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Research Study Title: Freeway System Plan Assistance, Incorporating Tollroad Effects

16. Abstract

The Dallas Freeway/High-Occupancy Vehicle (HOV) System Planning Study is a joint project in cooperation with the Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART), the North Central Texas Council of Governments (NCTCOG), and the Texas Transportation Institute (TTI). The mission of the study is to provide an intermediate planning step between the macroscopic-level planning performed by TxDOT's Regional Planning Office and the NCTCOG and the detailed corridor design analyses performed by the district office of TxDOT. The intent of this effort is to assist in the development of an area-wide freeway/HOV system that recognizes implementation constraints (right-of-way and construction costs), and provides reasonable peak-hour operating conditions on all freeway facilities, while incorporating the long-range plans developed by TxDOT, DART, and NCTCOG. The proposed system is a set of recommendations to be considered and evaluated as part of the development of the Mobility 2010 Plan Update, the long-range transportation plan for the Dallas area.

The recommended system in the Dallas System Planning Study was developed using a methodology that focuses on peak-hour passenger travel demand in the year 2015 (derived from the year 2010 24-hour volume assignment provided by NCTCOG) for the freeways in Dallas and surrounding counties. The goal of the Dallas System Planning Study has been to find the lowest public cost alternative in each corridor, for a given volume of peak-hour person trips. This framework views travel delay, construction, and operation of roadways as costs to the public. It also recognizes that some motorists will change their mode of travel when given the opportunity to avoid congestion, resulting in more transit and carpool use (rail passenger volumes were held constant as provided by NCTCOG).

The Dallas System Planning Study methodology uses an iterative process to examine congestion and the consequent shift in mode so that these two factors are consistent for an alternative. The proposed system balances money saved in construction against money lost in delay to find the optimum combination of mixed-flow, HOV, and express lanes necessary to move the demand.

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THE DALLAS FREEWAY/HOV SYSTEM PLANNING STUDY: YEAR 2015

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Sponsored by the
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In Cooperation with
Dallas Area Rapid Transit
and
North Central Texas Council of Governments

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IMPLEMENTATION STATEMENT

This study was sponsored by the Texas Department of Transportation (TxDOT) as part of an effort to identify a balanced transportation system for the future in the Dallas area. The system should accommodate the projected travel demand at the lowest public cost. The Dallas System Planning Study was a coordinated effort of the Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART), and the North Central Texas Council of Governments (NCTCOG) with technical assistance from the Texas Transportation Institute (TTI).

The mission of the study is to provide an intermediate planning step between the macroscopic planning analyses performed by NCTCOG and TxDOT's Regional Planning Office and the detailed corridor analysis performed during the design phase of a roadway improvement project. The proposed system is a set of recommendations to be considered and evaluated as part of the development of the Mobility 2010 Plan Update, the long-range transportation plan for the Dallas area.

The Dallas System Planning Study was developed using a methodology that focuses on peak-hour passenger travel demand for the freeways in Dallas and surrounding counties. The study analysis differs from other planning efforts in the region by its focus on peak-hour passenger travel demands and roadway operating conditions, the use of 2015 as the design year for the facilities, and the acceptance of congestion for some alternatives to induce travel in higher-occupancy modes. The intent of the effort was to provide a system that served the travel needs with a reasonable and balanced level of congestion.

The study methodology uses an iterative process to examine congestion and the consequent shift in mode so that these two factors are consistent for an alternative. The proposed system balances money saved in construction against money lost in delay to find the optimum combination of mixed-flow, HOV, and express lanes necessary to move the demand.

DISCLAIMER

The contents of this report reflect the views of the authors who are responsible for the opinions, findings, and conclusions presented herein. The contents do not necessarily reflect the official views of the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation, nor is it intended for construction, bidding, or permit purposes. The engineer in charge was Carol H. Walters, P.E. #51154.

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This study was conducted in cooperation with representatives from state and local agencies. These individuals provided valuable contributions in developing the methodology of the study, in reviewing the draft of this report, and in ensuring the comprehensiveness and accuracy of the final report. The following individuals are thanked for their assistance in the development of this document:

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SUMMARY

The Dallas Freeway/High-Occupancy Vehicle (HOV) System Planning Study is a joint project in cooperation with the Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART), the North Central Texas Council of Governments (NCTCOG), and the Texas Transportation Institute (TTI). The mission of the study is to provide an intermediate planning step between the macroscopic-level planning performed by TxDOT's Regional Planning Office and NCTCOG and the detailed corridor design analyses performed by the district office of TxDOT. The intent of this effort is to assist in the development of an area-wide freeway/HOV system that recognizes implementation constraints (right-of-way and construction costs), and provides reasonable peak-hour operating conditions on all freeway facilities, while incorporating the long-range plans developed by TxDOT, DART, and NCTCOG.

The Dallas System Planning Study is technical in nature and does not address issues such as the programming responsibilities of the agencies involved, the staging or priority of projects within each corridor, the source of funding for the recommended capacity improvements, or community concerns including the environmental effects of the recommended improvements. The proposed system is a set of recommendations to be considered and evaluated as part of the development of the NCTCOG Mobility 2010 Plan Update, the long-range transportation plan for the Dallas area.

