Commission Briefing Paper 4L-03

Implications of Investments Targeted at Reducing Highway Passenger and Freight Bottlenecks

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Introduction

This paper is part of a series of briefing papers to be prepared for the National Surface Transportation Policy and Revenue Study Commission authorized in Section 1909 of SAFETEA-LU. The papers are intended to synthesize the state-of-the-practice consensus on the issues that are relevant to the Commission's charge outlined in Section 1909, and will serve as background material in developing the analyses to be presented in the final report of the Commission.

This paper examines the nature of passenger and freight bottlenecks on the U.S. highway system. The paper draws on several recent studies focused specifically on bottlenecks. Improvement costs and expected reductions in congestion are provided. A series of investment options is also presented.

Background and Key Findings

- Bottlenecks are specific locations on the highway system where the available capacity cannot meet traffic demand for extended periods of time. The worst bottlenecks tend to be freeway-to-freeway interchanges in urban areas where total volumes are high. These locations affect both passenger and truck traffic. Although some locations are more important to truck traffic (due to more trucks), a list of the worst passenger and truck bottlenecks would be essentially the same. Besides freeway-to-freeway interchanges, interchanges with surface streets and places where a through lane is "dropped" (common at bridge crossings) are also bottlenecks. For trucks, steep grades in rural areas serve as bottlenecks. A different kind of truck bottleneck is the delay at ports and terminals. These can cause queuing while waiting to load and unload, as well as queues at gates and checkpoints. However, this paper is targeted at bottlenecks on the highway system and not those at port and terminal areas.

- Bottlenecks are the features that dominate the congestion in urban areas not caused by unusual events (e.g., incidents and bad weather). The congestion caused by bottlenecks typically happens every weekday. This "base of congestion" causes the congestion from unusual events to be even worse. Because of this, strategies to reduce bottleneck congestion will also reduce event-related delay as well.

- The delay caused by bottlenecks in urban areas is tremendous. Studies estimate that the top 250 urban bottlenecks in the country cause 1.3 billion hours of total delay annually, 124 million of which were incurred by trucks.

- Freight bottlenecks are a problem today because they delay large numbers of truck freight shipments, which increases the cost of transporting goods. They will become increasingly problematic in the future as the U.S. economy grows and generates more demand for truck freight shipments. If the U.S. economy grows at a conservative annual rate of 2.5 to 3 percent over the next 20 years, domestic freight tonnage will almost double and the volume of freight moving through the largest international gateways may triple or quadruple. Without new strategies to increase capacity, delay of freight at bottlenecks may impose an unacceptably high cost on the nation's economy and productivity.

- Fixing bottlenecks requires a multi-pronged approach, especially at the worst locations. Combinations of strategies – such as reconstruction, demand management, improved operations, and investment in other modes to divert demand – are usually called for. In addition, improvements often must extend well beyond the actual bottleneck location (e.g., the problem interchange) to avoid transferring the problem. Improving urban bottlenecks is expensive. Current costs range from about $250 million for a medium-sized interchange reconstruction to over $1.5 billion for major corridor improvements.

- In addition to large scale improvements that typically take many years to complete, more modest bottleneck improvement projects – such as ramp metering, extending ramps, and adding auxiliary lanes – can be implemented quickly and at lower cost. These can alleviate current congestion especially at the smaller bottlenecks and are highly cost-effective. Because of their modest nature, though, they cannot deal with the long term problem of congestion growth and must be combined with long term strategies to be effective solutions for bottlenecks.

What is a Bottleneck?

Basic Definition. For our purposes, a traffic bottleneck is a location on a highway where there is a loss of physical capacity, surges in demand (traffic volumes), or both together. Losses in physical capacity can occur at:

- Lane-Drops –where one or more traffic lanes are lost, these sometimes occur at bridge crossings and work zones.
- Weaving Areas – where traffic must merge across several lanes to access entry and exit points at interchanges.
- Freeway On-Ramps – merging areas where traffic from local streets can join a freeway.
- Freeway-to-Freeway Interchanges – a special case of on-ramps where flow from one freeway is directed to another. These are typically the most severe form of physical bottlenecks because of the high traffic volumes involved.
- Abrupt Changes in Highway Alignment – sharp curves and hills can cause drivers to slow down either because of safety concerns or because their vehicles cannot maintain speed on upgrades. Another example of this type of bottleneck is in work zones where lanes may be redirected or "shifted" during construction.

