore

Analysis of data reported to the Federal Highway Administration reveals a dramatic trend: Since 1988, traffic has grown substantially on rural highways and at a faster pace than on metropolitan highways. The table below shows that between 1988 and 1997, traffic on rural interstates increased 40 percent compared with an increase of 24 percent on urban interstates. Further analysis shows that traffic volumes per available lane also increased by 40 percent on rural interstates compared with 20 percent on urban interstates. Further, trucks now comprise 10 percent more of the rural interstate traffic stream than they did in 1988. By 2005, 10 percent of rural interstate mileage will be operating at what is generally considered to be unacceptable crowding levels for rural conditions,[7] while 6 percent will experience severe congestion.

Growth in Key Traffic Statistics, 1988–1997

Traffic Statistic	Rural Interstate Growth	Urban Interstate Growth
Total Daily Volume	+40%	+24%
Daily Volume per Traffic Lane	+40%	+20%
Trucks in Traffic Stream	+10%	+13%

Source: Analysis of Highway Performance Monitoring System data

[7] Level of service D, as defined in the *Highway Capacity Manual*, Transportation Research Board.

3. Unclogging America's Worst Bottlenecks

To identify, rank, and assess the nation's worst bottlenecks, we relied on information provided by local transportation planning agencies and state transportation departments, coupled with recently developed analytic methods for assessing the impacts of transportation decisions. Briefly described, our methodology involved a survey of transportation officials in the 30 most congested cities in the nation, as identified by the 1998 report on area-wide congestion by the Texas Transportation Institute. Transportation officials in those cities were asked to nominate candidate bottlenecks from their area, which were then examined and ranked by analysts at Cambridge Systematics, Inc. For a more thorough discussion of the methodology, see Appendix A.

Ranking the Bottlenecks

Based on the Cambridge analysis, the table on page 13 displays the 18 worst traffic bottlenecks in the United States, ranked by total hours of delay.[1] It should be noted that other analysis methods, distinct from the methodology employed by this report, might produce different rankings. Though such alternative analyses might cause some shifting in the ranking order, we would still expect the locations identified here to show up as severe bottlenecks because of the solicitation of these locations from local experts and the high-volume nature of these sites. Still, with such small differences between two adjacent bottlenecks on the list, care must be exercised before concluding that one location is substantially worse than another.

A cutoff point of 9 million annual hours of delay was established for identifying bottlenecks for detailed analysis. Bottlenecks below this cutoff were not studied in detail but are included in the national-level analysis later in this chapter. A total of 18 bottlenecks met this 9-million-hours-of-delay threshold. Several other bottleneck locations came close to the delay cutoff. Prominent among them are:

- I-95/I-595 interchange in Fort Lauderdale, Florida (8.7 million hours of annual delay);
- I-80 east of the Bay Bridge in San Francisco, California (7.6 million hours of annual delay);
- I-278 (Gowanus Expressway) in Brooklyn, New York (7.5 million hours of annual delay);
- I-35W Crosstown Commons in Minneapolis, Minnesota (7.4 million hours of delay); and
- I-95/I-495 at the Wilson Bridge in suburban Washington, D.C. (5.9 million hours of delay).

The delay estimates listed above are modeled according to the same assumptions used for the 18 bottlenecks selected for detailed analysis (see Appendix A).

The choice of total hours of delay as the ranking criterion implies that higher traffic volume roadways will be favored. For example, consider two bottlenecks, one with low volume and one with high volume. Also assume that the relationship between traffic volume and available capacity is the same at each bottleneck—that is, the *unit* delay (e.g., minutes of delay per vehicle) at each site is the same. In this example, *total* delay will be higher at the higher volume bottleneck simply because more

[1] The delay calculations for the rankings do not consider the effect of any current work zones.

vehicles are subjected to congested conditions. Consequently, it would be ranked higher on our list.

As a final caveat, congestion is systemic in many of the larger urban areas in the United States. Entire corridors can operate at unacceptable levels of service (characterized by low speeds over long distances), and several locations along the corridor can be potential bottlenecks, depending on daily conditions. In these cases, the one location with the most severe conditions was identified as the bottleneck. Transportation agencies have recognized the problem of systemic congestion and have created improvement strategies that treat the entire corridor, rather than a specific location. Even in cases in which a single severe bottleneck can be identified, planned improvements almost always include improvements to local streets in the bottleneck vicinity and often to interchanges upstream and downstream of the bottleneck. In the case of systemic congestion in corridors, highway improvements aimed at the entire corridor along with transit and demand management strategies are often employed.

Describing the Bottlenecks and the Benefits of Fixing Them

On the following pages, we detail each of the 18 bottlenecks and show the benefits that residents in those cities would realize—in terms of lives saved and injuries avoided, tailpipe pollutant and greenhouse gas emissions reduced, and time saved on the average commute—by fixing those chokepoints.

In every instance except one,[2] transportation officials have identified the location as a serious problem and plan to improve traffic flow through the bottleneck. Many of the bottleneck locations are under reconstruction or have specific design plans. Where the design is known, the benefits analysis is based on an estimate of the capacity increase attributable to that design. Where no specific improvements have been approved, our analysis posits hypothetical improvements that would bring traffic operations at the bottleneck up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers. This analysis is conservative, because traffic engineers typically design so that level of service D conditions or better will still exist 10 to 20 years in the future.

For each bottleneck, we provide two analyses—"Vital Statistics" and "Benefits of Improvements."

Vital Statistics

- **Vehicles per Day.** Current and projected future daily traffic volumes at the bottleneck. The most recent year for which complete data on current traffic volumes are available is 1997. Using the applicable traffic growth rate for each bottleneck location, we show projected traffic volumes at each site in 2020.
- **Peak Period Delay.** The additional time motorists currently spend stuck in traffic at this bottleneck, and the delay that will occur in 2020 at this site if no improvements are made.
- **Annual Traffic Growth Rate.** The percentage rate by which traffic volumes are projected to grow annually at the particular bottleneck location.

[2] The I-5/I-90 Interchange in Seattle, Washington.

- **Saving Lives.** The cumulative total reduction in crashes, fatalities, and injuries over the multiyear construction period and the 20-year life of the project.
- **Saving the Environment.** The cumulative total reduction in emissions of carbon monoxide, volatile organic compounds, nitrogen oxides, and carbon dioxide[3] over the multiyear construction period and the 20-year life of the project.
- **Saving Time.** The peak period delay, with improvements to the bottleneck and with no improvements, averaged over the multiyear construction period and 20-year project life.

The Clogs in America's Arteries*

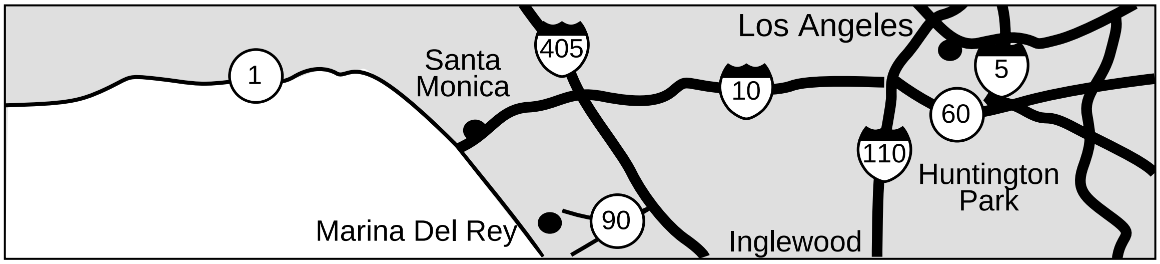
Rank	City	Freeway	Location	Vehicles per Day	Annual Hours of Delay (000)
1	Los Angeles	I-405	I-10 jct.	296,400	22,284
2	Houston	US-59 (SW Fwy)	I-610 jct.	321,000	22,085
3	Seattle	I-5	I-90 jct.	283,226	21,884
4	Boston	I-93 (Central Artery)	US-1 jct.	223,300	20,264
5	Washington, DC (MD)	I-495	I-270 jct.	255,500	20,145
6	Washington, DC (VA)	I-95	I-495 jct.	267,000	19,629
7	Los Angeles	US-101 (Ventura Fwy)	I-405 jct.	278,000	18,787
8	Los Angeles	SR-55 (Newport Fwy)	SR-22 jct.	221,500	18,049
9	Los Angeles	I-10 (Santa Monica Fwy)	I-5 jct.	308,787	16,364
10	Albuquerque	I-40	I-25 jct.	209,900	16,029
11	Atlanta	I-285	I-85 jct. (De Kalb Co.)	256,400	14,013
12	Atlanta	I-75	I-85 jct.	234,700	13,496
13	Chicago	I-290	I-88/I-294 jct.	220,635	12,628
14	Denver	I-25	I-225 jct.	192,000	11,296
15	Houston	I-610	I-10 jct.	251,540	10,877
16	Washington, DC (VA)	I-66	I-495 jct.	196,000	10,220
17	Washington, DC (MD)	I-95/I-495	US-1 to I-95 N jct.	168,025	10,115
18	Atlanta	I-285	I-75 jct.	220,400	9,585

* In reviewing the list of bottleneck locations identified by this report, readers will note that none of the worst bottlenecks are in the New York City area. As most travelers know, congestion in and around the boroughs of New York can be significant. However, a very large share of delay in the New York area is related to bridge and tunnel crossings into Manhattan, most of which are toll facilities. Early in the study, we decided to exclude toll facilities from our ranking of the worst bottlenecks in the United States. The reason for this exclusion is that toll facilities are fundamentally different from other physical bottlenecks (such as freeway-to-freeway interchanges) that are prevalent around the country. Delay comparisons between toll facilities and other types of bottlenecks might not be consistent since different modeling techniques would be used. If objective field measurements of delay could be made at all locations around the country, several river crossings into Manhattan would no doubt be included in a list of the nation's worst bottlenecks.

[3] Note: analysis does not assume implementation of "Tier II" emissions standards or "Zero Emission Vehicle" requirements in California, New York, and Massachusetts, although these changes should have little, if any, impact on the percentage change between emissions with and without improvements to the bottleneck site.

1 Los Angeles, California

I-405 (San Diego Freeway) at the I-10 Interchange



Summary

Once the proposed improvements to the I-405 corridor are completed, residents of Los Angeles will realize gains in safety, air quality, and overall quality of life. Over the 20-year life of the improvements, there will be 4,560 fewer crashes (including 18 fewer fatalities and 2,240 fewer injuries), a 33 percent decrease in smog-causing volatile organic compounds, and a 53 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours will shave 15 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, 30 minutes of commuting time will be saved daily. These figures include the effect of a two-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Vital Statistics: I-405 at the I-10 Interchange
Major Route: I-405

	1997	2020 (estimated)
Vehicles per Day:	296,395	401,600
Peak Period Delay (minutes per vehicle per trip):	15.4	32.7 (Without Improvements)
Annual Traffic Growth Rate:	1.33%	

Bottleneck Description

I-405, also known as the San Diego Freeway, connects to I-5 both north and south of Los Angeles and is a major access route for the coastal communities in the Los Angeles area. I-10 intersects with I-405 only a few miles from its western terminus in Santa Monica. The University of California at Los Angeles and Los Angeles International Airport are in close proximity to the interchange. The California DOT (Caltrans) District 7 estimates that the 11-mile segment of I-405 between I-10 and US-101 experiences congestion for almost five hours every weekday afternoon.

Benefits of Improvements: 2000–2021

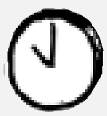
Over the 2-year construction period and the 20-year life of the project, completing the planned improvements to the I-405 corridor will significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

4,560 fewer total crashes, including 18 fewer fatalities and 2,240 fewer injuries in the vicinity of the interchange (a 17 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	527,296	353,126	33.0
Volatile Organic Compounds:	56,779	38,521	32.6
Nitrogen Oxides:	46,861	43,046	8.1
CO_2 ("greenhouse gas" emissions):	5,669,887	2,664,203	53.0



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	24.6	9.6	61.1

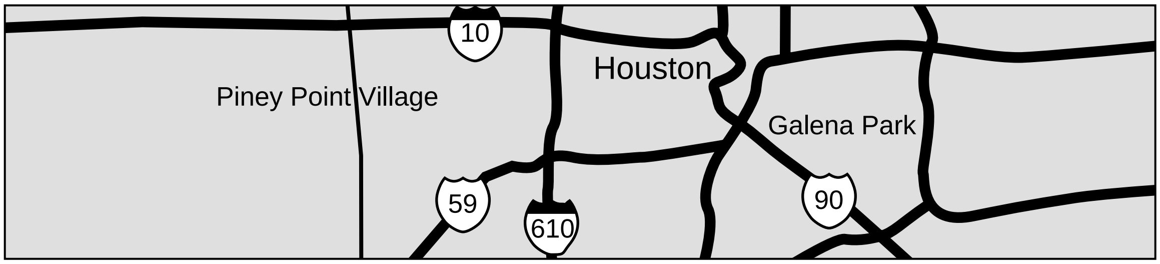
Proposed Improvements

The most recent federal Transportation Improvement Program from the Southern California Association of Governments identifies the addition of an HOV lane in each direction on I-405 on both sides of the interchange. The project is expected to start in 2000 and last two years. This is the improvement that was studied.

Federal law requires all metropolitan areas to prepare a Transportation Improvement Program (TIP). A TIP generally has a three-year planning horizon and details exactly which projects are proposed for federal funding during each of those three years.

2 Houston, Texas

US-59 (Southwest Freeway) at the I-610 Loop Interchange



Summary

If needed improvements to the US-59/I-610 interchange were implemented, Houston residents would realize significant gains in safety, air quality, and overall quality of life. The Texas DOT has identified this interchange as a major source of congestion. Major expansion of the interchange and adjacent highways, however, is constrained by nearby commercial development, making the purchase of needed right-of-way very expensive. While it is likely that the interchange will be reconfigured in the future to accommodate more traffic, no specific improvements have been designed at this time. Consequently, for purposes of this report, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

Vital Statistics: US-59 at the I-610 Interchange
Major Route: US-59

	1997	2020 (estimated)
Vehicles per Day:	321,000	513,400
Peak Period Delay (minutes per vehicle per trip):	14.1	49.7 (Without Improvements)
Annual Traffic Growth Rate:	2.06%	

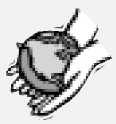
Better operations at this interchange might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps, to smooth the flow of merging traffic; the addition of HOV lanes; corridor access for bus or rail transit; and flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local levels, reflecting the wishes and concerns of

Benefits of Improvements: 2000–2022

Allowing for a 3-year reconstruction period and a 20-year project life, bringing the US-59/I-610 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

7,507 fewer total crashes, including 30 fewer fatalities and 3,685 fewer injuries in the vicinity of the interchange (a 21 percent decrease).



Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	818,933	461,319	43.7
Volatile Organic Compounds:	87,986	49,994	43.2
Nitrogen Oxides:	61,859	55,656	10.0
CO_2 ("greenhouse gas" emissions):	9,786,227	3,614,829	63.1

Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	33.5	10.1	69.9

the general public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

Over the 20-year life of the improvements, there would be 7,507 fewer crashes (including 30 fewer fatalities and 3,685 fewer injuries), a 43 percent decrease in smog-causing volatile organic compounds, and a 63 percent decrease in CO_2. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 23 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, over 45 minutes of commuting time would be saved each day. These delay numbers include the effect of a three-year reconstruction phase during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

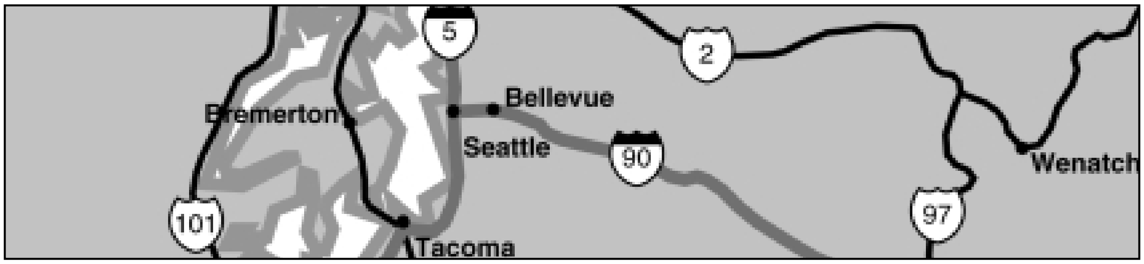
US-59, known locally as the Southwest Freeway, runs from Laredo on the Mexican border through the center of downtown Houston. It is heavily used by local and through traffic and, as a North American Free Trade Agreement trade corridor linking Mexico, the industrial northeastern United States, and Canada, carries a significant amount of truck traffic. It is also a major commuter route between Fort Bend County and Houston. Fort Bend is projected to grow at a rate faster than the rest of the region over the next 20 years. Traffic volumes on US-59 through the interchange are the second highest in the country.

I-610 was Houston's original "beltway." With the construction of the Sam Houston Parkway—a perimeter highway further out—I-610 now serves as an inner beltway.

It should be pointed out that Texas DOT has undertaken a Major Investment Study for the US-59 corridor in Fort Bend County, southwest of the US-59/I-610 interchange. The study indicates a "preferred alternative" of adding HOV lanes in the study area.

3 Seattle, Washington

I-5 at the I-90 Interchange



Summary

If traffic operations at the interchange or in the corridor were improved, Seattle residents would undoubtedly realize benefits in terms of safety, air quality, and time savings. Because state officials do not anticipate making any physical improvements at this site, however, we have not estimated benefits from such improvements.

Vital Statistics: I-5 at the I-90 Interchange
Major Route: I-5

	1997	2020 (estimated)
Vehicles per day:	283,226	479,600
Peak Period Delay (minutes per vehicle per trip):	13.3	39.7 (Without Improvements)
Annual Traffic Growth Rate:	2.25%	

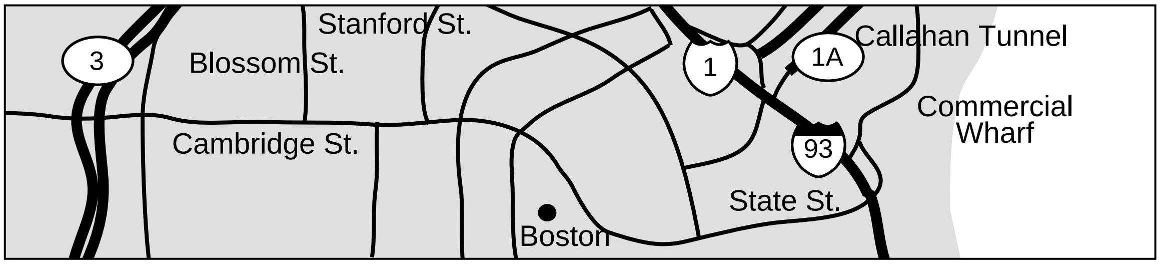
Bottleneck Description

I-5 and I-90 intersect less than two miles from downtown Seattle. The junction is the western terminus of I-90, one of the nation's major east-west interstates. Lake Washington limits access to downtown Seattle from the eastern suburbs, and I-90 is one of only two crossings providing this access. (SR-520 is the other crossing.) The entire I-5 corridor south of downtown Seattle is routinely congested in morning and afternoon peak hours.

Potential improvements at the I-5/I-90 interchange and in the I-5 corridor on either side are constrained by physical and topographic limitations. The interchange is elevated, and physical expansion of the ramps and through lanes would be very expensive. To deal with this dysfunctional interchange and with the rest of the corridor, the Washington DOT has already instituted aggressive transportation system management techniques in the corridor, including HOV lanes, ramp metering, and incident management. Officials also are considering expanding transit service in the corridor, including the construction of a light rail line. However, barring approval of expensive highway expansion in this area, Washington DOT does not anticipate any physical improvements to the I-5/I-90 interchange in the future.

4 Boston, Massachusetts

I-93 (Central Artery) in Downtown Boston: The "Big Dig"



Summary

When the "Big Dig" is completed, Boston residents will realize tremendous gains in safety, air quality, and overall quality of life. Over the 20-year life of the improvements, there will be 4,485 fewer crashes (including 18 fewer fatalities and 2,200 fewer injuries), a 60 percent decrease in smog-causing volatile organic compounds, and a 92 percent decrease in CO_2 emissions than would otherwise have occurred at this site without the improvements. In addition, motorists and truckers traveling on I-93 during morning or evening rush hours will shave 20 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice each day, 40 minutes of commuting time will be saved daily. Because the Big Dig is also connecting and improving many other highways in the area, motorists will realize significant time savings as a result of these improvements.

Vital Statistics: Central Artery
Major Route: I-93

	1997	2020 (estimated)
Vehicles per Day:	223,300	296,600
Peak Period Delay (minutes per vehicle per trip):	13.1	27.0 (Without Improvements)
Annual Traffic Growth Rate:	1.24%	

Bottleneck Description

The original section of I-93 was constructed as an elevated six-lane highway called the Central Artery, which runs through the center of downtown Boston. When it opened in 1959, the Central Artery comfortably carried about 75,000 vehicles a day. Today it carries as many as 223,300 vehicles daily, resulting in long periods of congestion. I-93 is a major commuter route into downtown Boston from the northern suburbs.

Proposed Improvements

The Central Artery/Tunnel (CA/T) project, the Big Dig, is one of the most massive tunneling projects undertaken in U.S. history. It spans 7.5 miles—161 lane miles in all, about half of which are in tunnels—and includes four major highway interchanges to connect the new roadways with the existing regional highway system.

The Big Dig has been under construction since late 1991. As of May 1, 1999, final design is about 98 percent complete and construction is about 53 percent complete. The next construction milestone, a bridge across the Charles River connecting I-93 in Charlestown with Leverett Circle and Storrow Drive, is scheduled to be finished in 1999. The I-90 extension through South Boston to the Ted Williams Tunnel and Logan Airport will open in 2001. The northbound lanes of the underground highway, replacing the elevated

Benefits of Improvements: 2004–2023

Over the 20-year project life, the planned improvements to the Central Artery will significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

4,485 fewer total crashes, including 18 fewer fatalities and 2,200 fewer injuries in the vicinity of the interchange (a 23 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Carbon Monoxide:	405,644	159,527	60.7
Volatile Organic Compounds:	43,633	17,452	60.0
Nitrogen Oxides:	33,630	38,915	(+15.7)*
CO_2 ("greenhouse gas" emissions):	4,594,618	347,347	92.4

Saving Time

	Minutes per Vehicle per Trip (averaged over project life)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Peak Period Delay	22.7	2.7	88.1

* Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides, however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of nitrogen oxides and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve.

Central Artery, are scheduled to open in 2002, and the southbound lanes will open in 2003. The entire project will be finished in 2004, including demolition of the elevated highway and restoration of the surface.

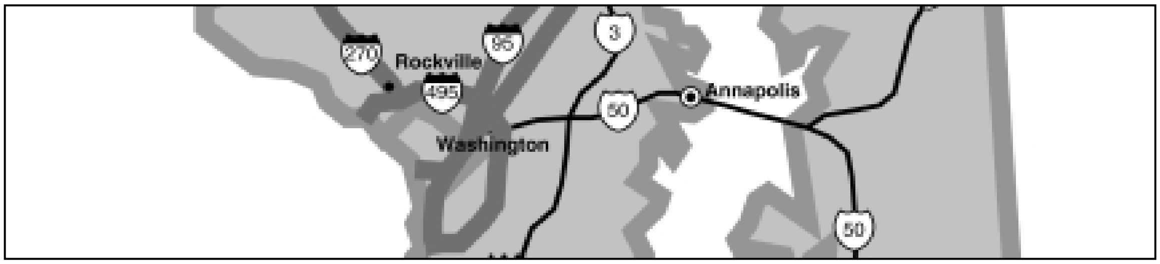
The CA/T project will cost $10.8 billion at its completion in 2004. Highlights of the improvements include the following:

- The Central Artery (I-93) will carry 245,000 or more vehicles a day comfortably, with normal urban peak periods of about two hours in the morning and evening. Even peak traffic is expected to move steadily compared with the stop-and-go pace of today, when as many as 223,300 vehicles clog the Artery with traffic jams for six to eight hours every day. If nothing were done, Artery traffic would be bumper to bumper for up to 16 hours a day—every waking hour—by 2010.
- The combination of 8 to 10 lanes on the underground expressway (compared with just 6 on today's elevated highway), fewer on- and off-ramps, and a new network of surface streets will allow through traffic to travel at highway speeds. Vehicles in local traffic will travel on city streets instead of weaving back and forth, jockeying for position on the freeway.

Because the existing I-93 structure is not being disturbed to any significant degree, there is no period of reconstruction during which traffic delays will increase substantially.

5 Washington, DC/Maryland

I-495 (Capital Beltway) at the I-270 Interchange



Summary

If needed improvements to the I-495/I-270 interchange were implemented, residents of the Washington, DC, metropolitan area would realize significant gains in safety, air quality, and overall quality of life. The Maryland State Highway Administration currently is studying the entire I-495 corridor within Maryland. The study will determine the feasibility of providing HOV lanes and/or other transit improvements. No specific improvements to the I-495/I-270 interchange are planned for the next five years, but the location remains a high priority, and the Maryland State Highway Administration recognizes that future physical improvements may be required. For the purposes of this report, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

Vital Statistics: I-495 at the I-270 Interchange
Major Route: I-495

	1997	2020 (estimated)
Vehicles per Day:	255,525	493,100
Peak Period Delay (minutes per vehicle per trip):	16.7	52.1 (Without Improvements)
Annual Traffic Growth Rate:	2.90%	

Better operations at this interchange might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps, to smooth the flow of merging traffic; the addition of HOV lanes; corridor access for bus or rail transit; and flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local levels,

Benefits of Improvements: 2000–2022

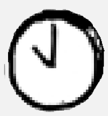
Allowing for a 3-year construction period and a 20-year project life, bringing the I-495/I-270 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

8,618 fewer total crashes, including 34 fewer fatalities and 4,230 fewer injuries in the interchange vicinity (26 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Carbon Monoxide:	881,065	425,924	51.7
Volatile Organic Compounds:	94,514	46,098	51.2
Nitrogen Oxides:	58,309	52,569	9.8
CO_2 ("greenhouse gas" emissions):	11,266,762	3,412,318	69.7



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Peak Period Delay	42.7	10.4	75.8

reflecting the wishes and concerns of the general public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

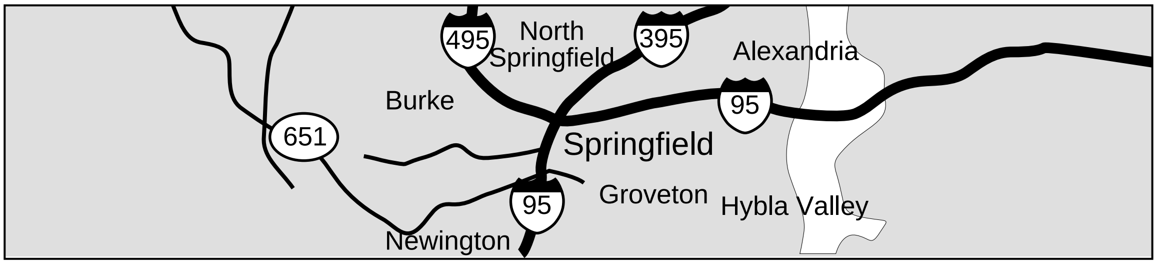
Over the 20-year life of the improvements, there would be 8,618 fewer crashes (including 34 fewer fatalities and 4,230 fewer injuries), a 51 percent decrease in smog-causing volatile organic compounds, and a 70 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 32 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, over one hour of commuting time would be saved daily. These figures include the effect of a three-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

I-495, the Capital Beltway, is the beltway for the Washington, DC, area, crossing through both Maryland and Virginia. I-270 terminates where it meets I-495 and runs northwest to Frederick, Maryland. It is a major commuter corridor that has experienced—and is expected to continue experiencing—rapid growth. I-270 has two "branches" where it intersects with I-495; the western branch is the I-270 spur, which connects with I-495 more than two miles from the main interchange of I-495 and I-270. Even with this bifurcation, traffic volumes at the I-495/I-270 interchange are extremely high. The problem is compounded by the nearby interchange of Wisconsin Avenue (SR-355).