The recommended system in the Dallas System Planning Study was developed using a methodology that focuses on peak-hour passenger travel demand in the year 2015 (derived from the year 2010 24-hour volume assignment provided by NCTCOG) for the freeways in Dallas and surrounding counties. The goal of the Dallas System Planning Study has been to find the lowest public cost alternative in each corridor, for a given volume of peak-hour person trips. This framework views travel delay, construction, and operation of roadways as costs to the public. It also recognizes that some motorists will change their mode of travel when given the opportunity to avoid congestion, resulting in more transit and carpool use (rail passenger volumes were held constant as provided by NCTCOG).

The Dallas System Planning Study methodology uses an iterative process to examine congestion and the consequent shift in mode so that these two factors are consistent for an alternative. The proposed system balances money saved in construction against money lost in delay to find the optimum combination of mixed-flow, HOV, and express lanes necessary to move the demand.

Multiple alternatives were evaluated for each corridor. Costs to the public, including construction, right-of-way, operating, and congestion costs, were summed for each alternative, and the *least public cost* alternative was selected as optimum. Figures S-1 and S-2 illustrate the recommended alternatives resulting from the analyses. These alternatives have been adjusted where necessary to maintain compatibility with adjoining freeway sections.

It is important to note the change in public goals implied in the Dallas System Planning Study: *Future congestion is accepted on freeways in Dallas during peak-hours, and carpooling or use of transit is the solution offered to escape it.* This is a policy issue that needs to be understood, debated, and accepted or rejected before the recommended system can be partially or wholly adopted by any agency in the region.

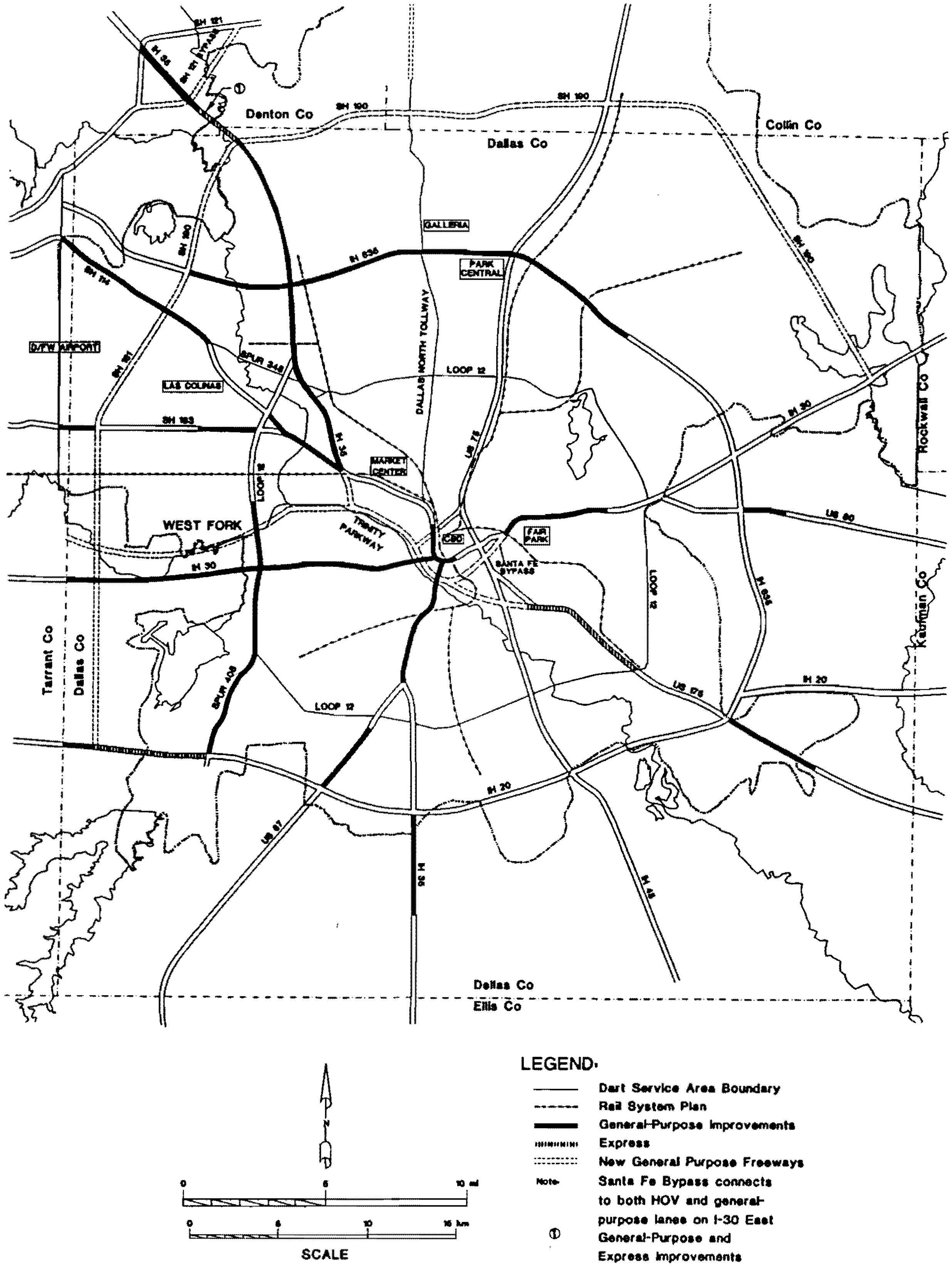


Figure S-1. Recommended System for Dallas in the Year 2015, General-Purpose and Express Improvements