- Intentional Interruption of Traffic Flow – "traffic disruptions on purpose" are sometimes necessary in order to manage flow. Traffic signals, freeway ramp meters, and tollbooths are all examples of this type of capacity loss. (Traffic signals are often necessary to provide orderly flow at intersections, but they do impede flow as well.)

In some cases the loss of physical capacity can be caused by flaws in highway design but in many cases very well designed highways are simply overwhelmed by the traffic volumes. In all these cases, bottlenecks can be defined as locations where *the demand for usage of a highway section periodically exceeds the section's physical ability to handle it, and is independent of traffic-disrupting events that can occur on the roadway*. The problems may be exacerbated by roadway events such as incidents, but the fundamental problem can be traced back to an imbalance in demand and capacity.

Bottlenecks also resonate with public officials and travelers, and making improvements to them can provide good publicity for transportation agencies. Major bottlenecks are well known to both travelers and the media who give them colorful nicknames, such as:

- "Spaghetti Bowl" in Las Vegas (I-15, I-515, and US-95);
- "Hillside Strangler" in Chicago (I-294, I-290, and I-88); and
- "Mixmaster" in Dallas (I-35W and I-30).

With such notoriety, it makes sense to address these high visibility locations.

Previous work by the American Highway Users Alliance (AHUA) on bottlenecks[1,2] indicates that there is a class of bottlenecks – "mega-bottlenecks" – which tend to dominate the congestion picture in urban areas. These are almost always major freeway-to-freeway interchanges, and are often designed to very high standards, indicating that not much additional physical capacity can be added without substantial (and sometimes infeasible) re-design. The Springfield Interchange (I-95 at I-495) in suburban Washington, D.C. (Virginia) is an example of the type of huge investment that must be made to fix a mega-bottleneck.

On the other end of the spectrum are lower-grade bottlenecks, usually freeway interchanges with surface streets. Geometric and capacity problems at these locations are often amenable to low-cost improvements. It is important to distinguish mega-bottlenecks and address them directly, especially given that delay is many orders of magnitude higher at these locations.

Passenger vs. Freight (Truck) Bottlenecks. Previous work for FHWA has shown that, in terms of total delay, passenger and freight bottlenecks are mostly indistinguishable.[3] That is, the major "commuter-oriented" bottlenecks in urban areas are also those that cause the highest amount of truck congestion. Because some interchanges have higher volumes of trucks, rankings of passenger and truck are different but the same locations appear on both lists. In addition to these bottlenecks, trucks are also affected strongly by inadequate highway geometry (steep grades and low underpasses) in rural areas.

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[1] *Unclogging America's Arteries: Prescriptions for Healthier Highways*, AHUA, November 1999, http://www.highways.org

[2] *Unclogging America's Arteries: Effective Relief for Highway Bottlenecks (1999-2004)*, AHUA, 2004, http://www.highways.org

[3] Cambridge Systematics, Inc., *An Initial Assessment of Freight Bottlenecks on Highways*, prepared for Federal Highway Administration, Office of Transportation Policy Studies, October 2005.

What is the Payoff for Fixing Bottlenecks?

Figure 1 shows the current estimation that bottlenecks contribute approximately 40 percent of total congestion. However, the effects of events, like incidents and bad weather, are partly determined by how much available capacity there is in the first place. ***This means that if bottlenecks are improved, other sources of congestion will also be improved.***

What is the size of the congestion problem? The Texas Transportation Institute's most recent *Urban Mobility Study*[4] finds that congestion continues to grow in America's urban areas (as of 2003). Despite a slow growth in jobs and travel in 2003, congestion caused 3.7 billion hours of travel delay and 2.3 billion gallons of wasted fuel, an increase of 79 million hours and 69 million gallons from 2002 to a total cost of more than $63 billion. The TTI study includes delay from bottlenecks as well as from incidents.

