The Tip of the Iceberg: A Research Project Revisited

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Research results are often like the tip of an iceberg. What are initially seen as the results of research may be only one-tenth of the actual results. The US-75 North Central Expressway Corridor research project in Dallas, Texas, is one such case. A review of this project demonstrates that research results can often provide many more benefits than originally expected, through improving urban mobility.

States and cities are continually searching for effective means in meeting transportation needs through improvements that provide the highest return for the money spent. A discussion here of a research project that is helping to meet these needs, and thus likely to encourage similar far-reaching research in the future, is timely.

Study Corridor in Texas

Carried out between 1971 and 1977 jointly by the Texas State Department of Highways and Public Transportation (Texas SDHPT), the city of Dallas, the Federal Highway Administration, and the Urban Mass Transportation Administration, with research work conducted by the Texas Transportation Institute (TTI), the US-75 North Central Expressway Corridor project consisted of approximately 30 square miles of freeway and city streets stretching from the

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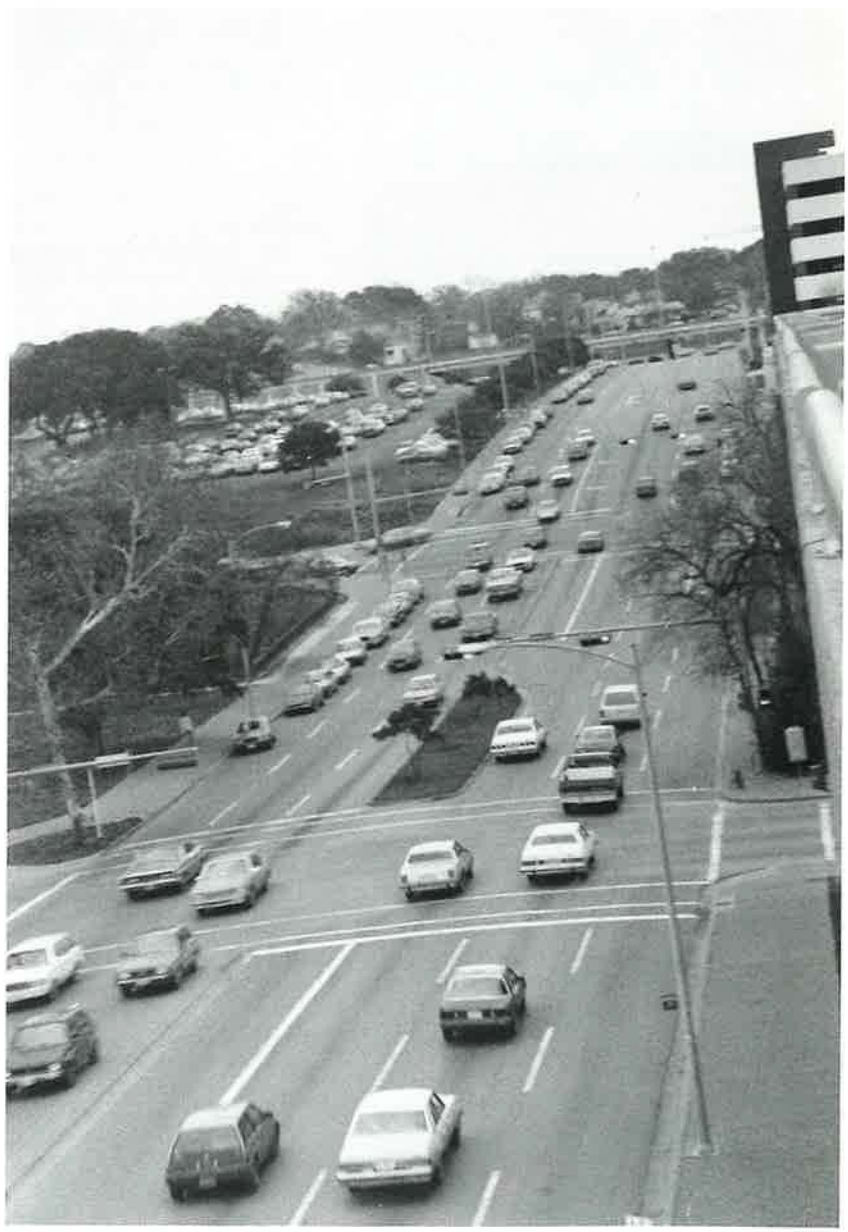
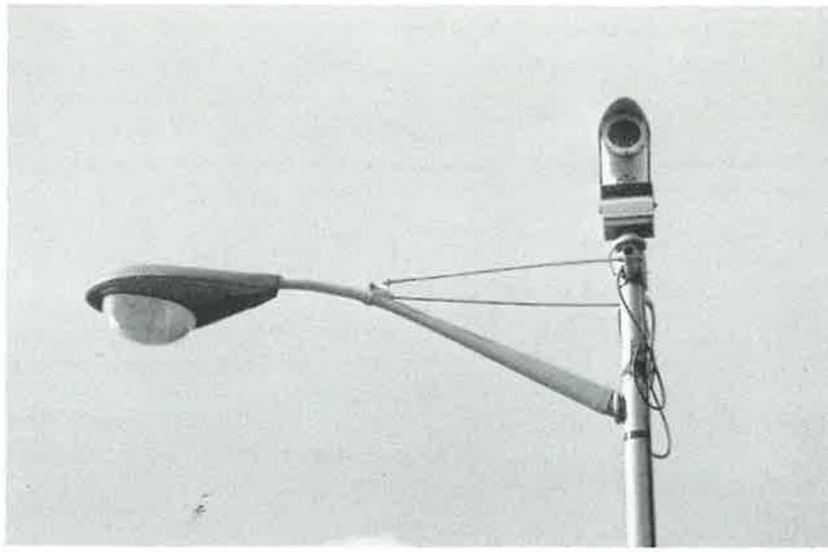