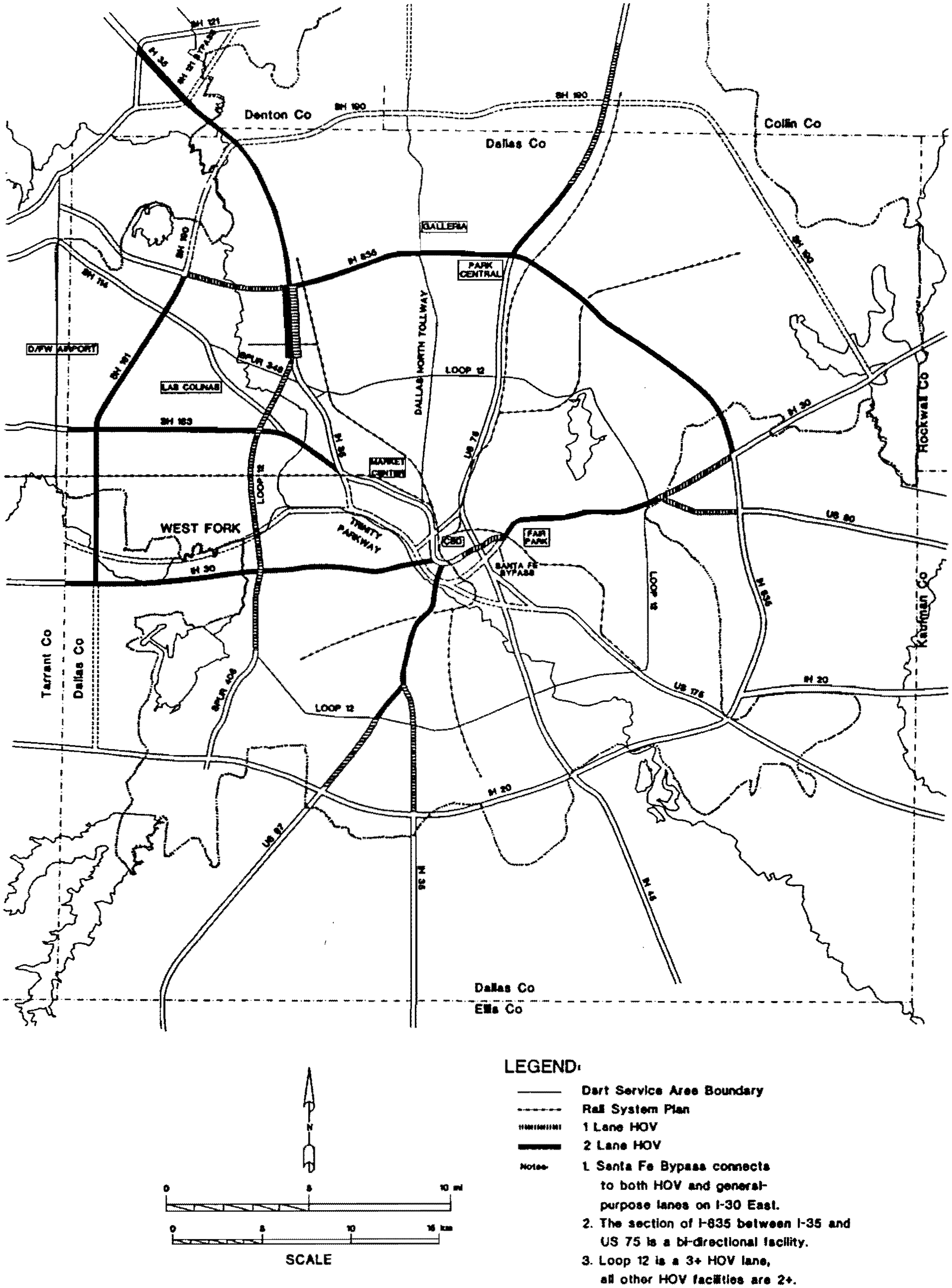


Figure S-2. Recommended System for Dallas in the Year 2015, HOV Lane Improvements

I. INTRODUCTION

The Dallas Freeway/HOV System Planning Study is a joint project in cooperation with the Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART), the North Central Texas Council of Governments (NCTCOG), and the Texas Transportation Institute (TTI). The mission of the study is to provide an intermediate planning step between the macroscopic-level planning performed by TxDOT's Regional Planning Office and NCTCOG and the detailed corridor design analyses performed by the district office of TxDOT. The intent of this effort is to assist in the development of an area-wide freeway/HOV plan that recognizes implementation constraints (right-of-way and construction costs), provides lane balance and interchange configurations that will give balanced and reasonable peak-hour levels-of-service on all freeway facilities, and incorporates the long-range plans developed by TxDOT, DART, and NCTCOG.

The Dallas System Planning Study is technical in nature and does not address issues such as the programming responsibilities of the agencies involved, the staging or priority of projects within each corridor, or the source of funding for or the community concerns about recommended capacity improvements. The proposed system is a set of recommendations to be considered and evaluated as part of the development of the NCTCOG Mobility 2010 Plan Update, the long-range transportation plan for the Dallas area.