The delay caused by just bottlenecks in urban areas is tremendous and a major part of this total congestion. The latest AHUA study estimated that at the top 24 worst bottlenecks alone, 390 million hours of delay are experienced by travelers every year (1.3 billion hours at the top 250 bottlenecks) The FHWA study showed trucks incurring 243 million annual hours of delay nationwide (all bottlenecks), 124 million of which were at urban interchanges.

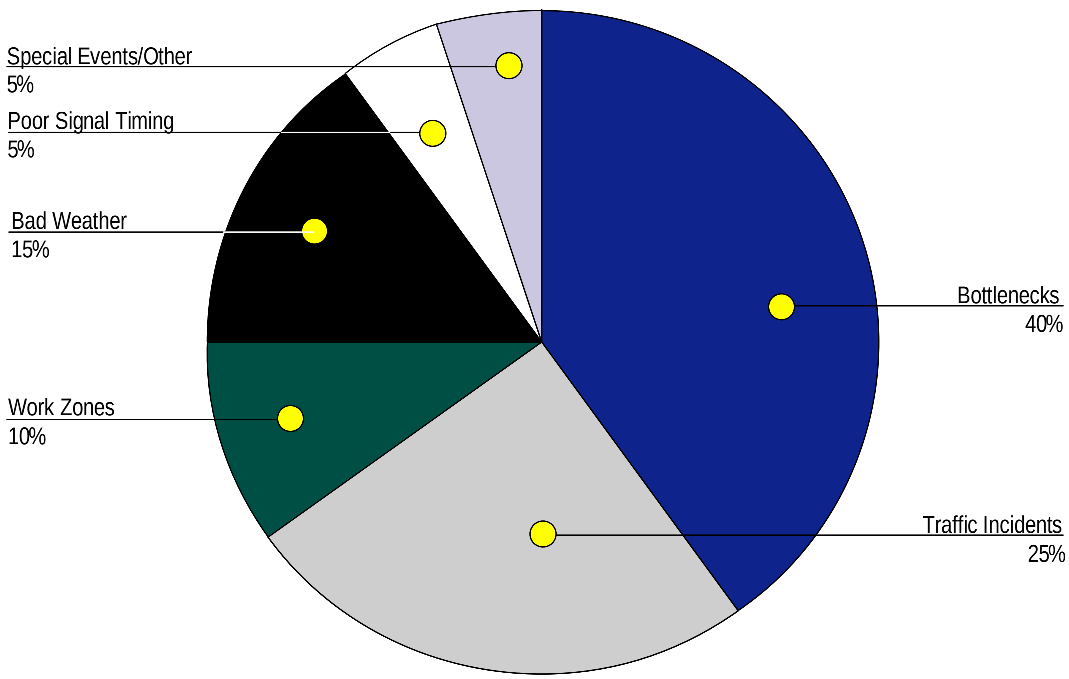


Figure 1. The Sources of Congestion: National Summary

How Can Bottlenecks be Fixed?

[4] Schrank, David and Lomax, Tim, *The 2005 Urban Mobility Report*, Texas Transportation Institute, May 2005, http://mobility.tamu.edu

The latest AHUA study revealed that states use a variety of methods for improving "mega-bottlenecks" (large urban interchanges, bridge crossings). Rarely, the problem can be traced to an antiquated design (e.g., simple interchange designs such as "diamonds" and "cloverleaves"); such problems are fixed by complete reconstruction. More commonly, major interchanges are already built to relatively high standards. The fixes undertaken by states at these locations are combinations of strategies that package together such as items as geometric improvements, demand management (high occupancy vehicle (HOV)/high occupancy toll (HOT) lanes), operations, and transit. Figure 2 shows some examples of strategies used to fix mega-bottlenecks.