6 Washington, DC/Virginia

I-95 at the I-495 (Springfield Interchange): "The Mixing Bowl"



Summary

When improvements to the "Mixing Bowl" are completed, residents of the Washington, DC, metropolitan area will realize gains in safety, air quality, and overall quality of life. Over the 20-year life of the improvements, there will be 6,223 fewer crashes (including 25 fewer fatalities and 3,055 fewer injuries), a 45 percent decrease in smog-causing volatile organic compounds, and a 68 percent reduction in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours will shave 17 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, nearly 35 minutes of commuting time will be saved per day. These figures include the effect of a nine-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Vital Statistics: I-95/I-495 Interchange (The Mixing Bowl) Major Route: I-95

	1997	2020 (estimated)
Vehicles per Day:	267,000	365,700
Peak Period Delay (minutes per vehicle per trip):	11.8	25.8 (Without Improvements)
Annual Traffic Growth Rate:	1.38%	

Bottleneck Description

Known locally as the Mixing Bowl (for its complex configuration of ramps and traffic movements), the Springfield interchange is located about 10 miles south of downtown Washington, DC. I-95, a major intercity corridor, intersects with I-495 (the Capital Beltway), and the two interstates continue together eastward into Maryland. Nearby, I-395 (Shirley Highway) takes traffic from I-95 and I-495 north into Washington, DC. The Springfield interchange was built in 1964 with the construction of the Capital Beltway. Since that time, the area has undergone rapid development, which has contributed significantly to congestion.

Benefits of Improvements: 2000–2028

Over the 9-year construction period and the 20-year life of the project, completing the planned improvements to the Mixing Bowl will significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

6,223 fewer total crashes, including 25 fewer fatalities and 3,055 fewer injuries in the vicinity of the interchange (an 18 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	755,581	411,882	45.5
Volatile Organic Compounds:	81,240	44,682	45.0
Nitrogen Oxides:	60,459	79,882	(+32.1)*
CO_2 ("greenhouse gas" emissions):	8,729,286	2,798,545	67.9

Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	24.3	7.4	69.6

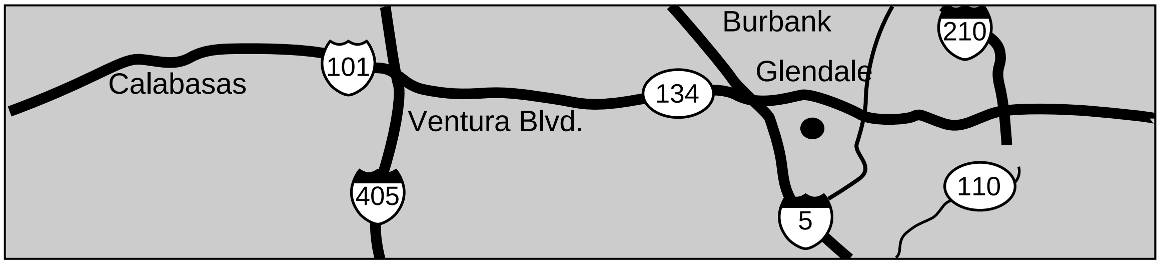
* Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides, however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of nitrogen oxides and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve.

Proposed Improvements

The improved interchange is being designed to accommodate future growth, and its construction is a massive, nine-year undertaking. Through traffic will be separated from local traffic, so the current weaving and merging sections will be eliminated. The new interchange will have 24 lanes at its widest point and include 50 bridges. In addition, significant improvements to local streets in the vicinity are also being undertaken. The cost of the project is estimated to be $350 million.

7 Los Angeles, California

US-101 (Ventura Freeway) at the I-405 Interchange



Summary

If needed improvements to the Ventura Freeway/I-405 interchange were implemented, Los Angeles residents would realize significant gains in safety, air quality, and overall quality of life. The most recent federal Transportation Improvement Program of the Southern California Association of Governments recognizes this interchange as congested, but it does not identify specific improvements to be undertaken. Like many freeways in Los Angeles, it is difficult to distinguish a dominating physical bottleneck; long stretches of highway operate at similar levels of service (usually poorly) during peak periods. For that reason, corridor- or area-wide strategies, including the addition of HOV lanes, transit improvements, traffic lights on freeway entrance ramps, and real-time traveler information systems are employed to address congestion. Such strategies, combined with the reconfiguration of the US-101/I-405 interchange, may improve traffic flow at this site. Because no specific improvements to the interchange have been designed at this time, however, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Vital Statistics: US-101 at the I-405 Interchange
Major Route: US-101

	1997	2020 (estimated)
Vehicles per Day:	278,000	374,750
Peak Period Delay (minutes per vehicle per trip):	13.9	28.5 (Without Improvements)
Annual Traffic Growth Rate:	1.31%	

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local level,

Benefits of Improvements: 2000–2022

Allowing for a 3-year construction period and a 20-year project life, bringing the US-101/I-405 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

5,230 fewer total crashes, including 21 fewer fatalities and 2,570 fewer injuries in the vicinity of the interchange (a 20 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	496,427	287,950	42.0
Volatile Organic Compounds:	53,484	31,307	41.5
Nitrogen Oxides:	45,574	46,006	(+1.0)*
CO_2 ("greenhouse gas" emissions):	5,193,470	1,595,752	69.3

Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	23.0	6.4	72.3

* Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides, however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of nitrogen oxides and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve.

reflecting the wishes and concerns of the general public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

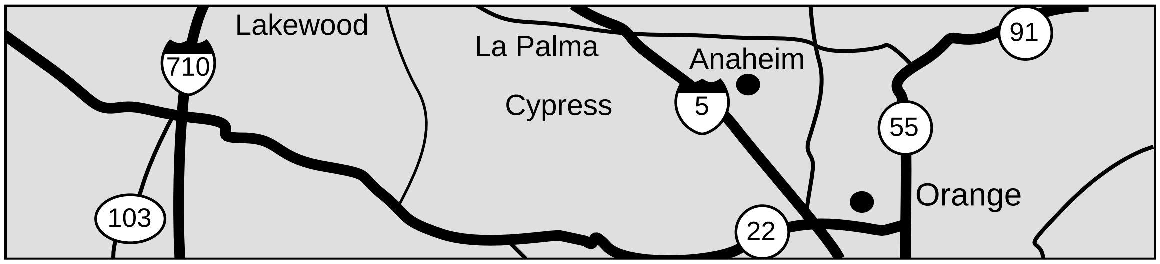
Over the 20-year life of the improvements, there would be 5,230 fewer crashes (including 21 fewer fatalities and 2,570 fewer injuries), a 42 percent decrease in smog-causing volatile organic compounds, and a 69 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 17 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice each day, nearly 35 minutes of commuting time would be saved daily. These figures include the effect of a three-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

The US-101/I-405 interchange is located in the San Fernando Valley area north of Beverly Hills. Commuters from the west and north destined for downtown Los Angeles must pass through this area. Caltrans District 7 estimates traffic is congested in this area for nearly five hours every weekday afternoon.

8 Los Angeles, California

State Route 55 (Newport Freeway) at the State Route 22 Interchange



Summary

Once the improvements to the Newport Freeway corridor are completed, the people of Los Angeles will realize gains in safety, air quality, and overall quality of life. Over the 20-year life of the improvements, there will be 5,600 fewer crashes (including 22 fewer fatalities and 2,750 fewer injuries), a 51 percent decrease in smog-causing volatile organic compounds, and a 74 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours will shave 26 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, more than 50 minutes of commuting time will be saved per day. These figures include the effect of a three-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Vital Statistics: SR-55 at the SR-22 Interchange
Major Route: SR-55

	1997	2020 (estimated)
Vehicles per Day:	221,518	335,400
Peak Period Delay (minutes per vehicle per trip):	16.3	49.7 (Without Improvements)
Annual Traffic Growth Rate:	1.82%	

Bottleneck Description

The SR-55/SR-22 interchange is located on the border of the cities of Orange and Santa Ana in Orange County. SR-55 links to SR-91 about five miles north of the interchange; together they represent a major commuter route from the San Bernardino-Riverside area to the commercial districts of coastal Orange County. Caltrans District 7 estimates that an eight-mile segment through the SR-55/SR-22 interchange area is congested for four and a half hours every weekday afternoon.

Benefits of Improvements: 2000–2022

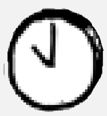
Over the 3-year construction period and the 20-year life of the project, completing the planned improvements will significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

5,600 fewer total crashes, including 22 fewer fatalities and 2,750 fewer injuries in the vicinity of the interchange (a 24 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	550,360	268,513	51.2
Volatile Organic Compounds:	59,126	29,144	50.7
Nitrogen Oxides:	41,341	38,577	6.7
CO_2 (“greenhouse gas” emissions):	6,602,540	1,738,662	73.7



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	34.0	7.7	77.4

Proposed Improvements

The most recent federal Transportation Improvement Program from the Southern California Association of Governments recommends the addition of HOV lanes on SR-55 from the SR-22 interchange to the junction with SR-91. The work is currently under way and should be completed within a year. This is the improvement that was studied.

9 Los Angeles, California

I-10 (Santa Monica Freeway) at the I-5 Interchange

Summary

If needed improvements to the I-10/I-5 interchange were implemented, Los Angeles residents would realize significant gains in safety, air quality, and overall quality of life. The most recent federal Transportation Improvement Program of the Southern California Association of Governments recognizes this interchange as a congestion area, but it does not identify specific improvements to be undertaken. As with many freeways in Los Angeles, it is difficult to distinguish a dominating physical bottleneck; long stretches of highway operate at similar levels of service (usually poor) during peak periods. For that reason, corridor- or area-wide strategies, including the addition of HOV lanes, transit improvements, traffic lights on freeway entrance ramps, and real-time traveler information systems, are employed to address congestion. Such strategies, combined with the reconfiguration of the I-10/I-5 interchange, may work to improve traffic flow at this site. No specific improvements to the interchange have been designed at this time; however, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Those decisions are properly made at the state and local level, reflecting the wishes and concerns of the general public, budgetary priorities, and applicable

Vital Statistics: I-10 at the I-5 Interchange
Major Route: I-10

	1997	2020 (estimated)
Vehicles per Day:	308,787	415,200
Peak Period Delay (minutes per vehicle per trip):	10.9	24.5 (Without Improvements)
Annual Traffic Growth Rate:	1.30%	

Benefits of Improvements: 2000–2022

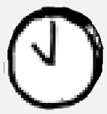
Allowing for a 3-year construction period and a 20-year project life, bringing the I-10/I-5 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

4,865 fewer total crashes, including 19 fewer fatalities and 2,400 fewer injuries in the vicinity of the interchange (a 17 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	500,693	315,443	37.0
Volatile Organic Compounds:	54,012	34,255	36.6
Nitrogen Oxides:	49,294	50,627	(+2.7)*
CO_2 ("greenhouse gas" emissions):	4,899,124	1,698,903	65.3



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	19.5	6.2	68.3

* Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides, however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of nitrogen oxides and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve.

legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

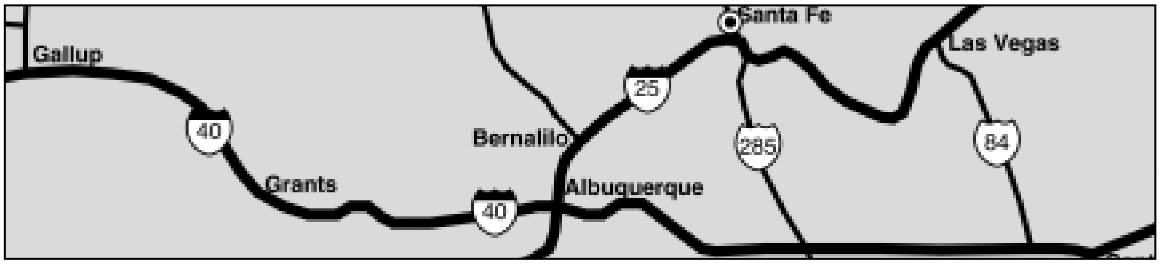
Over the 20-year life of the improvements, there would be 4,865 fewer crashes (including 19 fewer fatalities and 2,400 fewer injuries), a 37 percent decrease in smog-causing volatile organic compounds, and a 65 percent reduction in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 13 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, over 25 minutes of commuting time would be saved each day. These delay numbers include the effect of a three-year reconstruction phase during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

The I-10/I-5 interchange is located on the eastern edge of the City of Los Angeles in an area where many freeways converge. Dodger Stadium, the University of Southern California, and the Civic Center are all in close proximity to the interchange. Caltrans District 7 estimates that traffic is congested in this area for four hours every weekday afternoon.

10 Albuquerque, New Mexico

I-40 at the I-25 Interchange: The "Big I"



Summary

Once the proposed improvements to the "Big I" are completed, the people of Albuquerque will realize enormous gains in safety, air quality, and overall quality of life. Over the 20-year life of this reconstructed intersection, there will be 4,800 fewer crashes (including 19 fewer fatalities and 2,300 fewer injuries), a 56 percent decrease in smog-causing volatile organic compounds, and a 77 percent decrease in carbon dioxide (CO_2) emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours will shave 31 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice each day, more than an hour of commuting time will be saved daily. These figures include the effect of a two-year construction phase, during which the state anticipates moderate additional delays attributable to reduced highway capacity.

Vital Statistics: The Big I
Major Route: I-40

	1997	2020 (estimated)
Vehicles per Day:	209,900	384,800
Peak Period Delay (minutes per vehicle per trip):	15.3	48.4 (Without Improvements)
Annual Traffic Growth Rate:	2.67%	

Bottleneck Description

So called because it resembles a giant eye when viewed from the air, the Big I is the junction of Interstate 25 and Interstate 40 near Albuquerque's downtown district. These two highways are vital to both the regional and local transportation systems. At the regional level, both I-25 and I-40 are primary routes used for interstate travel and goods shipment. I-25 serves as the primary highway connecting the international border area of the United States and Mexico with I-10, I-40, SR-70, and other regional highways used for travel and transporting goods within and across the southwestern United States. I-40 is a transcontinental highway extending from California to North Carolina and is heavily used for commercial goods transport and by interstate travelers.

The current structures at the interchange are over 30 years old and approaching the point at which major reconstruction will be needed just to keep the current overpasses and ramps in a safe physical condition. It is estimated that one out of every three trips taken in the Albuquerque region passes through the Big I.