There are two key aspects that distinguish this system planning effort from typical planning efforts. First, the sizing of the facilities is based on peak-hour operation of the freeways and freeway interchanges. Sections of facilities should have no more capacity than can be loaded and unloaded during the peak-hour. Peak-hour constraints on the existing and future freeway systems were analyzed to determine where any bottlenecks could be removed, where additional parallel capacity could be built, and where the constraints would be inevitable.

Second, the different transportation modes (commuter rail, light-rail, buses, carpools, and single-occupant vehicles) were analyzed as a system. During the analysis, the peak-hour person demand for each corridor and for the system was held constant, while various alternatives were evaluated on how efficiently and cost effectively the demand was served. An important difference between the Dallas System Planning Study and traditional freeway planning efforts is the quantification of congestion on the mainlanes for any alternative. The cost of building additional capacity is weighed against the cost of congestion to the motorist. The alternative with the total lowest cost is selected as the "best" alternative, assuming the alternative is compatible with the connecting facilities.

This report describes the methodology used to develop the recommended Dallas freeway/HOV system, the assumptions that went into each step, and the final output of the system planning analysis.

II. BACKGROUND

The Dallas urban area considered in the Dallas System Planning Study includes all of Dallas County and the southern portion of Denton and Collin Counties. The existing freeway system and four proposed freeways (SH 161, SH 190, Trinity Parkway/West Fork Freeway, and Santa Fe Bypass) are shown in Figure 1. All of these corridors were evaluated in the study except for the southern half of US 75 (between the central business district and IH 635) and the Dallas North Tollway. US 75 is currently being upgraded to an eight-lane freeway with a light-rail transit facility in the corridor. Acquisition of any additional right-of-way in this corridor for the purpose of increasing capacity would be very costly due to the development along the corridor. The Dallas North Tollway is also within a narrow right-of-way with little room for additional capacity.

TxDOT maintains a 10-year Project Development Plan that includes all freeway and principal arterial facilities planned on the state system (1). This plan gives priority to the approved projects in the Dallas District. In 1985, TTI developed an HOV System Plan for the Dallas District of TxDOT (2). This plan evaluated the viability of HOV facilities in corridors that did not include fixed-guideway transit facilities proposed by DART. In 1989, DART updated their long-range transit system plan to include light-rail facilities, HOV lanes, and a commuter rail line (3). In 1990, NCTCOG produced the Mobility 2010 Plan (4). This plan is the region's current 20-year transportation plan for guiding the implementation of roadway and transit improvements in the Dallas/Fort Worth metropolitan area. The NCTCOG Mobility Plan incorporates the plans of all agencies and municipalities, evaluates future travel demand and system alternatives, and presents the alternatives necessary to best meet the mobility needs of the region.

The plans from the different agencies produced slightly different alternatives within the system due to the starting assumption and the goal of each plan. TxDOT developed a freeway plan with no preferential treatment; NCTCOG developed a plan to best meet the mobility needs of the region with traffic flow speeds of 72 kph (45 mph) or better during the peak-hours of travel, and DART developed a long-range transit system plan. As these plans move toward implementation, it is becoming essential that all the components be compatible. The Dallas System Planning Study was an effort to bring together the various plans and develop an analysis technique to balance the supply of, and demand for, transportation facilities in the Dallas area.

