Abridgment

Recapturing Capacity by Removing Freeway Bottlenecks

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Congestion on urban freeways affects safety, air quality, energy consumption, and motorist delay. In areas where travel demand far exceeds capacity, some level of congestion is inevitable. However, when imbalances in the freeway system exist, bottlenecks restrict the use of available capacity. If these bottlenecks are removed, valuable capacity can be recaptured, congestion reduced, and impacts diminished. Detection of bottleneck locations requires knowledge of traffic volumes and travel speeds and observations of traffic patterns and driver behavior. Bottleneck relief can be found in many cases by restriping lanes, by modifying weaving areas, or by converting some shoulders to driving lanes. Implementation of low-cost improvements, even on an interim basis before permanent improvements, can have an excellent result. Because removal of congestion on one segment of the freeway system may move congestion and impacts to other segments, consideration must also be given to the system implications. In addition, issues such as state and federal policies, public acceptance, and funding for any improvement must be addressed before implementation. However, if these obstacles can be cleared, low-cost improvements to remove bottlenecks will provide significant benefits. In a time of fiscal constraints and with public attention focused on urban congestion, every attempt must be made to get the most efficiency out of our existing freeway systems.

Most urban freeway facilities are planned and designed for traffic volumes forecast 25 years into the future. During the life of the facility, unanticipated changes in travel patterns can occur because of increased growth rates, unforeseen urban land development, or the failure to implement other transportation facilities previously assumed. Whatever the cause, the result is more demand than capacity on some elements of the facility. When these imbalances occur in the system bottlenecks may arise. These sections differ from overcapacity freeway corridors in that often a low-cost improvement can be implemented over a short section of the freeway to significantly relieve congestion and return the system to balance.

WHY TARGET FREEWAY BOTTLENECKS?

One bottleneck in a corridor can create severe congestion for the entire corridor. Considering the high volumes during the peak periods of many urban freeways, the annual delay cost to motorists can be substantial. In addition, capacity is wasted because the bottleneck is effectively "metering" traffic volumes downstream and causing stop-and-go conditions upstream.

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There are also environmental and safety effects of bottlenecks. Vehicles operating in congested sections of freeways emit more hydrocarbons and carbon monoxide into the atmosphere. Vehicles caught in stop-and-go traffic consume more fuel. Accidents and vehicle breakdowns (with associated safety impacts) tend to increase in freeway sections with severe congestion. In addition, motorists make erratic maneuvers in attempts to bypass congestion and save time, causing further hazard.

DETECTIVE WORK: WHAT'S HAPPENING HERE?

The first step in attempting to remove freeway bottlenecks is to determine the cause. It is easy to identify the congested freeway sections within an urban area. However, detective work is required to determine which congested freeway sections are caused by bottlenecks and why.

Four different data collection efforts are necessary at a suspected bottleneck site:

1. Peak-period traffic volume counts by 15-min periods,
2. Peak-period travel time runs (every 15 min),
3. Traffic demand patterns (if weaving is involved), and
4. Videotaping of freeway operations (at the bottleneck and drive-through).

Each of these data collection efforts provides clues to the existence of a true bottleneck and its cause.

Peak-Period Traffic Volume

It is recommended that traffic volumes be collected in the peak direction by 15-min time intervals. The small time increment allows detection of patterns in the volume profiles; for instance, capacity may be reached in one 15-min period and then followed by a drop in volume from stop-and-go operations that result from over-capacity conditions. As an example Figure 1 shows plots of peak-period traffic volumes for the southbound section of IH-35E Freeway in Dallas, Texas, at the merge with the westbound-to-southbound ramp from IH-30. The peak-hour (4:30 p.m. to 5:30 p.m.) volume on IH-35E in this section is below the theoretical capacity of the two-lane roadway. At first glance this would not indicate a problem. However, the expected traffic pattern (under free-flow operation) is peaking during the peak period. In Figure