Arterial street with signal progression.

Dallas central business district to Richardson (Figure 1). The 10-mile section of freeway included 35 metered entrance ramps and 9 closed-circuit television cameras. Included in the corridor system were 3 changeable message signs located on streets that crossed the corridor, 15 signalized frontage road interchanges, and 78 signalized arterial street intersections, all of which were utilized in various aspects of the research work. The research project was the first to study an integrated freeway corridor system.

The cost of the project in 1985 dollars was approximately $11,000,000. The city of Dallas has maintained the system since installation with financial support from the Texas SDHPT and has operated the system since June 1977 when the research work was completed.



Surveillance camera for monitoring freeway conditions.

Major Study Results

- Total corridor delay was decreased by 7,440,000 vehicle minutes per year and more than 10,000 person minutes per year during the two afternoon peak hours.
- The number of accidents along the freeway was reduced by 47 percent during ramp meter control.
- A total of 73 percent of the motorists responded to the changeable message sign messages that suggested that motorists take alternate routes along corridor streets when there was congestion along the freeway.
- During peak periods frontage road travel improved by 30 percent under computer control in contrast with isolated interchange control.
- Implemented and tested as part of the research project was a bus priority system that utilized a bus-driver operated device, special controls at the signalized intersections, and a central computer. In addition, the number of bus trips scheduled within the corridor areas was increased from 583 to 677 between 6:00 a.m. and 6:00 p.m. Before implementation of the bus priority system, 36.2 percent of the riders on buses within the corridor had diverted from automobiles; after implementation these figures increased to 40.9 percent. The total number of passengers at the maximum load point increased from 16,333 to 16,814 during the 12-hour study period from 6:00 a.m. to 6:00 p.m.
- Over all, the project demonstrated the productivity of the application of traffic management along freeway corridors.

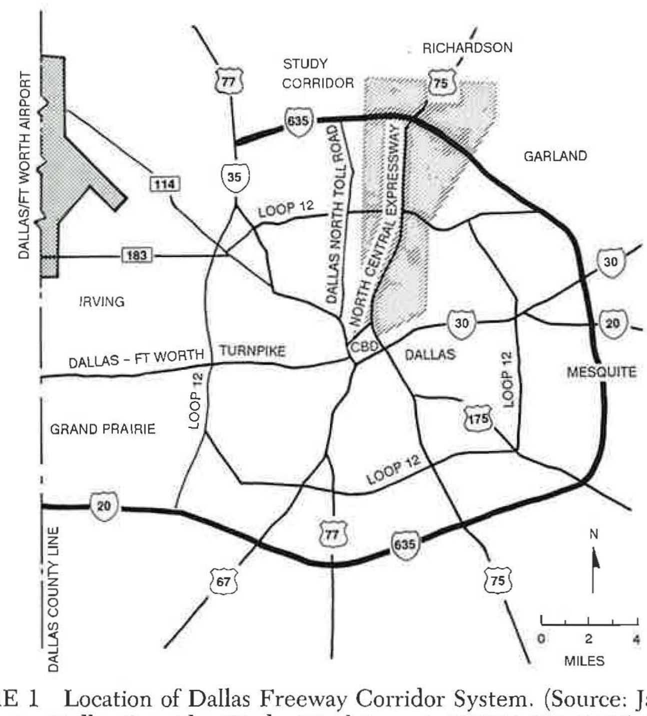


FIGURE 1 Location of Dallas Freeway Corridor System. (Source: James D. Carvell, Jr. *Dallas Corridor Study*. Final Report, FHWA-RD-77-15. Prepared by Texas Transportation Institute for FHWA, U.S. Department of Transportation, 1976, p. 3.)