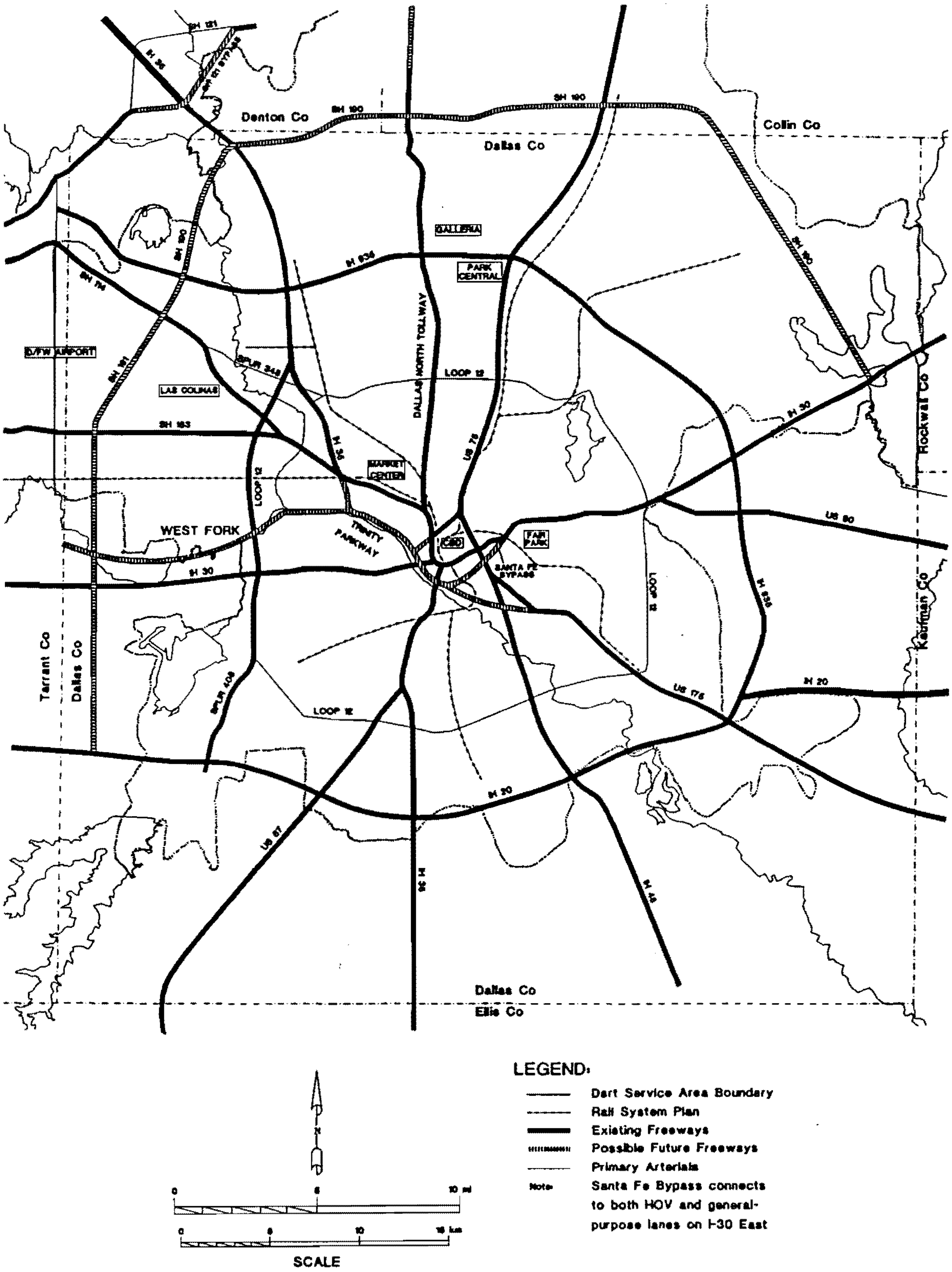


Figure 1. Dallas System Planning Study Freeways

III. METHODOLOGY

A major effort in the Dallas System Planning Study was developing a methodology to create and analyze both a freeway and HOV system. As procedures were formulated they had to be tested for viability. The IH 30 East corridor was the test corridor for the methodology because: 1) there were extensive vehicle data from other projects previously completed by TTI and 2) this corridor exhibited the typical problems expected in an urban area such as existing congestion, high demand, major freeway-to-freeway interchanges, and lane balance questions.

The goal of the study was to provide an efficient and cost effective transportation system to the public. This would be measured by: 1) the cost to construct the system (including right-of-way and rehabilitation to existing freeways); 2) the cost to operate the system; and 3) the cost of congestion where the system does not adequately meet the demand.

The methodology consists of five major efforts:

1) Data input;
2) Alternatives analysis;
3) Cost analysis;
4) Alternative selection; and
5) Operational analysis.

Each of these steps in the study will be discussed in more detail in subsequent sections of this report.

The strategy of the Dallas System Planning Study was to determine the demand, try to serve the demand with different alternatives, apply mode shift (commuters who change their modes of travel due to congestion) as appropriate, and estimate the cost of the alternative. This, however, quickly became an iterative procedure, because the design of one section impacted the design of adjacent sections. After the critical sections of the system were examined, adjacent sections in the system had to be analyzed for compatibility.

IV. INPUT NEEDED FOR THE FREEWAY/HOV SYSTEM PLANNING STUDY

Because the Dallas System Planning Study is a new planning effort, the methodology evolved as the system was developed. Similarly, the data and background material needed to produce the system were defined at different stages of the system planning effort. The following are the primary input items required for the Dallas System Planning Study analysis:

1) Existing 24-hour volumes for freeways, HOV lanes, bus systems, and transit systems at critical locations;

2) Complete design year 24-hour volumes for freeways, HOV lanes, bus systems, and transit systems;

3) Data on percent of daily traffic in the peak-hour, peak-hour directional splits, and peak-hour truck percentages at several points throughout the system;

4) Roadway plan sheets for freeway corridors showing existing lanes, right-of-way limits, roadway structures, and buildings adjacent to the corridor; and

5) Updated lists of planned projects in the region.

EXISTING FREEWAY TRAFFIC VOLUMES

For the Dallas System Planning Study, TTI conducted extensive weekday freeway and ramp counts during 1989 and 1990. These data were collected by both manual and machine methods. Mechanical counters were used to obtain 24-hour volumes on the freeway mainlanes when loops were present in the pavement and on each freeway ramp. Manual peak period mainlane counts were also conducted at various locations throughout the freeway system.

The mainlane volumes were then computed for each freeway subsection by adding and subtracting ramp volumes along each corridor from a manual or machine mainlane count. The mainlane volumes were spot checked for accuracy through additional manual counts and/or machine counts. The accuracy check criteria was a 10 percent difference between computed volumes and volume counts on the freeway mainlanes. If a calculated volume differed from a count by more than

10 percent, the ramp counts throughout the corridor were adjusted by 10 percent or less to bring the calculated volumes back in balance with the count. The one exception was the northern section of IH 635 (between IH 35E and US 75) which had a plus or minus 20 percent tolerance due to the variability of existing daily traffic volumes in that corridor.