Figure 2. Examples of Major Bottleneck Improvements

US-59 (Southwest Freeway)/I-610 Loop in Houston

The Texas Department of Transportation's (TxDOT) reconstruction of the I-610 (West Loop) encompasses almost a five-mile stretch of highway, from US 59 (Southwest Freeway) to I-10 (Katy Freeway). The reconstruction includes the renovation of the existing roadway and the addition of new entrances and exits, as well as the creation of "hot links": slip ramps and frontage roads that provide direct and exclusive access into and out of local land, while removing traffic from the West Loop main lanes, helping to dramatically reduce congestion.

Cost: $263M interchange only, plus $1.1B for corridor improvements (15 miles)

I-25/I-225 Interchange in Denver

Nicknamed "T-REX" (for Transportation Expansion), this project exhibits the principles we found being applied to complex bottleneck mitigation projects across the country: a single solution is rarely effective but when multiple strategies are applied, real progress can be made. The T-REX project involves:

Transit Strategies

- Adding 19 miles of double-track light rail, new stations, and additional trains

Highway Strategies : 17 miles total

- Adding additional through lanes
- Reconstructing eight interchanges, including I-25/I-225; reconstructing and widen numerous bridges; adding and improving shoulders; improving ramps and acceleration/deceleration lanes

Cost: $1.7B

Springfield Interchange in Virginia

Complete reconstruction of I-495 and I-95 interchange.

Cost: $700M

"Big I" Interchange in Albuquerque

Complete reconstruction of I-25 and I-40 interchange.

Cost: $270M

Many states recognize that bottlenecks cannot be treated in isolation, and improvements must be implemented with a broader view. In many cases this is necessary because increasing traffic flow through one bottleneck may create others downstream. Therefore, bottleneck fixes are likely to include improvements to a whole corridor (e.g., several miles of highway including multiple interchanges) rather than an individual bottleneck. States are now starting to consider pricing in this regard as well – by charging tolls for peak period use, travelers are encouraged to travel at other times and revenue can be generated for other improvements.

Lower-level bottlenecks (e.g., freeway interchanges with surface streets) are more amenable to modest geometric improvements. These include adding or extending auxiliary lanes, adding frontage roads, using shoulders as travel lanes during peak times, ramp metering, and removing weaving areas. These fixes can be implemented quickly and at low-cost, and can noticeably improve congestion in the short-term. However, such fixes are rare – current funding programs are not set up to handle these quick fixes. It is common for states to know about these problems but the improvements identified tend to be major reconstruction and corridor-wide – this means that the project must wait its turn in the annual funding cycle before anything is done.

What Would a National Bottleneck Mitigation Program Look Like?

Investment and Policy Options

1. **Status Quo**

   Description: Under this option, bottleneck improvements are left up to the states, as is currently done. Bottlenecks are improved at a slower pace (i.e., the same as for the past several years). Because of funding shortfalls, only those improvements currently "on the books" are made.

   Performance Implications: Because of high cost, only a few mega-bottlenecks are improved. Lower cost, short-term improvements are not made. It is doubtful that more than 20 percent of the top 250 bottlenecks can be fixed by 2020 under this scenario.

   Impact on Transportation Agencies: No new funding is developed under this option and as a result bottlenecks are not aggressively addressed.

2. **Targeted Bottleneck Removal Program (Low-Cost improvements)**

   Description: This option would increase the funding for implementing low-cost bottleneck improvements, in addition to the improvements made under the Status Quo above. States may have to reallocate their maintenance (or other) funds, or the Federal government could bring dedicated funding grants or other.

   Performance Implications: In the short run, these types of improvements can have a dramatic effect on traffic flow because they target the specific conditions causing problems at bottlenecks. However, since the capacity increases are modest compared to mega-projects, they too will eventually be overwhelmed by traffic growth. Their implementation essentially "buys time" before implementing more sophisticated strategies such as demand management, especially pricing alternatives, which will suppress traffic volumes at key times of the day.