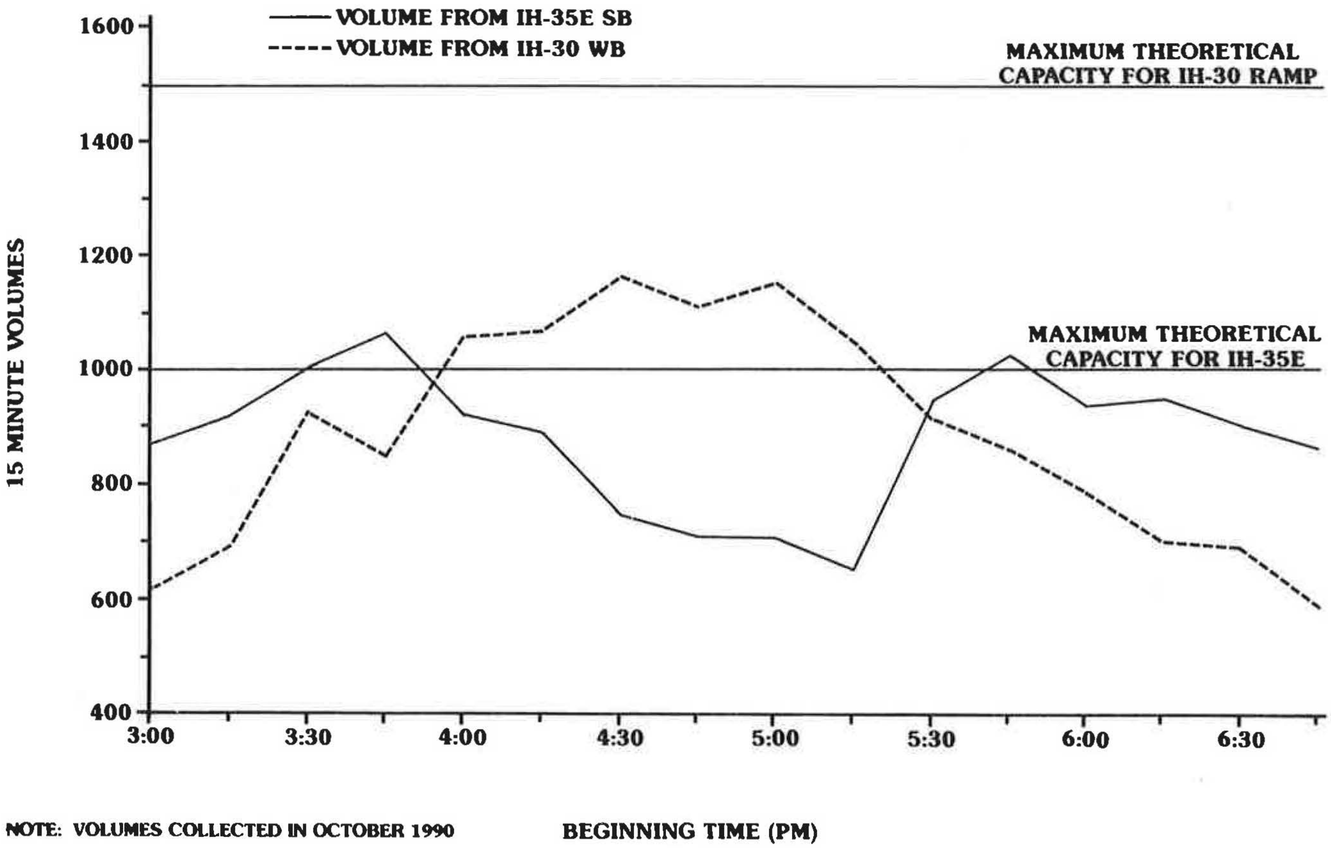

FIGURE 1 **15-min volumes for IH-35E southbound and IH-30 ramp (p.m., October 1990).**

1, the traffic volumes on IH-35E at 3:00 p.m. are low and start to increase in the following 15-min intervals. However, from 3:45 p.m. to 5:15 p.m. the traffic volumes take a downward trend, indicating constrained operation due to the increase in volume on the competing IH-30 entrance ramp. The traffic pattern on the IH-30 ramp, which is three lanes, indicates that the demand is better served by this facility because of the increase in volumes during the peak hour of the peak period. Traffic on the two approaches fills the capacity of the downstream section (four lanes), but does not accurately reflect the demand from the two approaches. Thus, one of the approaches is experiencing severe congestion from a bottleneck, whereas the other is not.

Peak-Period Travel Times

Peak-period travel times along a section of freeway can give considerably more information about the impacts of a bottleneck. For the example discussed above, peak-hour travel time runs are presented in Figure 2 for both IH-35E and the IH-30 ramp to IH-35E. The speeds along IH-35E immediately upstream of the bottleneck reach a low of 10 mph and speeds below 30 mph last for about 10 min of travel time. Congestion extends for 2 mi and is considerably more severe than that along IH-30 upstream of the merge. The lowest speeds observed on the IH-30 ramp upstream of the merge are 25 mph. Speeds below 30 mph last only a minute or two of the total trip time and congestion extends for only ¼ mi.