The problems facing the Big I demonstrate that serious congestion is no longer a concern primarily experienced in major metropolitan

Benefits of Improvements: 2000–2021

Over the 2-year construction period and the 20-year life of the project, the planned improvements to the Big I will significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

4,800 fewer total crashes, including 19 fewer fatalities and 2,300 fewer injuries in the vicinity of the interchange (a 17 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	624,150	274,070	56.0
Volatile Organic Compounds:	66,962	29,472	55.6
Nitrogen Oxides:	37,240	33,925	8.9
CO_2 ("greenhouse gas" emissions):	7,840,499	1,799,111	77.0

Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay:	39.5	8.9	77.0

areas. When the right combination of factors come together, big-league congestion can occur even in a city the size of Albuquerque (385,000 population). In the case of the Big I, the intersection of major north-south and east-west trade routes in the center of downtown, coupled with Albuquerque's recent fast growth and outdated interchange design, produces a level of congestion usually reserved for much larger cities. Many cities have dealt with similar conditions by building "beltways" around the downtown perimeter. However, in the case of the Big I, where the traffic choke-point is the interchange itself, reconstruction is a more cost-effective solution than a beltway.

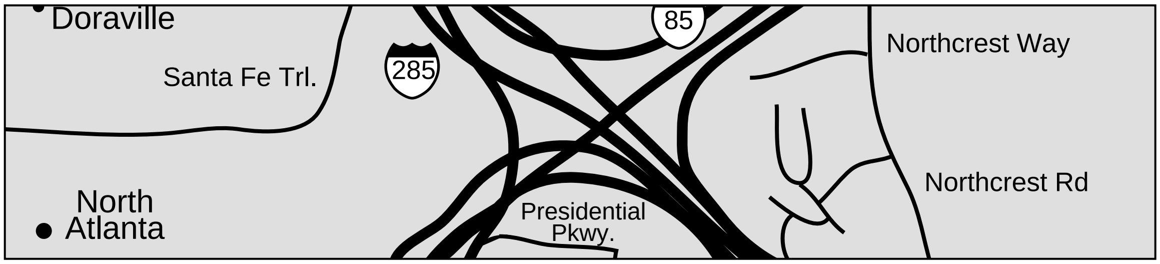
Proposed Improvements

The proposed improvements to the Big I include the reconstruction of the I-25/I-40 interchange and adjacent sections of the interstate system and frontage roads. Improvements are also proposed to arterial streets where they cross and/or intersect with the interstate system. The project area includes the portions of I-25 and I-40 bounded at the north by the Comanche Road interchange, at the east by the Carlisle Boulevard interchange, at the south by the Dr. Martin Luther King, Jr. Avenue interchange, and at the west by the 6th Street interchange. The estimated cost of the improvement is $210 million. Construction is scheduled to start in January 2000 and be completed by March 2002.

The New Mexico State Highway and Transportation Department (NMSHTD) has developed an aggressive traffic management plan for dealing with the construction's effect on traffic. The most important impact on construction-related delay may be the two-year time frame; it represents an accelerated scheduling of the required activities. NMSHTD also is instituting a Traffic Management Center, which will include video surveillance of the interchange to detect crashes and stalled vehicles, variable message signs to alert drivers to delays, roving highway courtesy patrols, and highway advisory radio alerts.

11 Atlanta, Georgia

I-285 at the I-85 Interchange



Summary

If needed improvements to the I-285 and I-85 interchange were implemented, Atlanta residents would realize significant gains in safety, air quality, and overall quality of life. The Georgia DOT recognizes the severity of traffic congestion problems on these two major freeways, but no specific improvements are scheduled for the I-285/I-85 interchange at this time. Consequently, for purposes of this report, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

Better operations at this interchange might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps, to smooth the flow of merging traffic; the addition of HOV lanes; corridor access for bus or rail transit; and flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local levels, reflecting the wishes and concerns of the general public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

Vital Statistics: I-285 at the I-85 Interchange
Major Route: I-285

	1997	2020 (estimated)
Vehicles per Day:	256,400	473,200
Peak Period Delay (minutes per vehicle per trip):	11.2	48.6 (Without Improvements)
Annual Traffic Growth Rate:	2.70%	

Benefits of Improvements: 2000–2022

Allowing for a 3-year construction period and a 20-year project life, bringing the I-285/I-85 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

6,957 fewer total crashes, including 28 fewer fatalities and 3,420 fewer injuries in the vicinity of the interchange (a 23 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Carbon Monoxide:	750,484	418,548	44.2
Volatile Organic Compounds:	80,599	45,289	43.8
Nitrogen Oxides:	54,708	49,501	9.5
CO_2 ("greenhouse gas" emissions):	9,136,067	3,407,798	62.7

Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Peak Period Delay	35.5	10.7	69.7

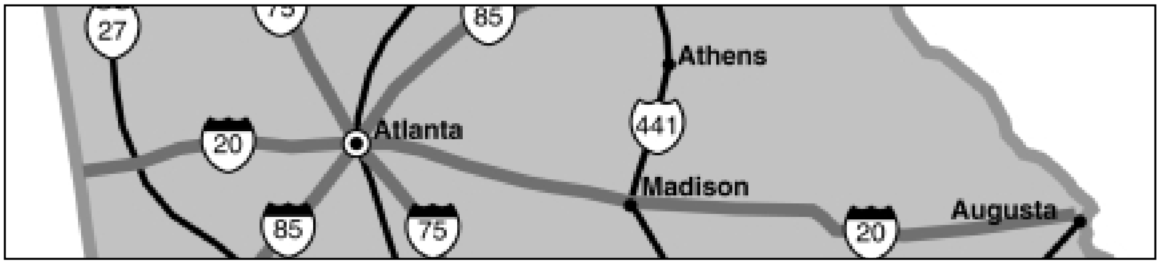
Over the 20-year life of the improvements, there would be 6,957 fewer crashes (including 28 fewer fatalities and 3,420 fewer injuries), a 44 percent decrease in smog-causing volatile organic compounds, and a 63 percent decrease in CO_2 emissions than would otherwise occur at this site without the improvements. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 25 minutes off their driving time each trip. For commuters, who typically negotiate the interchange once in the morning and once in the evening, 50 minutes of commuting time would be saved each day. These delay numbers include the effect of a three-year reconstruction phase during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

I-285 and I-85 intersect in De Kalb County about 15 miles northeast of downtown Atlanta. I-85 serves both as a commuter route and as a major intercity route for the southeastern United States. The area around the interchange has undergone rapid growth during the past decade, and this trend is expected to continue. The Georgia DOT maintains an aggressive traffic management program on Atlanta freeways, including surveillance, incident management, and traveler information.

12 Atlanta, Georgia

I-75 at the I-85 Interchange



Summary

If needed improvements to the I-75 and I-85 interchange were implemented, Atlanta residents would realize significant gains in safety, air quality, and overall quality of life. The Georgia DOT recognizes the severity of traffic congestion problems on these two major freeways, but no specific improvements are scheduled for the I-75/I-85 interchange at this time. Consequently, for purposes of this report, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Vital Statistics: I-75 at the I-85 Interchange
Major Route: I-75

	1997	2020 (estimated)
Vehicles per Day:	234,700	358,900
Peak Period Delay (minutes per vehicle per trip):	11.8	38.0 (Without Improvements)
Annual Traffic Growth Rate:	1.86%	

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

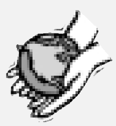
Better operations at this interchange might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps, to smooth the flow of merging traffic; the addition of HOV lanes; corridor access for bus or rail transit; and flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local levels, reflecting the wishes and concerns of the general public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

Benefits of Improvements: 2000–2022

Allowing for a 3-year construction period and a 20-year project life, bringing the I-75/I-85 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

4,887 fewer total crashes, including 20 fewer fatalities and 2,400 fewer injuries in the interchange vicinity (a 20 percent decrease).



Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	497,949	297,499	40.0
Volatile Organic Compounds:	53,589	32,256	39.8
Nitrogen Oxides:	42,488	39,739	6.4
CO_2 (“greenhouse gas” emission):	5,506,118	2,045,375	62.8

Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	26.5	8.4	68.4

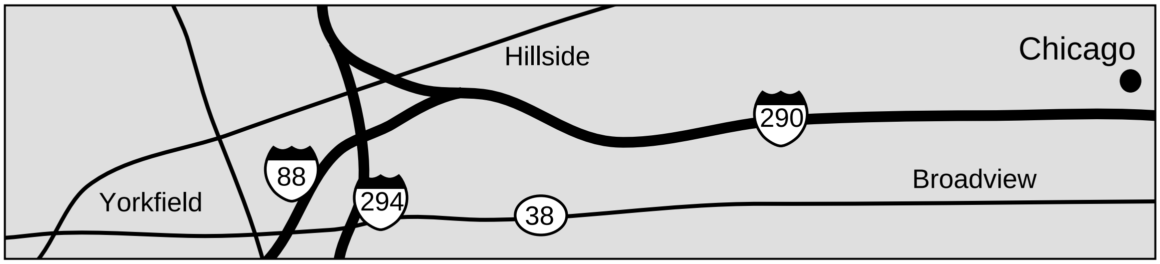
Over the 20-year life of the improvements, there would be 4,887 fewer crashes (including 20 fewer fatalities and 2,400 fewer injuries), a 40 percent decrease in smog-causing volatile organic compounds, and a 63 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 18 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, over 35 minutes of commuting time would be saved each day. These delay numbers include the effect of a three-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

I-75 and I-85 intersect about three miles north of downtown Atlanta. The area just south of the interchange, where the interstates run parallel to one another, has the highest traffic volume of any U.S. freeway: 389,000 vehicles per day on 14 lanes of traffic. The Georgia DOT maintains an aggressive traffic management program on Atlanta freeways, including surveillance, incident management, and traveler information.

13 Chicago, Illinois

I-290 at the Interchange of I-88 and I-294: The "Hillside Strangler"



Summary

Once improvements to the "Hillside Strangler" are completed, Chicagoland residents will realize significant gains in safety, air quality, and overall quality of life. Over the 20-year life of the improvements, there will be 2,746 fewer crashes (including 11 fewer fatalities and 1,356 fewer injuries), a 43 percent decrease in smog-causing volatile organic compounds, and a 76 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours will shave 15 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, 30 minutes of commuting time will be saved daily. These figures include the effect of a two-year reconstruction phase during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Vital Statistics: The Hillside Strangler
Major Route: I-290

	1997	2020 (estimated)
Vehicles per Day:	220,635	290,300
Peak Period Delay (minutes per vehicle per trip):	9.6	18.5 (Without Improvements)
Annual Traffic Growth Rate:	1.20%	

Bottleneck Description

The name "Hillside Strangler" comes from the nearby town of Hillside and the convoluted tangle of three intersecting freeways and several local streets that make up the interchange. The design of I-290 was completed in the early 1950s and does not meet the current design standards for freeways. A significant problem with the configuration of the I-290 interchange area is a lack of lane balance: Eight eastbound lanes approaching the interchange from the west must merge to only three lanes on I-290.

Benefits of Improvements: 2000–2021

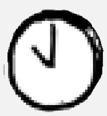
Over the 2-year construction period and the 20-year life of the project, the planned improvements to the "Hillside Strangler" would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

2,746 fewer total crashes, including 11 fewer fatalities and 1,356 fewer injuries in the vicinity of the interchange (a 12 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Carbon Monoxide:	335,276	190,723	43.1
Volatile Organic Compounds:	36,168	20,791	42.5
Nitrogen Oxides:	33,024	37,116	(+12.4)*
CO_2 ("greenhouse gas" emissions):	3,279,560	784,992	76.1



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Peak Period Delay	19.5	4.5	76.8

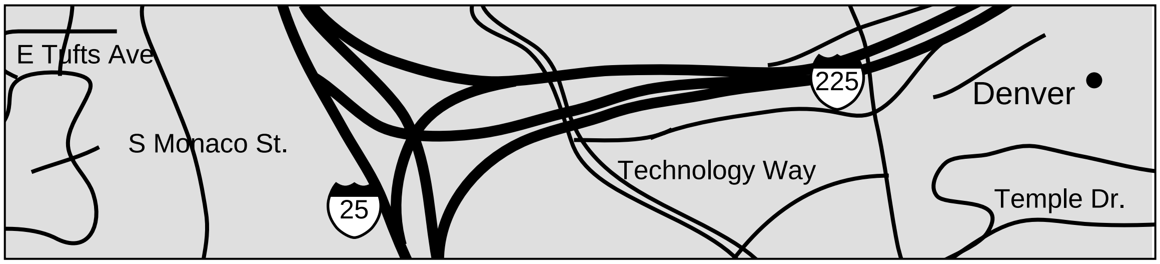
* Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides, however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of nitrogen oxides and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve.

Proposed Improvements

The Illinois Department of Transportation (DOT) has identified the Hillside Strangler as a high-priority improvement. The addition of new ramps, lanes, and parallel service roads are all planned. Construction will proceed in phases and is expected to take two years. Specifically, there will be construction of auxiliary lanes and reconstruction of I-290 pavement from I-88 to Mannheim Road, as well as an exclusive I-88 eastbound ramp, a partial cloverleaf at Mannheim Road, and an auxiliary lane from Mannheim Road to 25th Avenue. This improvement should provide significant relief to traffic congestion in the area where I-290 and I-88 merge, at a cost of $110 million.

14 Denver, Colorado

I-25 at the I-225 Interchange: The Tech Center Interchange



Summary

Once the proposed improvements to the I-25/I-225 interchange are completed, the people of Denver will realize enormous gains in safety, air quality, and overall quality of life. Over the 20-year life of this reconstructed interchange, there will be 4,600 fewer crashes (including 18 fewer fatalities and 2,270 fewer injuries), a 35 percent decrease in smog-causing volatile organic compounds, and a 60 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the Tech Center interchange during morning or evening rush hours will shave 14 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, that's almost 30 minutes of commuting time saved daily. These figures include the effect of an eight-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Vital Statistics: The Tech Center Interchange
Major Route: I-25

	1997	2020 (estimated)
Vehicles per Day:	192,000	255,500
Peak Period Delay (minutes per vehicle per trip):	12.1	28.4 (Without Improvements)
Annual Traffic Growth Rate:	1.25%	

Bottleneck Description

The Southeast Corridor has long been recognized as one of the Denver region's highest priority travel corridors. The corridor follows I-25, the only north-south freeway in the state, for approximately 14 miles, and I-225, which provides access to I-70, the region's major east-west freeway, for approximately 4 miles. The Southeast Corridor connects the two largest employment centers in the region: the Denver Central Business District, with approximately 112,000 employees in the mid-1990s, and the Southeast Business District, with approximately 120,000 employees in the mid-1990s. With employment centers at both ends, the Southeast Corridor is the highest volume, most congested corridor in the region.