Subsequent Research Projects and Implementation in Texas

The results of the research project just listed represent the visible tip of the iceberg. Beyond that, the project stimulated imagination, the desire to learn more, and the challenge to implement the research findings. And implementation work in some areas provided results even better than those obtained from the research. Work subsequent to the US-75 corridor research project is described in the following sections.

PASSER II, PASSER III, and PASSER IV

As a result of the US-75 corridor project and using Highway Planning and Research (HPR) funding, Texas SDHPT developed the PASSER II, PASSER III, and PASSER IV computer models. These projects have been carried out by TTI. Both PASSER II and PASSER III have been included in the Federal Highway Administration's Arterial Analysis Package (AAP) because of their practical applications. PASSER IV is still under development by TTI.

The Progressive Analysis and Signal System Evaluation Routine (PASSER) II is a computer model that determines the greatest amount of green time for vehicle groups traveling along a street. The original concept was developed as part of the US-75 corridor project. PASSER II was unique when first developed because the system could analyze traffic signals that have separate movements for left turns. The most recent version of the system (PASSER II-84) attempts to minimize delay for each traffic movement at each intersection while simultaneously determining the greatest time for through-traffic movement. The PASSER II computer model is now being used throughout the United States and in several foreign countries.

The PASSER III model is a variation that determines the maximum green time for groups of vehicles traveling along frontage roads. The system also determines the optimal operation of each signalized interchange under both coordinated system operation and isolated interchange traffic control.

PASSER IV is a freeway corridor analysis package that permits a step-by-step analysis of traffic conditions along the freeway main lanes, frontage roads, and corridor streets. The project was initiated directly because of the benefits demonstrated by the US-75 corridor project and the need to develop the available capacity of the corridor streets as well as the freeway main lanes.

Interconnection of Traffic Signals

Guidelines for determining when to interconnect traffic signals along an arterial street are also being developed through research, extending the initial work carried out as part of the US-75 corridor project.

Implementation of US-75 Corridor Research Results

A substantial amount of implementation work, as well as continued research, has resulted from the US-75 corridor project.

Change in Left-Turn Phase Sequence

One of the results of the US-75 corridor project has been to give traffic engineers several choices regarding which sequence of left-turn phases to apply at an intersection. The phase sequences available at an intersection are

1. Both left turns on an arterial street move concurrently in advance of the straight-through movements.
2. Both left turns on an arterial occur concurrently after the straight-through movements.
3. One left turn moves before the straight-through movements and the second left turn from the opposite direction moves after the straight-through movements.

The first two phase sequences just listed are known as dual left and the third is called leading and lagging (or lead-lag).

The US-75 corridor project is believed to be the first to show the practical aspects of changing the phase sequence at an intersection from dual-left operation during one traffic condition (for example, average off-peak traffic conditions) to lead-lag operation during another traffic condition (for example, morning peak-period traffic condition). The purpose of the change in phase sequences is to provide both improved operation at the intersection and optimum through-movement of traffic along both arterial streets at each intersection. The proper phase sequence is chosen by the traffic engineer for each traffic condition and implemented at each intersection minicomputer controller by the central computer so that it automatically occurs when the appropriate traffic condition occurs.

Before the US-75 corridor project demonstration took place, traffic engineers hesitated to use a phase sequence other than the dual-left phasing. Since then, use of the lead-lag operation at one intersection and the dual-left leading (or lagging) operation at the next intersection during system control has become widespread in Texas. In these operations, the left-turn sequence chosen does not usually change as traffic conditions change.

Changing the left-turn phase sequence when traffic conditions change has been incorporated into the FACTS (Flexible Advanced Computer Traffic Signal) System developed by the Texas SDHPT. The FACTS System is a flexible traffic responsive computer-controlled traffic signal system designed for use with full actuated controllers (which can skip a phase when there is no traffic for that phase approach) and/or pretimed traffic signal controllers (which move from phase to phase) on arterial streets, freeway corridor grid streets, complex freeway interchanges, and continuous frontage roads. Four of the FACTS systems with the changeable left-turn phase sequence feature have been installed and installation of two additional systems is under way in Texas. Observations of intersection operation when left-turn phase sequences are changed by the central computer have shown that motorist confusion does not occur.