Using peak-period traffic volumes and speeds, the delay to motorists can be estimated compared with travel at free-flow speeds. For example, with a 2-hr peak period, the estimated annual delay from this bottleneck on IH-35E is 110,000 vehicle-hr/year and for the IH-30 westbound ramp, only 11,000 vehicle-hr. Clearly, the imbalance in congestion shows that the demands are not proportional to the design capacity of this section.

Traffic Patterns

Often important to understanding the causes of a freeway bottleneck are the origins and destinations of the vehicles in the traffic stream. If the problem is a weaving section that is over capacity, the entire freeway upstream can experience congested conditions. Even major capacity improvements may be ineffective if the problem lies in excessive weaving volumes.

Videotaping of Freeway Operations

Unusual traffic patterns that may be contributing to, or even causing, bottlenecks cannot be detected by simply examining the traffic volumes and travel speeds. Field observations and videotaping are essential in discovering traffic patterns. Observations sometimes also reveal dangerous erratic maneuvers made by motorists as a result of extreme congestion on freeways. It is uncommon to observe motorists driving on shoul-

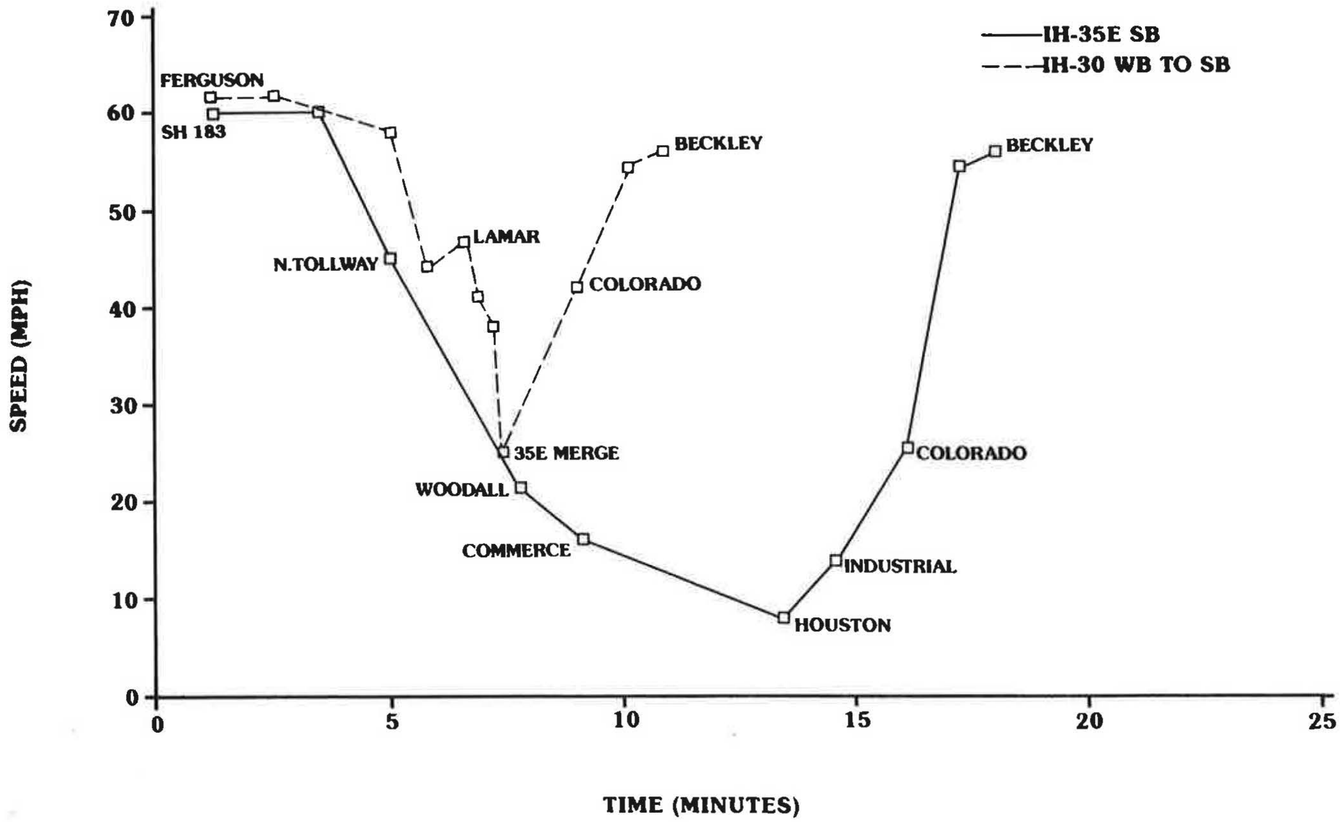

FIGURE 2 Typical travel speeds on IH-30E southbound and IH-30 ramp, p.m. peak period.

ders or driving two and three abreast in wide ramp gore areas. From an operational standpoint, these maneuvers sometimes result in stretching capacity, and they may even point toward the solution needed for the problem. However, in general, they simply provide an advantage for those making the erratic maneuver. These motorists are a distinct disadvantage to the overall freeway operation and frustrate those driving legally. The safety implications can be enormous.