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

Benefits of Improvements: 2000–2027

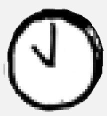
Over the 8-year construction period and the 20-year project life, completing the planned improvements to the I-25/I-225 interchange would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

4,600 fewer total crashes, including 18 fewer fatalities and 2,270 fewer injuries in the vicinity of the interchange (a 21 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	420,702	270,283	35.8
Volatile Organic Compounds:	45,336	29,335	35.3
Nitrogen Oxides:	39,074	42,197	(+8.0)*
CO_2 ("greenhouse gas" emissions):	4,353,258	1,757,451	59.6



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	22.4	8.5	61.8

* Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides, however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of nitrogen oxides and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve.

Proposed Improvements

The proposed improvements in the Southeast Corridor include a combination of highway and transit projects. The Colorado DOT, in partnership with the Regional Transportation District, proposes to improve 17.9 miles of the two interstate highways and add a new light rail transit (LRT) line with 17.9 miles of track and 13 new stations. Planned highway improvements would include one additional lane in each direction on I-25 and I-225 (between Parker Road and the DTC Parkway) with a second lane added in each direction between I-225 and C-470/E-470. Also included are

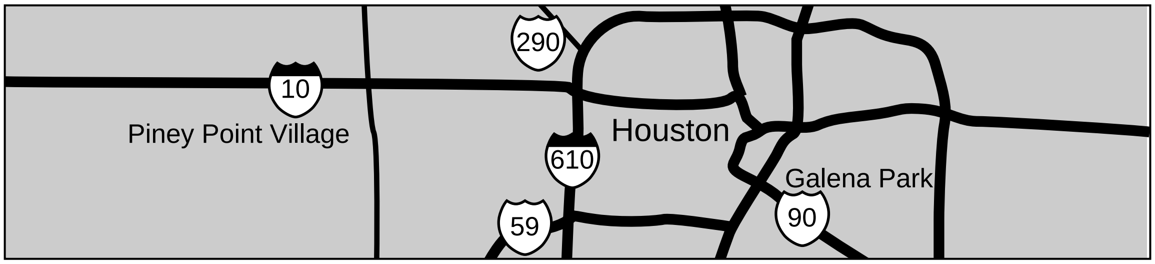
- Inside and outside shoulders
- Improvements to eight interchanges (the major one being the improvement of the I-25/I-255 interchange)
- Drainage improvements
- Acceleration/deceleration lanes or collector/distributor roads

For the purposes of this analysis, only improvements to the I-25/I-225 interchange are considered. Additional benefits would be realized if the LRT were also included, because some highway trips would be diverted to transit. However, in keeping with the conservative approach taken in this analysis, those benefits are not considered.

The improvements to the entire corridor—including both highway upgrades and LRT—are expected to cost around $550 million in 1997 dollars.

15 Houston, Texas

I-610 Loop at the I-10 Interchange



Summary

If needed improvements to the I-610/I-10 interchange were implemented, Houston residents would realize significant gains in safety, air quality, and overall quality of life. The Texas DOT is completing a major investment study of the 40-mile corridor of I-10 from downtown Houston westward; this study includes the I-610/I-10 interchange. The study indicates a "preferred alternative" of additional general purpose and HOV lanes through the I-10 corridor, plus upgrades to the configuration of the I-610/I-10 interchange. At this time, however, no specific improvements to the interchange have been designed. Consequently, for purposes of this report, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic.

Vital Statistics: I-610 Loop at the I-10 Interchange
Major Route: I-610

	1997	2020 (estimated)
Vehicles per Day:	251,540	410,500
Peak Period Delay (minutes per vehicle per trip):	8.9	36.6 (Without Improvements)
Annual Traffic Growth Rate:	2.15%	

Highway designers typically set a goal of level of service C or D for traffic in future years.

Better operations at this interchange might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps, to smooth the flow of merging traffic; the addition of HOV lanes; corridor access for bus or rail transit; and flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local

Benefits of Improvements: 2000–2022

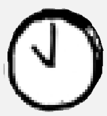
Allowing for a three-year reconstruction period and a 20-year project life, bringing the I-610/I-10 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

5,715 fewer total crashes, including 23 fewer fatalities and 2,800 fewer injuries in the vicinity of the interchange (a 21 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Carbon Monoxide:	535,381	301,137	43.8
Volatile Organic Compounds:	57,644	32,726	43.2
Nitrogen Oxides:	46,984	46,697	0.01
CO_2 ("greenhouse gas" emissions):	5,788,934	1,746,555	69.8



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	**With Improvements**	**Decrease**
Peak Period Delay	25.0	6.7	73.3

levels, reflecting the wishes and concerns of the general public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

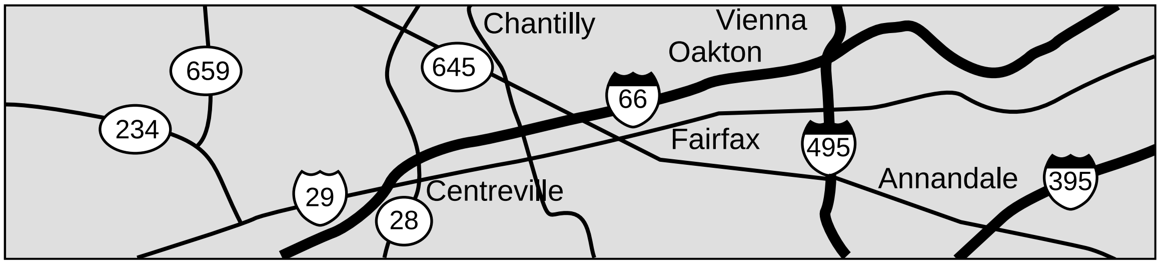
Over the 20-year life of the improvements, there would be 5,715 fewer crashes (including 23 fewer fatalities and 2,800 fewer injuries), a 43 percent decrease in smog-causing volatile organic compounds, and a 70 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 18 minutes off their driving time each trip. For commuters, who typically negotiate the interchange once in the morning and once in the evening, over 35 minutes of commuting time would be saved each day. These figures include the effect of a three-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

I-610 was Houston's original "beltway." With the construction of the Sam Houston Parkway—a perimeter highway further out—it now serves as an inner beltway. I-10, known locally as the Katy Freeway, is one of the nation's major east-west interstates, running from California to Florida. It is also a major commuter route to downtown Houston from both eastern and western suburbs.

16 Washington, DC/Virginia

I-66 at the I-495 (Capital Beltway) Interchange



Summary

If needed improvements to the I-66 and I-495 (Capital Beltway) interchange were implemented, residents of the Washington, DC, metropolitan area would realize significant gains in safety, air quality, and overall quality of life. The Virginia DOT recognizes the severity of traffic congestion problems on these two major freeways, but no specific improvements have been approved for the I-66/I-495 interchange at the time of this report. However, officials currently are studying improvements to the Beltway south of the I-66 interchange and proposals to widen I-66 to six lanes inside the Beltway. Consequently, for purposes of this report, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

Vital Statistics: I-66 at the I-495 Interchange
Major Route: I-66

	1997	2020 (estimated)
Vehicles per day:	196,000	292,000
Peak Period Delay (minutes per vehicle per trip):	10.7	30.8 (Without Improvements)
Annual Traffic Growth Rate:	1.75%	

Better operations at this interchange might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps, to smooth the flow of merging traffic; the addition of HOV lanes; corridor access for bus or rail transit; and flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local levels, reflecting the wishes and concerns of the gen-

Benefits of Improvements: 2000–2022

Allowing for a 3-year construction period and a 20-year project life, bringing the I-66/I-495 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

4,297 fewer total crashes, including 17 fewer fatalities and 2,110 fewer injuries in the vicinity of the interchange (a 22 percent decrease).

Saving the Environment

	Emissions (in tons) No Improvements	Emissions (in tons) With Improvements	Percentage Decrease
Carbon Monoxide:	373,950	200,813	46.3
Volatile Organic Compounds:	40,288	21,870	45.7
Nitrogen Oxides:	34,123	37,590	(+10.2)*
CO_2 ("greenhouse gas" emissions):	3,917,856	929,999	76.2

Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life) No Improvements	Minutes per Vehicle per Trip (averaged over construction period and project life) With Improvements	Percentage Decrease
Peak Period Delay	23.1	5.1	77.9

* Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides, however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of nitrogen oxides and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve.

eral public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

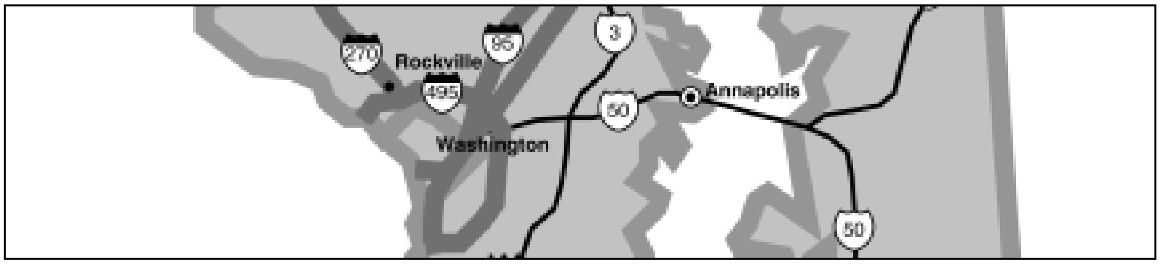
Over the 20-year life of the improvements, there would be 4,297 fewer crashes (including 17 fewer fatalities and 2,110 fewer injuries), a 46 percent decrease in smog-causing volatile organic compounds, and a 76 percent decrease in CO_2 emissions than would otherwise occur at this site without the improvements. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 18 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, more than 35 minutes of commuting time would be saved daily. These figures include the effect of a three-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

I-66 is a major commuter route in the Washington, DC, area. West of the I-495 interchange, it includes an HOV lane in each direction; east of the interchange, the entire four-lane facility is HOV in the peak direction during the peak period of travel. Even with HOV implemented, traffic volumes are very high in the vicinity of the interchange.

17 Washington, DC/Maryland

I-95 at the Northern Interchange with I-495



Summary

If needed improvements to the northern I-95/I-495 interchange were implemented, residents of the Washington, DC, metropolitan area would realize significant gains in safety, air quality, and overall quality of life. The Maryland State Highway Administration currently is studying the entire I-495 corridor within Maryland. The study will determine the feasibility of providing HOV lanes and other transit improvements. No specific improvements to the I-95/I-495 interchange are planned within the next five years, but the location remains a high priority, and the Maryland State Highway Administration recognizes that future physical improvements may be required. For purposes of this report, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

Vital Statistics: I-95 at the I-495 (MD) Interchange
Major Route: I-95

	1997	2020 (estimated)
Vehicles per Day:	168,025	267,360
Peak Period Delay (minutes per vehicle per trip):	12.4	49.7 (Without Improvements)
Annual Traffic Growth Rate:	2.04%	

Better operations at this interchange might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps, to smooth the flow of merging traffic; the addition of HOV lanes; corridor access for bus or rail transit; and flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local levels,

Benefits of Improvements: 2000–2022

Allowing for a 3-year construction period and a 20-year project life, bringing the northern I-95/I-495 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

4,358 fewer total crashes, including 17 fewer fatalities and 2,140 fewer injuries in the vicinity of the interchange (a 24 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	398,848	190,677	52.2
Volatile Organic Compounds:	42,883	20,739	51.6
Nitrogen Oxides:	58,309	52,569	9.8
CO_2 (“greenhouse gas” emissions):	4,615,814	1,023,380	77.8

Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Peak Period Delay	30.3	6.1	80.0

reflecting the wishes and concerns of the general public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

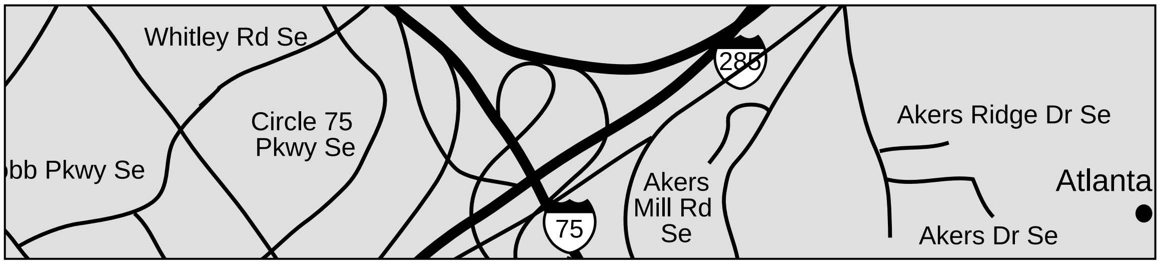
Over the 20-year life of the improvements, there would be 4,358 fewer crashes (including 17 fewer fatalities and 2,140 fewer injuries), a 52 percent decrease in smog-causing volatile organic compounds, and an overwhelming 78 percent decrease in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave an enormous 24 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, almost 50 minutes of commuting time would be saved daily. These figures include the effect of a three-year reconstruction phase during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

I-95 meets the Capital Beltway (I-495) in Virginia and tracks with it eastward into Maryland. At a point roughly 180 degrees from where it entered the beltway, I-95 veers off northward to Baltimore. The coincident section of I-95 and I-495 carries a high-volume mix of interstate and commuter traffic. At a point just before I-95 veers off northward, the total number of lanes on the coincident section is reduced from eight to five, leading to extensive congestion.

18 Atlanta, Georgia

I-285 at the I-75 Interchange



Summary

If needed improvements to the I-285 and I-75 interchange were implemented, Atlanta residents would realize significant gains in safety, air quality, and overall quality of life. The Georgia DOT recognizes the severity of traffic congestion problems on these two major freeways, but no specific improvements are scheduled for the I-285/I-75 interchange at this time. Consequently, for purposes of this report, we analyzed the benefits to be gained if improvements were made that would bring the interchange up to a minimum acceptable level of traffic flow—technically dubbed "level of service D" by traffic engineers—in the year 2000.

Level of service is a concept that traffic engineers have devised to describe how well highway facilities operate. Six levels of service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is characterized by free-flow conditions with high vehicle speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high, but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; at this level the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic. Highway designers typically set a goal of level of service C or D for traffic in future years.

Better operations at this interchange might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps, to smooth the flow of merging traffic; the addition of high occupancy vehicle (HOV) lanes; corridor access for bus or rail transit; and flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would ease congestion at the interchange. Such decisions are properly made at the state and local levels, reflecting the wishes and concerns of the general public, budgetary priorities, and applicable legal and regulatory requirements. We have assumed that a combination of improvements could achieve level of service D operations, and we have analyzed the benefits to be gained from such improvements.