The flexibility of changing phase sequences was also incorporated into a commercial traffic-signal system project. The project involved a 35-intersection (19 intersections in operation with another 16 under construction or planned for construction) Eagle COMTRAC traffic-responsive traffic signal system that was installed in College Station, Texas. The feature has been subsequently installed by Eagle Signal Company and other manufacturers in other traffic signal systems.

The change of phase sequencing permits optimal use of the green time along arterial streets. A study conducted along a six-intersection system along the NASA-1 highway route south of Houston showed a 29 percent increase in green time on the arterial street (increase in total two-way green time of 22 seconds), a reduction in total delay of 2.3 seconds per vehicle, a 33 percent reduction in the average number of stops, and a 28 percent reduction in travel time when compared with a design using only dual-left-turn operation at each intersection under all traffic conditions.

Diamond interchange.

Phase Sequence Change at Signalized Freeway Interchanges

The US-75 corridor project also showed that phase sequences could be changed at frontage road interchanges as traffic conditions changed. Two basic phase sequences were chosen for study by the traffic engineer for the project:

1. Allow both frontage-road movements (phases) to occur at the same time followed by the cross-street movements (phases).
2. Alternate the frontage road and cross-street phases (the type of operation generally provided at signalized frontage-road interchanges).

The first sequence is called a three-phase operation and the second is called a four-phase operation. The change in phase sequence permits the improved movement of vehicle platoons along the frontage road and/or through the interchange along the cross street. The change in phase sequence also benefits frontage road use as an alternate route during freeway main-lane incidents and maintenance activities.

The Texas SDHPT has installed the FACTS system incorporating the change in phase sequence along a continuous frontage road on SH-225 south of Houston. Subsequent studies showed a 20 percent reduction in delay and a 54 percent reduction in stops in comparison with isolated (no frontage-road coordination provided) full actuated traffic signals.

Also developed and implemented by the Texas SDHPT was a full actuated traffic signal controller providing both three-phase and four-phase sequences. The phase sequence is changed by either a time switch or automatically by changes in traffic condition. Fifty of these controllers at frontage road interchanges have been installed in Texas. In addition the city of Dallas extended the Texas SDHPT design to include even more flexibility in operation, and approximately 50 of these controllers have been installed by the cities of Dallas and Fort Worth.

Demonstration for Development of Advanced Traffic Signal Controllers

A total of 28 special-purpose computers (minicomputers) for providing multiphased operation at frontage-road interchanges and arterial-street intersections were installed for the US-75 corridor project. The central computer control caused the minicomputer controllers to change the phase sequences in order to provide the best operation as traffic conditions changed.

Personnel from the California Department of Transportation (Caltrans) observed the operation of the minicomputer-controlled traffic signals as the phase sequences changed. Based on their observations and their own experience in California, Caltrans personnel concluded that the same phasings could be provided by the new generation of microcomputers. The US-75 corridor project thus served as a catalyst in the initial development of the California and New York 170 traffic signal controller, which is now used by many states and cities across the nation.

Application of PASSER II and PASSER III in Traffic Signal Systems

The Texas SDHPT utilizes PASSER II and PASSER III in computer operations in Austin for developing traffic movement designs (patterns) for arterial-road and frontage-road traffic signal systems (including the FACTS and College Station computer-controller systems). A microcomputer version of PASSER II has also been developed jointly by the Texas SDHPT and TTI.

An initial design for the use of PASSER II in developing signal-timing plans from loop-detector information has been successfully implemented by the Texas SDHPT on its NASA-1 system. This design reduces the need for manual traffic count information and for time-consuming completion of input forms. The NASA-1 application has proven successful in obtaining improved timing plans with reduced use of manpower.

Research Pays Off: Successful Implementation

The following excerpts from a Federal Highway Administration internal report on Passer II-84 illustrate a direct and substantial benefit of the research conducted by the Texas State Department of Highways and Public Transportation in its US-75 North Central Expressway Corridor project in Dallas. The information from the FHWA report was supplied to *TR News* by Wilson (Red) Lindsay, Research Engineer with FHWA.

Study Title: Reduced Delay Optimization and Other Enhancements for Passer II-80 (Passer II-84).

Objectives: Fine tune computer model to improve delay characteristics. Add number of stops and fuel consumption to ease B/C calculations.