The result of this effort was 24-hour and morning and evening peak-hour volumes for each ramp and freeway section between ramps on urban freeways in the Dallas urban area. These data have been summarized by corridor in a separate document (5). From these counts, researchers calculated peak-hour directional splits and peak-hour truck percentages. In addition, they used these data to estimate the percentage of daily traffic occurring in the peak-hour (also referred to as the K-factor).

DESIGN YEAR 24-HOUR VOLUMES

The design year two-way 24-hour volumes and selected link data were obtained from NCTCOG. The design year 24-hour volumes are the result of several computer model assignments performed for NCTCOG's Regional Mobility Plan, which includes a regional HOV, express lane, and light-rail system. The analysis year for those assignments was 2010, and the forecasted volumes include carpools, buses, commuter rail, light-rail, and general-purpose freeway vehicles. While the NCTCOG volumes were forecast for the year 2010, TxDOT required a design year of 2015 for the Dallas System Planning Study. The NCTCOG volumes were, therefore, increased at a growth rate of two percent per year for five years for use in the study. The two percent growth per year is a typical historical annual growth rate in the Dallas urban area.

Year 2015 24-hour volumes were determined on each link in the existing Dallas freeway system. These were compared to the 1989/1990 traffic counts collected by TTI as well as the base year 1986 assignment by NCTCOG to ensure reasonable growth rates. Working with staff from all agencies, researchers agreed upon some adjustments to the year 2015 assignment in areas where the 1986 base assignment did not correlate well with the 1989/1990 TTI counts. These comparisons are plotted by corridor and presented in Appendix A.

The year 2015 assignment was used to develop volumes for all freeway sections and ramps. In some cases where existing ramps were not modeled in the NCTCOG assignment, other refinements had to be made to the year 2015 volumes to determine the freeway ramp volumes. The 1989/1990 24-hour volumes and the year 2015 24-hour volumes are also presented in Appendix A.

Researchers requested and obtained from NCTCOG selected link data, which give the origins and destinations of trips on a specific link of roadway. They used more than 20 selected link locations to determine the most logical path of vehicles throughout the system during the peak-hour. The base assumption was that the 24-hour selected link data would replicate the peak-hour conditions. While there is some question as to the validity of this assumption, NCTCOG felt that their peak-hour model, at the time the data were requested, was not sufficiently refined for use in the Dallas System Planning Study.

K-FACTORS AND DIRECTIONAL SPLITS

The design hour volume is used to determine the size of a facility, which in turn affects the amount of right-of-way needed, the quantity of materials needed to build the facility, the design of the connections to other sections of freeway or arterial streets, and the effort needed to operate and maintain the facility. Accurate estimations of design year peak-hour volumes is, therefore, critical in the Dallas System Planning Study. During the initial stages of the study, it was suggested that the NCTCOG peak-hour assignment could be used to estimate peak-hour demand. It was, however, determined that the peak-hour assignment was not sufficiently calibrated for use in the study. Traditional use of K-factors and directional splits applied to forecasted 24-hour volumes was, therefore, employed to determine peak-hour demand.

The 24-hour volume is multiplied by the K-factor (ratio of the 30th highest hour to average daily traffic) and the directional split (the proportion of traffic occurring in the peak direction of travel during the peak-hour) to estimate the amount of traffic that will use a facility during the design hour. Examination of research on K-factors and directional splits found that little information existed on the use of these planning parameters for forecasting purposes in urbanized areas. This need initiated a research project in 1987 to analyze these parameters.

A TTI research report titled "Development of Planning Values for Urban Freeways in Large Texas Cities" presents the results of this research (6). The data base used in that research effort to evaluate these planning parameters was the permanent automatic traffic recorders in five major cities in Texas. The permanent automatic traffic recorders are installed at limited locations on the freeway system throughout the state. The traffic recorders are operated and maintained by TxDOT. Data from the traffic recorders are summarized annually by TxDOT (7).

The problem with the data base used in the research was that many of these count locations are located in congested sections of freeway, thus resulting in constrained volumes and relatively low values of K-factors and directional split (as compared to unconstrained sections). The constrained points were, therefore, eliminated from the data base. There were not enough remaining count locations to do a statistically significant analysis. The research report does, however, include reference tables that stratify ranges of K-factors and directional splits based on values of the following variables: 1) daily volume per lane; 2) distance from major employment centers; 3) employment density in the corridor; 4) volume-to-capacity ratio; 5) length of peak-period congestion; and 6) type of facility (radial or circumferential).

Two findings from the research are significant, however, and were used in developing the Dallas System Planning Study. First, the traditional K-factor is inappropriate for use in estimating design hour volumes because the 24-hour volumes are forecast for a typical weekday and K-factors are based on average daily traffic which includes holidays and weekends. Second, the directional split during the 30th highest hour may not be appropriate for a typical weekday because it also includes holidays and weekends.

The K-factors used in the Dallas System Planning Study for each freeway were representative values selected from multiple sources. K-factors were obtained from permanent automatic traffic recorders, TxDOT's Transportation Planning and Programming Division in Austin, and data collected by TTI. The directional split for each section of freeway was computed from the peak-hour manual counts conducted by TTI. Table 1 summarizes the K-factors and directional splits used for each freeway corridor.