Vital Statistics: I-285 at the I-75 Interchange
Major Route: I-285

	1997	2020 (estimated)
Vehicles per Day:	220,400	406,800
Peak Period Delay (minutes per vehicle per trip):	8.9	49.6 (Without Improvements)
Annual Traffic Growth Rate:	2.70%	

Benefits of Improvements: 2000–2022

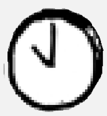
Allowing for a 3-year construction period and a 20-year project life, bringing the I-285/I-75 interchange up to level of service D operations would significantly reduce congestion, thereby smoothing the flow of traffic and

Saving Lives

5,833 fewer total crashes, including 23 fewer fatalities and 2,860 fewer injuries in the vicinity of the interchange (a 22 percent decrease).

Saving the Environment

	Emissions (in tons) No Improvements	Emissions (in tons) With Improvements	Percentage Decrease
Carbon Monoxide:	600,023	333,927	44.3
Volatile Organic Compounds:	64,485	36,179	43.9
Nitrogen Oxides:	46,173	42,790	7.2
CO_2 ("greenhouse gas" emissions):	7,077,891	2,485,836	64.9



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life) No Improvements	Minutes per Vehicle per Trip (averaged over construction period and project life) With Improvements	Percentage Decrease
Peak Period Delay	32.0	9.2	71.1

Over the 20-year life of the improvements, there would be 5,833 fewer crashes (including 23 fewer fatalities and 2,860 fewer injuries), a 44 percent decrease in smog-causing volatile organic compounds, and a 65 percent reduction in CO_2 emissions. In addition, motorists and truckers traveling through the interchange during morning or evening rush hours would shave 23 minutes off their driving time each trip. For commuters, who typically negotiate the interchange twice a day, more than 45 minutes of commuting time would be saved each day. These delay numbers include the effect of a three-year reconstruction phase, during which it is assumed that available highway capacity is reduced by 20 percent every day. In reality, state transportation departments endeavor to keep all lanes open through reconstruction zones as much as possible.

Bottleneck Description

I-285 serves as the beltway for the Atlanta region. It intersects with I-75 about 10 miles from downtown Atlanta. The I-75 corridor north of the interchange is heavily developed and is expected to continue growing rapidly. The Georgia DOT maintains an aggressive traffic management program on Atlanta freeways, including surveillance, incident management, and traveler information.

Bottlenecks Nationwide: Benefits Analysis

Summary

In addition to the 18 bottlenecks profiled above, there are many other bottlenecks in freeways throughout the country. The 1997 Highway Performance Monitoring System (HPMS) data were used to identify these sites, although we have not updated and verified the data with state transportation agencies. The HPMS data, including information on the traffic and physical characteristics of the nation's highways, are collected by state transportation agencies and reported to the Federal Highway Administration (FHWA) annually. The data are a basic monitoring tool for FHWA. They are used to produce the annual trend analyses in their publication *Highway Statistics* and serve as the basis for the biennial Highway Conditions and Performance report to Congress. Because the data for these additional locations were not independently verified by state transportation agencies, conservative assumptions and data checks were used to avoid overestimating delay and other impacts. Appendix A has a full discussion of the assumptions and methodology used.

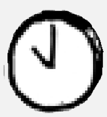
In total, 149 other freeway locations were identified as potential bottlenecks and are listed in Appendix B. When the effects of improving these locations, along with the 18 profiled bottlenecks, are considered, the following results are obtained for the 20-year benefits period plus the associated reconstruction periods:

Saving Lives

287,200 fewer total crashes, including 1,150 fewer fatalities and 141,000 fewer injuries in the vicinity of the interchanges (a 20 percent decrease).

Saving the Environment

	Emissions (in tons)		Percentage
	No Improvements	With Improvements	Decrease
Carbon Monoxide:	28,771,594	15,849,181	44.9
Volatile Organic Compounds:	3,097,254	1,722,616	44.4
Nitrogen Oxides:	2,491,945	2,649,803	(+6.3)*
CO_2 ("greenhouse gas" emissions):	313,770,674	90,766,614	71.0



Saving Time

	Minutes per Vehicle per Trip (averaged over construction period and project life)		Percentage
	No Improvements	With Improvements	Decrease
Average Peak Period Delay	25.2	6.2	75.4

* Emissions of carbon monoxide and volatile organic compounds decrease as speed increases up to 55 mph, and increase very slightly between 55 and 65 mph. Emissions of nitrogen oxides, however, decrease as speed increases up to approximately 20 mph, hold steady between 30 and 45 mph, and then increase sharply above 45 mph. Therefore, when a transportation improvement leads to increases in vehicle speeds, it is possible to decrease levels of carbon monoxide and volatile organic compounds while increasing emissions of nitrogen oxides. Transportation analysts have dubbed this phenomenon "The NO_X Dilemma," and it is evident in the improvements studied in this report. The relationship between levels of nitrogen oxides and volatile organic compounds in the formation of ground-level ozone (also known as "smog") is complex. However, because the improvements studied also show dramatic decreases in volatile organic compounds, overall smog levels are expected to improve.

4. Summary and Conclusions

Through a combination of local interviews and data analysis, this study has identified the most severe traffic bottlenecks in the country. The study then estimated the impacts of improving traffic flow in these locations using a methodology that is based on the latest available delay estimation techniques used in planning analyses, along with available information on improvements at sites where these are currently planned. The scale of the analysis focused on individual bottleneck locations and did not consider systemwide impacts.

Based on the assumptions and methodology, the study finds that enormous benefits can be derived from improvements designed to unclog major freeway bottlenecks. If delay is reduced and the flow of traffic is made smooth at these specific locations, tailpipe emissions of criteria pollutants can be reduced substantially, and the number and severity of vehicle crashes can be lessened, saving lives and preventing injuries. The study also indicates large reductions in carbon dioxide (CO_2) emissions at sites where traffic constrictions are eliminated—an important consideration for those concerned about possible global climate change. In addition, the potential time savings for motorists and commercial shippers gained by improving bottlenecks can be substantial, adding—at some of the sites studied—as much as an hour each day for activities other than sitting in traffic.

Achieving these gains would be valuable but, in many cases, costly. Indeed, for purposes of this study, we have noted the cost of improvements only in those cases where construction is already under way or where construction plans are advanced enough that reliable cost estimates can be obtained. In numerous cases, no specific improvements have been designed at the bottlenecks we analyzed, so identifying the improvement cost is not possible. What this study does, however, is identify the benefits to be realized if the bottlenecks are eliminated and, conversely, the price to be paid if nothing were done. For each bottleneck in each metropolitan area, state and local officials must weigh the cost of improvements against the benefits to be gained once the project is complete. This study should help illuminate the significant benefits that can be obtained by opening bottlenecks on our most congested freeways.

Another key finding of the study is that for onerous bottlenecks, the benefits of implementing improvements are not negated by the temporary additional delays caused by reconstruction, based on the assumptions used in this analysis. The study clearly indicates that the reduced highway capacity during the construction phase is outweighed by the positive effects realized over the life of the completed project. The reason for this is clear: These bottlenecks already experience high congestion delays, and delay increases exponentially with traffic volume. As a result, smoothing the flow of traffic through these choke points produces more dramatic delay-sensitive benefits than one might achieve by improvements to other, less congested locations. The effects are even more significant in areas that are expected to experience rapid traffic growth.

Eliminating the bottlenecks that cause a large portion of delay is the starting point for an effective congestion management program. Indeed, many other "nonexpansion" strategies—such as Intelligent Transportation Systems (ITS) and HOV lanes—must have a functioning highway system as a base. Therefore, when combined with other improvement tactics, strategic targeting of key bottleneck locations can be a highly effective component of a region's overall transportation improvement program.

The study found that many transportation agencies have already adopted this philosophy of combining highway capital expansion with other strategies to alleviate congestion. For example, in the I-25 Southeast Corridor in

Denver, a light rail line is being planned in conjunction with bottleneck improvements and other highway upgrades. In some areas, identifying a dominant bottleneck is obvious: The Big I in Albuquerque and the Hillside Strangler in Chicago are two good examples. In other areas—particularly the geographically larger metropolitan areas—it is difficult to identify a single "controlling" bottleneck in a corridor. For example, most of the freeway locations studied in Los Angeles are characterized by high flows throughout their lengths with no dominant bottleneck area. In these cases, strategies that target the entire corridor, such as HOV and ITS treatments, have been identified. Even in cases where a dominant bottleneck exists, remediation almost always includes improvements to the local street system in the vicinity of the bottleneck, because improving the bottleneck will increase traffic through these areas. Also, adjacent interchanges often are key elements of an effort to alleviate congestion in particular corridors. Transportation agencies realize that congestion is a complex problem with *systemwide* implications, and comprehensive mitigation strategies must be developed to deal with it.

Appendix A: Methodology

Bottleneck Identification

Interstate highways and freeways were the focus of this report. We limited our consideration to these highways because their traffic volumes are far higher than those of signalized highways. They are, therefore, locations where the longest delays are likely to occur. The study used three sources as a starting point to identify potential bottleneck locations: (1) the most recently available (as of September 1999) report on national congestion trends produced by the Texas Transportation Institute (TTI),[1] (2) an October 31, 1996 report from the American Automobile Association (AAA) that identified major traffic bottlenecks, and (3) analysis of the 1997 Highway Performance Monitoring System (HPMS) Universe data. From the TTI report, the top 30 cities with the worst congestion were identified. The next step was to contact the Metropolitan Planning Organizations in these cities, explain the study, and ask them to nominate one to three freeway bottleneck locations for further study. In some cases, study investigators were directed to state Department of Transportation (DOT) personnel. The cities and the corresponding agencies contacted were

- Los Angeles, CA (Caltrans District 7)
- San Francisco, CA (Metropolitan Transportation Commission)
- Seattle, WA (Puget Sound Regional Council)
- Denver, CO (Denver Regional Council of Governments)
- San Bernardino-Riverside, CA (SANBAG)
- San Diego, CA (SANDAG)
- Albuquerque, NM (Mid Rio Grande Council of Governments)
- Honolulu, HI (City of Honolulu)
- Las Vegas, NV (Nevada DOT)
- Portland, OR (Portland METRO)
- Atlanta, GA (Atlanta Regional Commission and Georgia DOT)
- Chicago, IL (Chicago Area Transportation Study and Illinois DOT)
- Fort Lauderdale, FL (Broward County Office of Planning)
- New York City, NY (New York Metropolitan Transportation Council)
- Baltimore, MD (Baltimore Metropolitan Council)
- Columbus, OH (Mid-Ohio Regional Planning Commission and Ohio DOT)
- Austin, TX (Austin Urban Transportation Study and Texas DOT)
- New Orleans, LA (Regional Planning Commission)
- Minneapolis, MN (Metropolitan Council of the Twin Cities Area and Minnesota DOT)
- Houston, TX (Houston Galveston Area Council)
- Washington, DC (Council of Governments)
- Miami, FL (Miami Urbanized Area MPO)
- Detroit, MI (Southeast Michigan COG)
- Dallas, TX (North Central Texas COG)
- Phoenix, AZ (Maricopa Association of Governments)
- Boston, MA (Boston MPO)
- Cincinnati, OH (Ohio-Kentucky-Indiana Regional COG)
- Milwaukee, WI (Southeastern Wisconsin RPC)
- Louisville, KY (Kentuckiana Regional Planning and Development District)
- Philadelphia, PA (Delaware Valley Regional Planning)

[1] Lomax, Tim, and Schrank, David, *Urban Mobility Study—1996*, Texas Transportation Institute, Texas A&M University, 1998.

To supplement the suggestions received from the local planning agencies and those in the AAA report, the HPMS Universe data were analyzed to identify potential problem areas. These data are compiled by state DOTs and submitted to the Federal Highway Administration (FHWA) annually. The data report highway and traffic conditions for every mile of major road in the United States. The data are broken out by small highway segments, usually defined by significant changes in highway or traffic conditions. (The average segment length for urban freeways is 0.7 mile.) Sections that had high ratios of traffic volume to available highway capacity were identified in the data as a preliminary list of candidate bottleneck sites.

Preliminary Ranking

From these three sources, candidate bottlenecks were listed in a preliminary ranking, exact locations were identified from the HPMS data, and a delay estimation was produced by applying a method developed for FHWA.[2] This method has been incorporated into FHWA's Surface Transportation Efficiency Analysis Model (STEAM) and Highway Economic Requirements System (HERS) models, and is being adapted for use by the Washington DOT for identifying highway deficiencies. The delay estimation method was developed by running microscopic traffic simulation models to determine basic traffic parameters, especially for congested traffic flow. These results were then incorporated into a macroscopic queuing model (QSIM) developed specifically for studying the effects of varying traffic conditions on delay. QSIM keeps track of traffic queues as they build and dissipate over time. It calculates delay on a hypothetical highway segment from this queue tracking. It also allows for traffic levels to vary from day to day. From QSIM runs, a series of equations were developed that predict delay (in terms of hours of delay per vehicle-mile traveled) as a function of average annual daily traffic (AADT, the average number of vehicles on a road per day) and highway capacity. Because delay—not speed—is the predicted value, delay does not change with assumptions about what the free-flow speed is. Rather, the predicted delay value is combined with a free-flow speed to estimate actual speed. Therefore, changing assumptions about what the free-flow speed is on a facility does not affect the delay estimates or the actual speed estimates. The method is similar in concept to the one used by TTI in developing national congestion trends, but its development is more detailed, particularly with regard to queuing.

This method provides a consistent basis for comparing locations and doing the rankings. It is not as detailed as performing traffic simulation at each of the locations or measuring existing delay, but both of those methods have drawbacks, too. Simulation requires extensive data and testing; it was deemed impractical for the scope of this study. Measuring delay is extremely costly because of field data collection and is usually based on a limited number of samples. Separating out the effect of incidents in field-collected delay measurements is highly problematic. Also, many transportation agencies do not routinely collect field-measured delay, and those that do use varying methods. On the other hand, the selected method is more sophisticated than the impact analyses traditionally conducted by transportation planners in long-range planning activities. Therefore, the delay equations discussed above were felt to be the most appropriate method for this study.