Findings: Met objectives. Research claims a 10 percent improvement in delay.

Implementation Status: Immediate. This technique has been incorporated in the 1985 *Highway Capacity Manual*, published by TRB. We have implemented the model on the Texas SDHPT mainframe and prepared a microcomputer version of the model. More than 500 users have benefited.

What means, if any, have been used or are proposed to aid in implementing the findings: A letter to all Districts and past users of the model was issued. Training workshops have been conducted. A TRB paper has been published. FHWA has incorporated the new model in the Arterial Analysis Package. Texas A&M University is distributing the micro version for $20 per copy instead of the $400 that we previously charged. Results include more frequent and widespread use.

Estimated annual savings and other benefits from use of research: 10 systems per year are retimed in Texas; 10 additional throughout the nation. 9 vehicle-hours/hour x 12 hours/system x 260 days/year x $4/hr x 20 systems = $2,246,000 per year for delay improvement. 20 systems x 34 gallons/hour x 12 hours x 260 days x $1/gallon = $2,120,000 for fuel. Benefits = $4,368,000. Cost = $17,000.

Benefit/Cost Ratio: 257 to 1.

Can other states implement or benefit from this study? How? They are already doing so.

Additional Comments: This research has been productive enough to pay for all the research projects that I have been involved with over the past 10 years. I wish they were all this productive. We spent this money to great benefit.

Freeway Corridor Surveillance and Control

On the basis that it is beneficial to coordinate freeway and corridor street operation, as demonstrated by the US-75 corridor research project, the Texas SDHPT has been working with the cities of Austin, Corpus Christi, El Paso, Fort Worth, and Houston in developing freeway and corridor street traffic-signal systems that will provide coordinated operation. This is being accomplished in two ways:

1. The overall city-wide freeway-arterial street system design is being accomplished by means of a design-team concept. The team includes personnel from the city, state, and public transportation traffic operations agencies; thus the ultimate operating agency is involved in the system design from the beginning. The need for a design committee was one of the conclusions of the report in which the US-75 corridor project was evaluated *(1)*.
2. The Texas SDHPT has developed the PEGASUS (People, Goods and Services Urban System) concept for coordinating systems of freeway main lanes, HOV lanes, frontage roads, and corridor streets. The PEGASUS concept is designed to provide traffic management for a freeway corridor on a 24-hour, 7-day-a-week basis in order to move people, services, and goods during both peak and off-peak periods.

The PEGASUS concept utilizes an unstaffed "satellite" minicomputer system. This minicomputer system for the freeway main lanes, the HOV lanes, and the frontage road and arterial streets is located in a building along the freeway right-of-way. The satellite computers provide for automatic freeway control and surveillance and transmit traffic data and traffic operations control information to the central computer at the staffed control center. Flexible in that it can be coordinated with the systems being developed by each of the cities mentioned previously as well as other cities in the future, the PEGASUS system is designed to make the most efficient use of

Intersection with variable phase sequence.

staff in the design, operation, and maintenance of freeway corridor systems.

Future Applications

The US-75 corridor research project offers still more opportunities for implementation. Motorist response to changeable message signs (CMS) and reduced delay along the corridor streets demonstrate the value of increased application of CMS and overall freeway corridor traffic management. Bus priority systems using state-of-the-art equipment also appear to be valid in expanding the person-moving capacity of the freeway corridor. Thus, the integrated freeway-city street traffic management system, as demonstrated by the US-75 corridor project, offers many benefits at reasonable cost in the moving of people, services, and goods during both peak and off-peak periods.

Conclusion

It is difficult, if impossible, to measure the benefits obtained from the US-75 corridor research project. As the application of the research results has expanded in Texas, the benefits appear to exceed by far the initial $11,000,000 cost of the project. These benefits will continue to be realized as the results are further used across Texas and the rest of the country.

In addition to the initial improvements and benefits realized within the US-75 freeway corridor in Dallas, the research project has served as a springboard for subsequent research projects and for implementation, as well as stimulated further inventiveness and creativity. As in other research projects, these functions are often unseen and unsung until reviewed in retrospect. Thus the research is often like the "tip of an iceberg"initially only a small portion of the benefits can be seen (at times even these are received coolly by the engineering profession). But ultimately, it can be documented that the public benefits many times over through the direct research results and their subsequent implementation elsewhere.

Ramp metering signal on US-75 North Central Expressway.

Reference

1. *Evaluation of the Dallas Freeway Corridor System.* Report FHWA/RD-81/058. FHWA, U.S. Department of Transportation, 1981.