Impact on Transportation Agencies: Assuming $10 million per bottleneck (based on the cost figures presented earlier), a total of $2.5 billion would be required to fix all 250 of the top bottlenecks, just 2 percent of total annual highway expenditures.

3. **Targeted Bottleneck Removal Program (High-Cost improvements)**

   Description: This scenario involves the kinds of major improvements shown in Figure 2 but would require accelerated funding *beyond* that which currently exists towards mega-projects and planned infrastructure. (That is, absent accelerated funding, we get the status quo.)

   Performance Implications: As the features that dominate everyday congestion not related to incidents, bad weather and other unusual events, the top 250 bottlenecks in the country produce 1.3 billion hours of delay annually (90 million hours are truck–related). We expect this delay to more than double to 2.8 billion hours by 2020. Plus, the longer we wait, the more expensive fixes become due to escalating land and construction prices.

   Impact on Transportation Agencies: Using the case studies from Figure 2 as a basis, assuming that the cost of fixing the 25 worst bottlenecks would be $1 billion each (which includes corridor improvements) and that the remaining 225 bottlenecks would cost an average of $500 million each, the total cost of fixing the top 250 bottlenecks in the country would be roughly $140 billion. In comparison current ***total*** highway expenditures (including construction, maintenance, and operations) are about $104 billion per year. Assuming the average length of a bottleneck improvement project is 4 years, the cost would be $35 billion per year, or one-third of total annual highway spending. These costs appear to be huge, but it must also be remembered that the potential gains in congestion savings are larger.

4. **Investment in Nonhighway Modes**

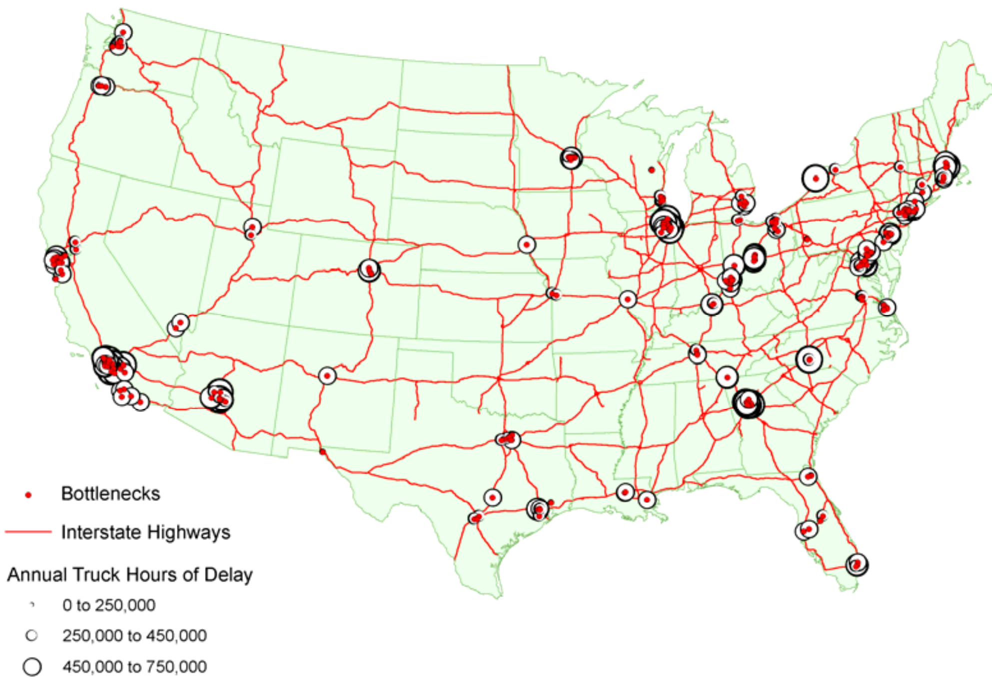
   It is doubtful that investments in nonhighway modes (transit for passenger, rail service for freight) alone can alleviate the problems at the major national bottlenecks. These are locations that are "badly broken" in terms of traffic congestion and shifting passenger and freight demand to other modes is not likely to have a major impact. At the same time, there is little doubt that they form part of an overall investment package in combination with other strategies. (See Figure 2 for an example.)