Table 1. K-Factors and Directional Splits

FREEWAY	SECTIONS														
IH20	County Line		SH 161		Spur 408		US 67		IH35		IH45		IH635		Belt-Line
K-Factor:		.105		.105		.105		.105		.105		.105		.105	
Directional Split:		.58		.58		.58		.58		.58		.58		.58	
IH30 East R.L. Thornton	IH45		Peak		E. Grand		Ferguson		US 80		IH635		SH190		
K-Factor:		.085		.085		.085		.085		.085		.085			
Directional Split:		.69		.69		.69		.69		.69		.69			
IH30W	SH 360		SH 161		Loop 12		Hampton		Trinity		IH35E				
K-Factor:		.085		.085		.085		.085		.085					
Directional Split:		.65		.65		.65		.65		.60					
IH35E Stemmons	SH 121		SH 121 Bypass		SH 190		IH635		Loop 12		SH 183		D.N.T.		
K-Factor:		.09		.085		.09		.09		.09		.09			
Directional Split:		.58		.58		.58		.56		.56		.53			
IH35E South R.L. Thornton	Trinity		Ewing		US 67		IH20		Belt-Line						
K-Factor:		.085		.085		.085		.085							
Directional Split:		.60		.65		.65		.65							
IH45	IH30		US 175		Santa Fe Bypass		Illinois		IH20		Dowdy Ferry		Belt-Line		
K-Factor:		.10		.10		.10		.10		.10		.10			
Directional Split:		.70		.70		.70		.70		.70		.70			
IH635 EAST LBJ	US 75		Skillman		Garland		IH30		US 80		IH20				
K-Factor:		.08		.085		.085		.085		.085					
Directional Split:		.55		.65		.65		.60		.60					

Table 1. K-Factors and Directional Splits (continued)

FREEWAY	SECTIONS										
IH635 N (EB) LBJ	County Line		SH 190/161		IH35E		D.N.T.		US 75		
K-Factor:		.08		.08		.08		.08			
Directional Split:		.60		.60		.50		.50			
IH635 N (WB) LBJ	County Line		SH 190/161		IH35E		D.N.T.		US 75		
K-Factor:		.08		.08		.08		.08			
Directional Split:		.40		.40		.50		.50			
US 67	IH 35		Hampton		IH 20		Belt-Line				
K-Factor:		.085		.085		.085					
Directional Split:		.65		.65		.65					
US 75	IH 635		Spring Valley		Arapaho		SH 190		15th		Parker
K-Factor:		.08		.08		.08		.08		.08	
Directional Split:		.55		.55		.55		.55		.55	
US 80	IH 30		Town East		IH 635		Belt-Line				
K-Factor:		.085		.085		.085					
Directional Split:		.69		.69		.69					
US 175	IH 45		Santa Fe Bypass		2nd Ave.		Jim Miller		IH 20		Belt-Line
K-Factor:		.10		.10		.10		.10		.10	
Directional Split:		.69		.69		.69		.69		.69	

Table 1. K-Factors and Directional Splits (continued)

FREEWAY	SECTIONS														
SH 114	County Line		SH 161		Spur 348		Loop 12		SH 183						
K-Factor:		.094		.094		.094		.094							
Directional Split:		.65		.65		.55		.55							
SH 161	IH 20		IH 30		SH 183		Belt Line		IH 635						
K-Factor:		.095		.095		.095		.095							
Directional Split:		.65		.60		.55		.55							
SH 183	County Line		Belt Line		MacArthur		Loop 12		SH 114		IH 35E				
K-Factor:		.085		.085		.085		.085		.085					
Directional Split:		.65		.65		.60		.60		.60					
SH 190	IH 635		IH 35		D.N.T.		Coit		US 75		Blackburn		US 78		IH 30
K-Factor:		.095		.095		.095		.095		.095		.095		.095	
Directional Split:		.55		.55		.55		.55		.55		.55		.55	
Loop 12/ Spur 408	IH 35		SH 183		SH 356		IH 30		Spur 408		IH 20		Camp Wisdom		
K-Factor:		.089		.089		.089		.089		.089		.089			
Directional Split:		.55		.65		.65		.65		.65		.55			
Trinity Pkwy.	IH 35		Wycliff		Spur 366		IH 30		IH 35		Santa Fe Bypass		IH 45		US 175
K-Factor:		.10		.10		.10		.10		.10		.10		.10	
Directional Split:		.70		.70		.70		.70		.70		.70		.70	

ROADWAY PLANS AND PLANNED PROJECTS

Roadway plans and an updated list of planned projects for each freeway corridor were obtained from TxDOT. The roadway plans were used to verify the existing configuration of the freeways and to identify any existing operational problems due to geometrics on the freeways. Roadway plans also assisted in identifying sections of freeway on structure and the existing right-of-way, which had an effect on the cost of capacity improvements.

A list of planned projects was required to identify any change to the existing system that would be implemented prior to any recommendations in the Dallas System Planning Study. This included any projects that are currently under construction or will be constructed in the near future.

V. SYSTEM LEVEL CONSTRAINTS

Limitations such as geometric constraints, right-of-way constraints, operational constraints, environmental constraints, and community concerns will directly impact the viability of alternatives for the Dallas System Planning Study. The intent of this effort is to recognize implementation constraints and allow detailed corridor designs to proceed with the assurance that the design will be compatible with the ultimate design of the remainder of the freeway system.