The candidate bottleneck locations were ranked on the basis of *total hours of delay* by applying the delay equations assuming that each traffic lane at the location had a capacity of 2,100 vehicles per hour. (Capacity values were refined in the detailed analysis using the HPMS sample data.) Then, the total hours of delay were computed by multiplying the equations results by the vehicle-miles traveled (VMT) for the segment. From the resulting list, the top 30 locations were identified for further analysis.

[2] Margiotta, Richard, and Cohen, Harry, *Improved Speed Estimation Procedures For Use In STEAM and Air Quality Planning*, Metropolitan Planning Division, Federal Highway Administration, June 1998.

Data Verification

The equations for computing delay depend on the quality of the data used for input. Therefore, for the top 30 locations, the appropriate state DOTs were contacted to verify the available data, verify that the location was indeed a bottleneck, obtain any existing information on the location (a schematic diagram, traffic analysis reports), and identify planned improvements (including design and impact studies).

Final Ranking

Based on input from the state DOTs, the final rankings were produced using the methods discussed above with one refinement. Instead of using the assumed capacity of 2,100 vehicles per lane, the actual capacity computed from HPMS Sample data for each location was used. From the rankings, the top 18 bottlenecks were identified for detailed impact assessments, based on a cutoff point of nine million hours of delay per year.

Impact Assessments

The effect of improving the bottleneck locations was determined using the following procedures and assumptions:

- *Delay Estimation*. The same method for estimating the current delay at the bottleneck locations was used to estimate delay impacts caused by improvements. Most of the bottleneck locations identified were freeway-to-freeway interchanges. In all cases, the data identified the problem occurring on one of the "legs" of the interchange (i.e., the highway referred to as the "Major Route" in the Chapter 2 analyses). Therefore, it was assumed that this "critical leg" was the cause of the delay at the location, even though this simplifies the actual situation where complex weaving movements may produce even higher delays. Since the volumes on the "critical leg" are a function of traffic merging from various ramps, many of the queues may not actually form on the route specified. It is therefore an indicator that a queuing problem exists in the interchange, but doesn't specify where the problem occurs. For design purposes, a more stringent type of analysis is usually undertaken by transportation agencies. However, a more detailed traffic analysis would require information on traffic volumes and design criteria for each leg and ramp in the interchange, for both current and forecast years. Such information is usually developed by transportation agencies only when redesign is being considered.

  Most of the locations did not have this level of detail available for this study, particularly in cases for which design analysis had not been undertaken. Therefore, by focusing on the conditions on the "critical leg" of the interchange, a consistent method is used for comparing bottlenecks in different states.

  In addition, no estimation of incident-related delay was made, although it is a major component of total delay and can be reduced by many of the same improvement types used to alleviate physical bottlenecks. The net result of these assumptions is to avoid overestimating delay and the other impact categories.

- *Traffic Growth*. The HPMS Sample data were used to identify traffic growth rates on each section. Data checks were performed and growth rates were not allowed to drop below 0.5 percent per year or above 3.0 percent per year. (The average growth rate for all urban freeways in the HPMS data is about 2 percent per year.) The same traffic growth rate is applied for both the "no improvement" and "with improvement" cases. While congestion in the "no improvement" case worsens considerably in future years, which would tend to suppress traffic growth, no attempt was made to correct for this influence. Rather, it was assumed that even if the amount of traffic would not materialize on the particular facility, projected traffic growth still represents demand for transportation in the region and would have to be accommodated elsewhere. Also, traffic was not suppressed during the reconstruction period. Increased congestion could moreover lead to lower economic growth because of increased costs for transportation. Because a system-level network analysis was not performed, it is not possible to say what the net effect of these diverted trips would be on areawide congestion and travel patterns. However, for high congestion cases, the use of a maximum delay value and five-mile project length (discussed below) help to offset the problems caused by assuming a constant growth rate.

- *VMT Estimation*. In order to capture adequately the full effect of queuing caused by bottlenecks, a total highway length must be established over which the impacts are measured. For detailed analysis of the top 18 bottlenecks, all of which are currently characterized by extensive queuing in the peak period, a length of five miles was chosen. (A length of five miles was chosen to produce the initial rankings as well.) In reality, queues at these high-volume locations often exceed this distance, especially as traffic continues to grow. When queuing is present, it is extremely important to select a constant highway distance over which delay is calculated to capture the full effects on travelers. The implications of using this five-mile length are to overestimate delays when queues are shorter than five miles and to underestimate delays when queues are longer. For the purpose of the rankings, as long as a constant length is used, the order of the bottlenecks would not be changed.

  In addition to the delay calculations, VMT is used to scale the various impact categories, which are usually computed on a per VMT basis (e.g., accidents per VMT, grams of pollutants per VMT). An abnormally high VMT will produce high estimates of these impacts. However, the focus of this study is on the *relative* impacts of improving bottleneck locations and these will not be affected.

- *Criteria Emissions*. Generalized relationships between speeds and emission factors for carbon monoxide, volatile organic compounds, and nitrogen oxides from the MOBILE5a model were used.[3] Speeds were calculated by combining delay estimates with an assumed free-flow speed of 60 mph.
- *Carbon Dioxide (CO_2)*. A fuel consumption relationship from HPMS was used to estimate gallons of fuel as a function of delay;[4] a factor of 19.5 pounds of CO_2 per gallon of fuel was then applied.[5]
- *Safety*. The total number of crashes was estimated with a relationship that predicts accident rate as a function of average annual daily traffic (AADT) and capacity.[6] Fatalities were estimated by applying a factor of 0.004 fatalities per crash, and injuries were estimated by applying a factor of 0.491 injuries per crash.[7]
- *Project Improvements*. Many of the bottleneck locations are under reconstruction or have specific design plans. Where the design is known, an estimate of the capacity increase is made; the revised capacity is then used to estimate delay. Where no specific improvements have been identified, a hypothetical improvement is assumed—the scale of this improvement is to increase capacity to the level at which the facility would be operating at level of service D in the year 2000. Level of service is a concept that traffic engineers have devised to

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[3] Science Applications International Corporation, *Vehicle Emission Procedures for the Highway Performance Monitoring System*, prepared for the Federal Highway Administration, July 2, 1995.

[4] Science Applications International Corporation, *Speed Determination Models for the Highway Performance Monitoring System*, prepared for the Federal Highway Administration, October 1993.

[5] Transportation Research Board, *Toward a Sustainable Future: Addressing the Long-Term Effects of Motor Vehicle Transportation on Climate and Ecology*, National Research Council, Washington, DC, 1997.

[6] Cambridge Systematics, *New Safety Analysis Procedures for HERS*, prepared for the Federal Highway Administration, September 28, 1998.

[7] Ibid.

describe how well highway facilities operate. Six level-of-service categories are used: A, B, C, D, E, and F. In layman's terms, they roughly correspond to the letter grades used in education. On freeways, level of service A is free-flow conditions characterized by high speeds and wide spaces between vehicles. As level of service goes from B to D, speeds stay high but vehicle spacing decreases. The physical capacity of the roadway is reached at level of service E; the highest traffic flows are observed and speeds start to fall off sharply. Level of service F is stop-and-go traffic.

The hypothetical improvement is nonspecific. Better operations might be achieved through a combination of improvements (e.g., a redesigned interchange to alleviate weaving caused by through traffic mixing with other traffic entering and exiting the highway; operational controls, such as traffic lights on entry ramps to smooth the flow of merging traffic; the addition of HOV (high-occupancy vehicle) lanes; corridor access for bus or rail transit; or flexible work hours at major employment centers in the corridor). For the purposes of this analysis, we have not attempted to identify a specific combination of improvements that would result in improved operations at bottleneck locations. Such decisions are properly made at the state and local level, reflecting the wishes and concerns of the general public, budgetary priorities, and applicable legal and regulatory requirements. The level of service D condition in the year 2000 is considered to be a conservative assumption, because level of service D or better at a date 10 to 20 years in the future is usually the operational target for highway redesign.

- *Reconstruction Impacts*. If a specific improvement has been identified at a location, then the actual estimated project length is used as the reconstruction period. If no specific improvement was identified, then a reconstruction period of three years was used. Unless otherwise specified by a state DOT, it was assumed that 20 percent of highway capacity would be lost for the entire reconstruction period.
- *Peak Period*. In addition to daily numbers, delay is also reported by peak period, which is defined as three hours in the morning (7 to 10 AM) and three hours in the afternoon (4 to 7 PM). It is important to select multiple hours to capture the effects of queuing. Delays—in terms of minutes of delay per vehicle—are reported for the entire six-hour peak period. For example, if the peak period delay is found to be 10 minutes per vehicle, this means that every vehicle traveling through the bottleneck during these six hours experiences 10 minutes of delay. For the five-mile project length, the 10 minutes of delay translates to an average peak period speed of around 20 mph. In terms of daily trips by commuters, assuming they must go through the bottleneck both morning and evening and with an average of 1.2 persons per vehicle, each commuter trip would experience 10 minutes × 2 trips × 1.2 persons per vehicle, or 24 minutes of delay per vehicle. To make estimates conservative, it is assumed in the reporting that vehicle occupancy is 1.0. In other words, all delay is reported strictly on a vehicle basis rather than a person basis.
- *Analysis Period*. The impact analyses begin in year 2000. (Adjustments are made to account for locations that are currently under construction or not expected to be under construction until sometime beyond 2000.) First, impacts are accumulated for the reconstruction period. When that is completed, a 20-year project life is used. Therefore, the forecast period for each project is different depending on the length of the reconstruction period. For the total period, impacts with and without the improvement are calculated year-by-year. Each year, traffic is incremented by the growth rate. It should be noted that in high-growth areas this produces very high values for the AADT-to-capacity ratio in the delay equations for

the "do nothing" base case. The ratio was capped at a value of 24, ignoring any additional delay beyond that point. This value implies that speeds on the five-mile segment do not drop below five mph. The final reported statistics are the *net* impacts, considering that there will be a degradation in performance during the reconstruction period.

- *System-Level Effects*. The impact assessment was focused on the specific facilities and system effects were not assessed. A comprehensive analysis of all the impacts of these types of major projects would involve using each metropolitan area's network-level travel demand models and network-level transportation economic analysis models, such as STEAM.

National-Level Analysis

An additional 149 freeway bottleneck locations were identified in the HPMS data by selecting locations that had 700,000 or more annual hours of delay, based on applying the delay model discussed above. The same procedures as used for the individual bottleneck locations were applied to estimate impacts. Because the data had not been verified by transportation agencies, four assumptions were used in the analysis to avoid overestimating delay and other impacts:

1. The AADT-to-capacity ratio was capped at 16. This number was based on the fact that the highest ratio for the top 18 bottlenecks was 17.
2. An assumed project length of two miles was used as opposed to a five-mile length for the top 18. In addition to producing lower estimates of delay, these locations are not as severe bottlenecks as the top 18. Therefore, queue lengths are expected to be shorter, justifying the shorter segment length.
3. Only one location was selected for each highway in a county within an urban area to avoid double counting with the HPMS data. The selection was based on taking the highway section with the highest AADT-to-capacity ratio.
4. The hypothetical three-year level of service D in year 2000 improvement was used to estimate impacts, which were accrued over the three-year reconstruction period plus a 20-year project life.

Discussion

Two limitations of the methodology are the lack of system-level analysis of impacts and the use of a constant traffic growth rate for the "no-improvement" and "with-improvement" cases. Because proper assessment of these two items would require a detailed system analysis using network models and economic analysis tools, this could not be done within the scope of the study. In light of these limitations, care was taken not to overstate expected benefits in the analysis by:

- Not allowing delay to grow beyond a maximum level for the "no-improvement" case.
- Focusing the analysis on the "critical leg" of the bottleneck for interchanges, recognizing that traffic on other parts of the interchange are not subjected to the delay in the analysis.
- Measuring delay over a constant five-mile highway segment for all cases, acknowledging that much longer queues can result, particularly for future years under the "no-improvement" case.
- Focusing solely on congestion due to the characteristics of traffic flow through the physical bottleneck ("recurring delay"), rather than adding in the delay due to incidents, which would also be likely to be reduced with improvements.

For the analysis, traffic growth was assumed to be constant for both the "with-improvement" and "no-improvement" cases. For severe existing bottlenecks, future traffic growth will tend to be suppressed if no improvements are made. However, given the difficulties of determining this effect without a detailed system-level network analysis, a constant growth rate was used. The points made above at least partially compensate for this effect, particularly the delay cap. In addition, if congestion does indeed suppress traffic growth, then it would also be suppressed for the "with-improvement" case during the reconstruction period as existing travelers adjust their schedules, routes, and modes; this was also not addressed. Finally, in the case where expected growth of traffic on a facility is suppressed by congestion on that facility, trips will be diverted elsewhere. It is not possible to determine this effect without a system-level network analysis, which was beyond the resources available for this project. Depending on the characteristics of the transportation network in individual cases, these diverted trips may be subjected to congestion elsewhere and/or make circuitous routes to their destinations.

The analysis also considered the increased delay, emissions, and crashes during a construction period. During this period, a capacity decrease of 20 percent for the entire period was used. This number was determined by considering that construction effects will vary from minimal to significant on a "critical leg" and that agencies implementing major reconstruction projects try to maximize the number of lanes kept open to traffic. In practice, if agencies do not design projects and traffic mitigation plans so as to minimize disruptions, construction period impacts could be greater.