FOUND CAPACITY: THE LOGICAL SOLUTION

Once a bottleneck has been identified and its causes have been determined, solutions within the given right-of-way should be sought. Ideally, a bottleneck improvement will be a low-cost improvement designed to provide more capacity to a freeway section temporarily until some permanent capacity addition to the freeway can be constructed. Because the improvement is temporary in nature, minimum design standards may need to be considered. Future reconstruction of the freeway would allow for the minimum designs to be upgraded to more desirable standards. In the meantime, the potential safety impacts of allowing minimum design standards must be weighed against the safety benefits of decreasing congestion.

The following are some commonly implemented low-cost improvements that have been used in Texas:

1. Use a short section of shoulder as an additional lane,
2. Restripe merge and diverge areas to balance capacity and demand,
3. Modify weaving areas,
4. Add lanes for short segments, and
5. Use peak-period ramp metering or ramp closures.

The use of these improvements often depends on the approval of local, state, and federal agencies in a given area.

BENEFITS AND COSTS: WHAT'S THE PAY-OFF?

First, the most obvious benefits from removing bottlenecks are the increased peak-period speeds and the reduced delay to motorists. These benefits can considerably outweigh the cost of bottleneck improvements.

However, estimating the extent of delay reduction can be difficult. Theoretical analysis using the *Highway Capacity Manual* (*1*) does not always yield useful results in these cases. In sections with constrained volumes, theoretical analysis shows an adequate level of service when the volume is below capacity. Demand upstream of the bottleneck must first be estimated in order to quantify the congestion on the freeway. This estimated demand can be used to analyze the operation with the proposed improvement. The time savings with the improvement can be quantified and the motorists' benefits calculated. Common benefit-cost ratios of projects in Texas have ranged from 2.3 to 16.6, using $10/vehicle-hr (*2*).

Safety benefits are also likely to occur. Accident data collected at three bottleneck locations in Dallas, Texas, were analyzed to determine the types of accidents occurring during the peak period under congested conditions. The types of accidents attributed to congestion were rear end or single vehicles that ran off the road or into a barrier to avoid hitting a slow-moving vehicle. Almost 80 percent of all accidents that occurred during the peak period were attributable to congestion. If the congestion conditions were relieved, there would be fewer accidents. In addition, these accidents in themselves contribute to further delay, which would also be relieved.

CONCLUSION

Congestion on urban freeways increases delay to motorists, pollution to the environment, and accidents and incidents. Many freeways have simply too much demand for their capacity, but some short freeway sections are bottlenecks that may yield to low-cost solutions within the freeway right-of-way. With some detective work to uncover the causes of the problems, low-cost improvements can be designed to reduce the severe impacts of congestion and recapture the freeway capacity that bottlenecks deplete.

The following summarizes the key points to bottleneck removal:

1. Traffic volumes alone will not detect (but may suggest) locations of bottlenecks. Vehicle speeds, local traffic patterns, and field observations are needed to detect both the existence and the cause of freeway bottlenecks.
2. The amount of congestion on different approaches at freeway-to-freeway interchanges can be very imbalanced. Distributing the capacity to reflect the demand can greatly reduce the overall congestion in the system.
3. Improvements such as restriping lanes, using shoulders, and modifying weaving areas produce primary benefits of reduced congestion and improved safety. These improvements also produce secondary benefits in reductions in emissions, vehicle operating costs, and congestion on alternative routes.
4. These benefits can be accomplished at minimal cost compared to overall capacity improvements because they amount to recapturing existing capacity within the freeway system, smoothing out the problems.
5. Additional checks must confirm that implementation of a bottleneck improvement will not simply move the congestion to another location (which may cause further safety problems).

If design elements can be approved and if all involved agencies cooperate, low-cost improvements to remove freeway bottlenecks can provide significant benefits. In a time of fiscal constraints and public attention on urban congestion, every attempt must be made to get the most efficiency out of our existing freeway systems.

REFERENCES

1. *Special Report 209: Highway Capacity Manual*, TRB, National Research Council, Washington, D.C., 1985.
2. W. F. McFarland and M. Chui. *The Value of Travel Time: New Estimates Developed Using a Speed Choice Model.* Research Report 396-2F. Texas Transportation Institute, College Station, 1985.

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