5. **Nationally Significant Corridors**

   Description: This option involves improvements similar to the high-cost improvement strategy above, but investments are made on a more strategic basis rather than on an individual basis, combining urban passenger needs with intercity truck travel needs. Figure 3 displays the locations of major interchange bottlenecks (which are the major source of congestion for both passenger vehicles and trucks).

   Highway freight bottlenecks, especially interchange bottlenecks, are of Federal interest because they are a significant national problem for trucking and the efficient operation of the national freight transportation system. Highway interchange bottlenecks affecting trucking are widely distributed across the United States along Interstate freight corridors. The primary truck delay on these nationally significant routes is in the major urban areas, including major international trade gateways and hubs such as Los Angeles, New York, and Chicago, and major distribution centers such as Atlanta, Dallas-Fort Worth, Denver,

Figure 3 Major Highway Interchange Bottlenecks for Trucks



Constraint Type	Facility Type	Freight Route Type	Number
Interchange	Freeway	Urban Freight Corridor	227

Source: Cambridge Systematics, Inc.

Columbus (Ohio), and Portland (Oregon). These urban interchange bottlenecks create sticky nodes that slow long-distance truck moves along Interstate and other National Highway System regional, transcontinental, and NAFTA freight transportation corridors. A cursory review suggests these logical investment strategies:

- I-95 in the Northeast and again in Florida
- The I-75 corridor from Florida to Michigan, including brief sections of I-24 and I-65
- I-10 from California to Florida
- Pacific points of entry in California, Oregon, and Washington

Clearly, more in-depth analysis is needed, but this illustrates the need to think nationally about bottleneck problems.

Performance Implications: By focusing on important corridors and improving the bottlenecks in them, priorities can be determined on a national basis. The overall costs would be similar to the High-Cost option above, but the sequence of improvements would coincide with the national corridor perspective rather than improving individual bottlenecks in isolation. This will yield more benefits at an earlier date than the isolated approach. These benefits include a stimulus to growth in the Gross National Product due to more efficient freight (and to a lesser extent) passenger travel.

Impacts on Transportation Agencies: The Federal role would have to be increased under this option to ensure multi-state cooperation and timing of the improvements. Fixing individual bottlenecks would still be left to the states in which they reside, however, with the caveat that their design must be consistent with maintaining corridor (intercity) travel, not just local travel.

CONSOLIDATED COMMENTS FROM MEMBERS OF THE BLUE RIBBON PANEL OF TRANSPORTATION EXPERTS - PAPER 4L-03

One reviewer commented as follows:

The focus on bottlenecks as a major source of congestion is a very interesting one. From a policy standpoint, this reviewer feels the paper appropriately notes that physical improvements to remove bottlenecks should be part of an overall demand-management system, and this reviewer believes this point is worth emphasizing

Two minor comments –the focus on work zones should be dropped, as the solutions are different than those that would address a permanent bottleneck. Secondly, tollbooths should not be considered “intentional interruptions of traffic flow”! This reviewer does not think anyone ever installed a tollbooth in order to slow down traffic, and in fact the technology is well-evolved that allows the elimination of tollbooths.

Another reviewer commented as follows:

In describing bottlenecks, the paper could also mention international border crossings as often being bottlenecks, due to capacity and/or security/customs issues. The paper should note that although highway bottlenecks may be caused by interstate travel, the local/state governments often bear the burden of financing improvements at these locations. A possible federal role for investing in bottleneck solutions could apportion financial responsibility in relation to the amount of interstate traffic through the location versus local traffic.

Strategies to manage the operation of corridors over longer distances, and demand management (e.g. trucks moving to off-peak periods) could help in reducing congestion at some bottleneck locations and reduce the need for major capital projects.