Appendix B: Additional Freeway Bottleneck Locations

ARIZONA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
1	Phoenix	Maricopa, AZ	Interstate 10	147.282	231,123	3,742
2	Phoenix	Maricopa, AZ	Interstate 17	12.075	195,296	5,013
3	Phoenix	Maricopa, AZ	State Route 51	0.267	135,207	3,931
4	Phoenix	Maricopa, AZ	U.S. 60	150.294	174,277	2,887

CALIFORNIA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
5	Los Angeles	Los Angeles, CA	Interstate 110	18.425	269,365	7,736
6	Los Angeles	Los Angeles, CA	Interstate 5	8.307	218,391	6,230
7	Los Angeles	Los Angeles, CA	Interstate 605	5.046	259,927	6,631
8	Los Angeles	Los Angeles, CA	State Route 60	18.113	210,584	2,234
9	Los Angeles	Orange, CA	Interstate 5	16.528	276,122	8,561
10	Los Angeles	Orange, CA	State Route 22	3.577	181,071	3,510
11	Los Angeles	Orange, CA	State Route 91	3.726	207,751	3,764
12	Los Angeles	San Bernardino,CA	Interstate 10	3.468	213,420	2,413
13	San Francisco-Oakland	Alameda, CA	Interstate 580	45.282	248,105	5,347
14	San Francisco-Oakland	Alameda, CA	Interstate 80[1]	2.802	244,500	7,600
15	San Francisco-Oakland	Alameda, CA	Interstate 880	16.682	224,084	3,171
16	San Francisco-Oakland	Alameda, CA	Interstate 980	0.181	176,154	737
17	San Francisco-Oakland	San Francisco, CA	U.S. 101	1.976	253,294	5,895
18	San Francisco-Oakland	San Mateo, CA	Interstate 380	1.618	138,000	4,273
19	San Francisco-Oakland	San Mateo, CA	U.S. 101	19.090	238,136	4,368
20	San Diego	San Diego, CA	State Route 163	1.969	145,012	4,137
21	San Jose	Santa Clara, CA	State Route 17	8.885	123,976	2,666
22	San Jose	Santa Clara, CA	U.S. 101	46.479	174,110	2,873
23	Riverside-San Bernardino	Riverside, CA	Interstate 215	29.438	171,485	2,651

COLORADO

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
24	Denver	Denver, CO	Interstate 70A	280.000	155,003	1,501

CONNECTICUT

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
25	Hartford-Middletown	Hartford, CT	Interstate 84	62.630	137,200	4,174

DELAWARE

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
26	Wilmington (DE-NJ-MD-PA)	New Castle, DE	Interstate 95	8.310	194,766	1,398

[1] I-80 east of the Bay Bridge

DISTRICT OF COLUMBIA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
27	Washington DC	District of Columbia	Interstate 395	1.084	204,677	6,124

FLORIDA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
28	Miami-Hialeah	Dade, FL	Interstate 395	11.756	139,500	4,459
29	Miami-Hialeah	Dade, FL	Interstate 95	14.950	202,000	5,799
30	Miami-Hialeah	Dade, FL	State Route 826	23.908	153,500	4,379
31	Miami-Hialeah	Dade, FL	State Route 836	6.197	169,000	2,451
32	Miami-Hialeah	Dade, FL	State Route 874	1.446	112,000	1,582
33	Jacksonville	Duval, FL	Interstate 10	21.509	115,000	1,824
34	Jacksonville	Duval, FL	Interstate 95	9.313	117,000	1,996
35	Fort Lauderdale-Hollywood	Broward, FL	Interstate 95[2]	1.521	256,000	8,700
36	Orlando	Orange, FL	Interstate 4	2.655	161,200	1,885
37	Orlando	Seminole, FL	Interstate 4	3.691	105,700	1,142
38	Tampa-St Petersburg	Hillsborough, FL	Interstate 275	5.119	179,000	3,313
39	Tampa-St Petersburg	Hillsborough, FL	Interstate 4	8.700	122,000	2,466

GEORGIA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
40	Atlanta	De Kalb, GA	Interstate 20	7.580	170,500	2,571
41	Atlanta	De Kalb, GA	State Route 14100	5.370	112,600	1,629
42	Atlanta	Fulton, GA	State Route 40000	6.930	186,700	4,075

HAWAII

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
43	Honolulu	Honolulu, HI	Interstate 1	19.190	195,114	5,566

ILLINOIS

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
44	Chicago-Northwestern IN	Cook, IL	Interstate 294	4.060	111,847	1,570
45	Chicago-Northwestern IN	Cook, IL	Interstate 55	288.290	164,709	2,128
46	Chicago-Northwestern IN	Cook, IL	Interstate 80	160.510	119,705	2,243
47	Chicago-Northwestern IN	Cook, IL	Interstate 90	79.340	210,031	6,787
48	Chicago-Northwestern IN	Cook, IL	Interstate 94	59.180	247,597	5,294

INDIANA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
49	Indianapolis	Marion, IN	Interstate 465	39.350	172,010	2,695
50	Indianapolis	Marion, IN	Interstate 69	0.000	123,827	2,650
51	Indianapolis	Marion, IN	Interstate 70	82.200	190,729	4,504

[2] I-95/I-595 interchange

KENTUCKY

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
52	Louisville (KY-IN)	Jefferson, KY	Interstate 264	11.280	175,023	2,952
53	Louisville (KY-IN)	Jefferson, KY	Interstate 64	7.945	91,337	765
54	Louisville (KY-IN)	Jefferson, KY	Interstate 65	136.663	117,000	1,996

LOUISIANA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
55	New Orleans	Orleans, LA	Interstate 10	0.000	159,260	4,543
56	New Orleans	Orleans, LA	U.S. 90-Z	0.560	116,481	1,951

MARYLAND

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
57	Washington, DC	Prince Georges, MD	Interstate 95[3]	0.000	173,225	5,869
58	Baltimore	Anne Arundel, MD	Interstate 695	0.000	150,825	4,303
59	Baltimore	Anne Arundel, MD	State Route 695	1.670	111,825	1,569
60	Baltimore	Baltimore, MD	Interstate 695	14.200	163,825	2,065
61	Baltimore	Baltimore, MD	Interstate 83	3.040	192,555	4,705

MICHIGAN

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
62	Detroit	Oakland, MI	Interstate 696	0.988	187,221	1,091
63	Detroit	Oakland, MI	Interstate 75	1.100	252,030	5,759
64	Detroit	Oakland, MI	Interstate 96	0.000	169,163	4,826
65	Detroit	Wayne, MI	Interstate 75	8.598	205,618	6,239
66	Detroit	Wayne, MI	Interstate 94	28.202	170,654	2,583
67	Detroit	Wayne, MI	Interstate 96	2.010	193,985	1,363
68	Detroit	Wayne, MI	State Route 39	11.458	173,596	2,828

MINNESOTA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
69	Minneapolis-St Paul	Hennepin, MN	Interstate 35W[4]	11.745	169,979	7,422
70	Minneapolis-St Paul	Hennepin, MN	Interstate 494	5.726	164,171	2,089
71	Minneapolis-St Paul	Hennepin, MN	Interstate 694	35.411	110,172	1,445
72	Minneapolis-St Paul	Hennepin, MN	Interstate 94	221.277	109,122	1,370
73	Minneapolis-St Paul	Ramsey, MN	Interstate 35E	107.711	137,726	4,239

MISSOURI

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
74	St Louis (MO-IL)	St. Louis, MO	Interstate 70	1.851	187,562	4,165
75	Kansas City (MO-KS)	Jackson, MO	Interstate 35	1.426	130,365	3,361
76	Kansas City (MO-KS)	Jackson, MO	Interstate 70	8.760	120,054	2,277

[3] I-95/I-495 at the Wilson Bridge
[4] I-35W at the Diamond Lake Interchange

NEVADA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
77	Las Vegas	Clark, NV	Interstate 15	40.526	203,990	6,040
78	Las Vegas	Clark, NV	Interstate 515	19.764	166,535	2,262
79	Las Vegas	Clark, NV	U.S. 95	60.124	160,495	1,838

NEW JERSEY

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
80	New York-Northeastern NJ	Passaic, NJ	State Route NJ 3	0.000	122,893	2,555
81	Philadelphia (PA-NJ)	Camden, NJ	Interstate 295	26.920	114,599	1,790

NEW YORK

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
82	New York-Northeastern NJ	Bronx, NY	Interstate 278	2.180	134,231	3,814
83	New York-Northeastern NJ	Bronx, NY	Interstate 95	2.500	173,987	2,862
84	New York-Northeastern NJ	Kings, NY	Interstate 278[5]	6.260	136,171	7,505
85	New York-Northeastern NJ	Nassau, NY	Interstate 495	12.340	190,008	4,426
86	New York-Northeastern NJ	Nassau, NY	State Route 908	8.650	117,422	2,034
87	New York-Northeastern NJ	Nassau, NY	State Route 908	9.310	170,892	2,602
88	New York-Northeastern NJ	New York, NY	Interstate 95	1.270	177,802	3,202
89	New York-Northeastern NJ	Queens, NY	Interstate 495	7.270	171,156	2,624
90	New York-Northeastern NJ	Queens, NY	Interstate 678	5.470	142,196	4,799
91	New York-Northeastern NJ	Queens, NY	State Route 495	5.860	203,903	6,029
92	New York-Northeastern NJ	Richmond, NY	Interstate 278	6.340	170,105	2,539
93	Buffalo-Niagara Falls	Erie, NY	Interstate 90	9.940	128,800	3,184

NORTH CAROLINA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
94	Charlotte	Mecklenburg, NC	Interstate 77	3.310	133,800	700
95	Greensboro	Guilford, NC	Interstate 40	212.840	128,300	3,129

OHIO

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
96	Cleveland	Cuyahoga, OH	Interstate 271	9.390	130,357	3,360
97	Cleveland	Cuyahoga, OH	Interstate 480	7.660	119,304	2,206
98	Cleveland	Cuyahoga, OH	Interstate 71	5.530	112,301	1,605
99	Cincinnati (OH-KY)	Hamilton, OH	Interstate 275	24.380	149,247	1,196
100	Cincinnati (OH-KY)	Hamilton, OH	Interstate 71	16.970	115,306	1,849
101	Cincinnati (OH-KY)	Hamilton, OH	Interstate 75	4.700	147,232	1,101
102	Columbus	Franklin, OH	Interstate 270	22.780	135,860	4,010
103	Columbus	Franklin, OH	Interstate 670	2.380	143,422	4,091
104	Columbus	Franklin, OH	Interstate 70	13.090	159,719	4,556
105	Columbus	Franklin, OH	Interstate 71	17.730	157,316	4,488
106	Dayton	Montgomery, OH	Interstate 75	11.770	156,882	4,475
107	Akron	Summit, OH	Interstate 76	11.330	116,903	1,988
108	Akron	Summit, OH	Interstate 77	11.640	130,082	3,329
109	Akron	Summit, OH	State Route 8	0.200	118,775	2,157

[5] I-278 (Gowanus Expressway) in Brooklyn, NY

OREGON

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
110	Portland-Vancouver (OR-WA)	Multnomah, OR	Interstate 5	299.560	121,500	2,416
111	Portland-Vancouver (OR-WA)	Multnomah, OR	Interstate 84	1.210	172,700	2,752

PENNSYLVANIA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
112	Philadelphia (PA-NJ)	Chester, PA	U.S. 202	20.129	111,720	1,561
113	Philadelphia (PA-NJ)	Montgomery, PA	U.S. 202	0.000	111,720	1,561
114	Pittsburgh	Allegheny, PA	Interstate 279	5.328	111,340	1,532
115	Pittsburgh	Allegheny, PA	Interstate 376	1.980	120,424	2,312

RHODE ISLAND

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
116	Providence-Pawtucket (RI-MA)	Kent, RI	Interstate 95	24.734	141,500	4,711
117	Providence-Pawtucket (RI-MA)	Providence, RI	Interstate 95	36.878	231,200	3,749

TENNESSEE

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
118	Nashville	Davidson, TN	Interstate 24	12.830	128,900	3,196
119	Nashville	Davidson, TN	Interstate 65	11.560	158,260	4,515

TEXAS

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
120	Houston	Harris, TX	Interstate 10	751.823	140,493	821
121	Houston	Harris, TX	Interstate 45	38.042	243,570	4,889
122	Houston	Harris, TX	Interstate 610	8.859	244,610	4,992
123	Houston	Harris, TX	State Route 288	2.497	130,138	3,335
124	San Antonio	Bexar, TX	Interstate 10	561.423	112,448	1,617
125	San Antonio	Bexar, TX	Interstate 35	155.704	152,480	4,350
126	San Antonio	Bexar, TX	Interstate 410	16.708	170,212	2,547
127	Austin	Travis, TX	Interstate 35	229.961	158,180	1,690
128	Austin	Travis, TX	State Route 1	6.362	137,599	719
129	Dallas-Fort Worth	Collin, TX	U.S. 75	55.884	130,240	3,347
130	Dallas-Fort Worth	Dallas, TX	Interstate 30	45.647	155,760	1,545
131	Dallas-Fort Worth	Dallas, TX	Interstate 635	23.176	236,745	4,239
132	Dallas-Fort Worth	Dallas, TX	State Route 183	38.199	142,306	891
133	Dallas-Fort Worth	Tarrant, TX	Interstate 35W	51.790	120,300	2,300
134	Dallas-Fort Worth	Tarrant, TX	State Route 121	83.383	158,300	1,698
135	Dallas-Fort Worth	Tarrant, TX	State Route 360	10.890	134,050	3,792

VIRGINIA

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
136	Washington, DC	Arlington, VA	Interstate 395	8.850	194,000	4,866
137	Washington, DC	Fairfax, VA	Interstate 495	13.120	198,000	2,925
138	Richmond	Richmond, VA	Interstate 64	187.110	154,000	4,393
139	Norfolk-Virginia Beach	Norfolk, VA	Interstate 264	12.090	141,000	4,648
140	Norfolk-Virginia Beach	Norfolk, VA	Interstate 64	284.380	145,000	2,386
141	Norfolk-Virginia Beach	Norfolk, VA	State Route 44	0.000	184,000	3,798

WASHINGTON

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
142	Seattle	King, WA	Interstate 405	11.160	184,581	5,266
143	Seattle	King, WA	State Route 520	1.630	102,374	947
144	Seattle	Snohomish, WA	Interstate 5	183.960	156,258	1,574
145	Tacoma	Pierce, WA	State Route 16	0.130	109,343	1,385

WISCONSIN

No.	Urban Area	County	Route	Reference Milepoint	Vehicles/ Day	1997 Delay (Thous Hrs)
146	Milwaukee	Milwaukee, WI	Interstate 43	72.080	141,915	4,763
147	Milwaukee	Milwaukee, WI	Interstate 894	4.310	112,040	1,585
148	Milwaukee	Milwaukee, WI	Interstate 94	309.841	144,875	4,133
149	Milwaukee	Milwaukee, WI	State Route 119E	1.890	119,032	2,180

Note: For the five projects listed below, a project length of five miles is assumed because these were identified as prominent bottlenecks in the preliminary rankings and their data were verified by transportation agencies. Therefore, we expect them to have a larger influence on queuing. The remaining sites used a project length of two miles to avoid overestimation of delay and other impacts, in accordance with the discussion in Appendix A. Delay estimates for these remaining sites are approximate because their data have not been verified by transportation agencies.

1 I-80 east of the Bay Bridge
2 I-95/I-595 interchange
3 I-95/I-495 at the Wilson Bridge
4 I-35W at the Diamond Lake Interchange
5 I-278 (Gowanus Expressway) in Brooklyn, NY