GEOMETRIC CONSTRAINTS

The geometric constraints include situations where a section of freeway or a direct-connect freeway ramp in the system is currently near or at capacity during the peak-hour. These sections effectively "meter" traffic downstream and cause congestion upstream. Capacity improvements are essential in these areas if upstream corridor improvements are to be implemented. There are some instances where capacity improvements are not feasible in certain freeway sections. Alternatives other than freeway widening must, therefore, be considered.

The interchanging freeways around the central business district (CBD) are the most critical geometric constraints in the system. Figure 2 shows the existing morning constraints, and Figure 3 shows the existing evening constraints around the CBD. Additional capacity on the radial freeways simply could not be unloaded to the existing street and freeway system around the CBD in light of these constraints.

IH 30 is the most critical constraint. The cost of reconstructing the depressed sections of IH 30 south of the CBD is extremely high. The option of constructing the Trinity Parkway (from US 175 on the east side to IH-35E on the west side) and the Santa Fe Bypass (from IH-30 east along the Santa Fe railyard connecting to the Trinity Parkway) was, therefore, investigated. If these facilities could not be constructed, additional capacity on the radial freeways approaching the CBD could not be utilized. After discussing this problem with the agencies involved in the development of the system, the research team made the assumption that the Trinity Parkway and the Santa Fe Bypass could be constructed. Preliminary design verified the feasibility of this assumption.

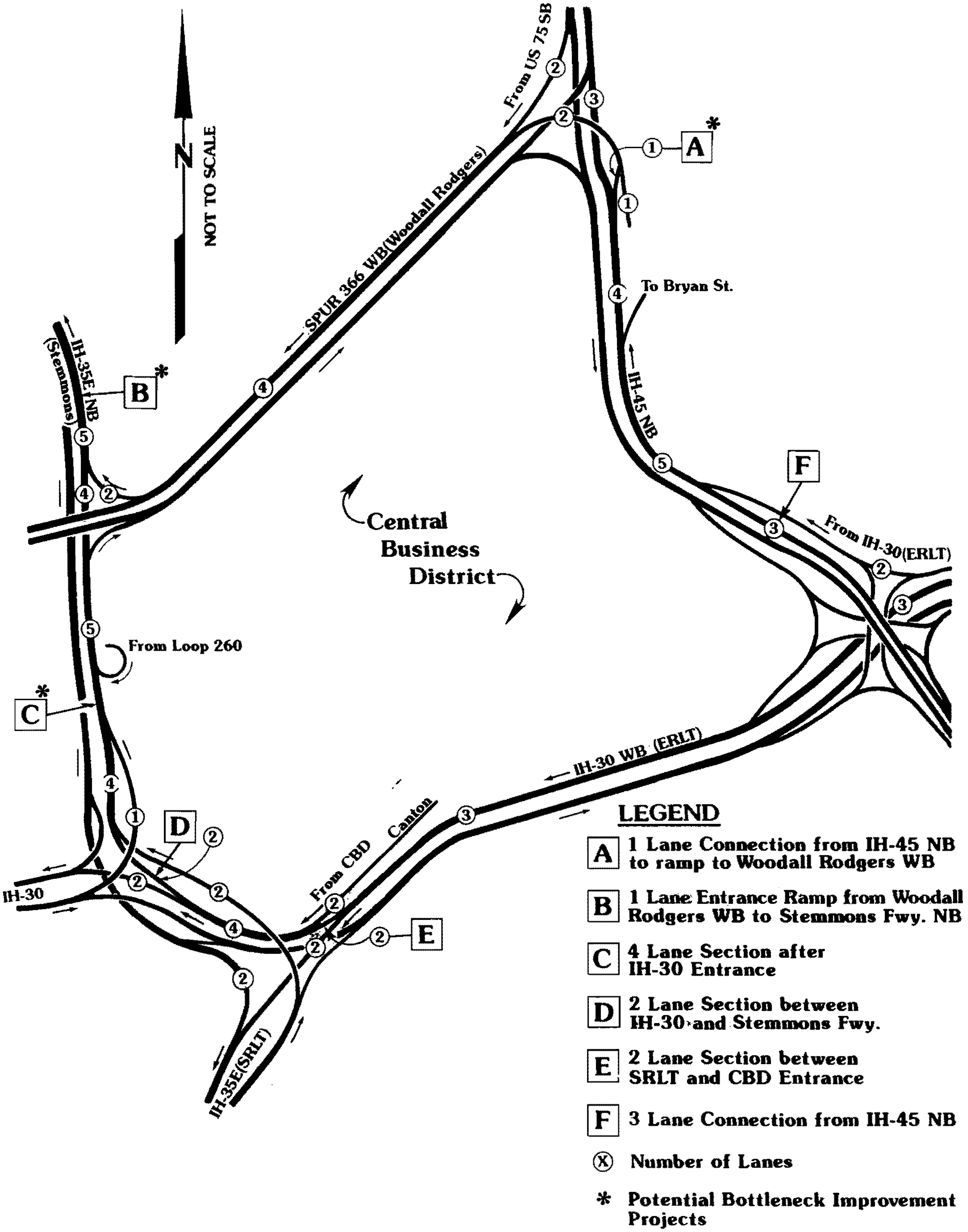


Figure 2. Morning Constraints Around Central Business District

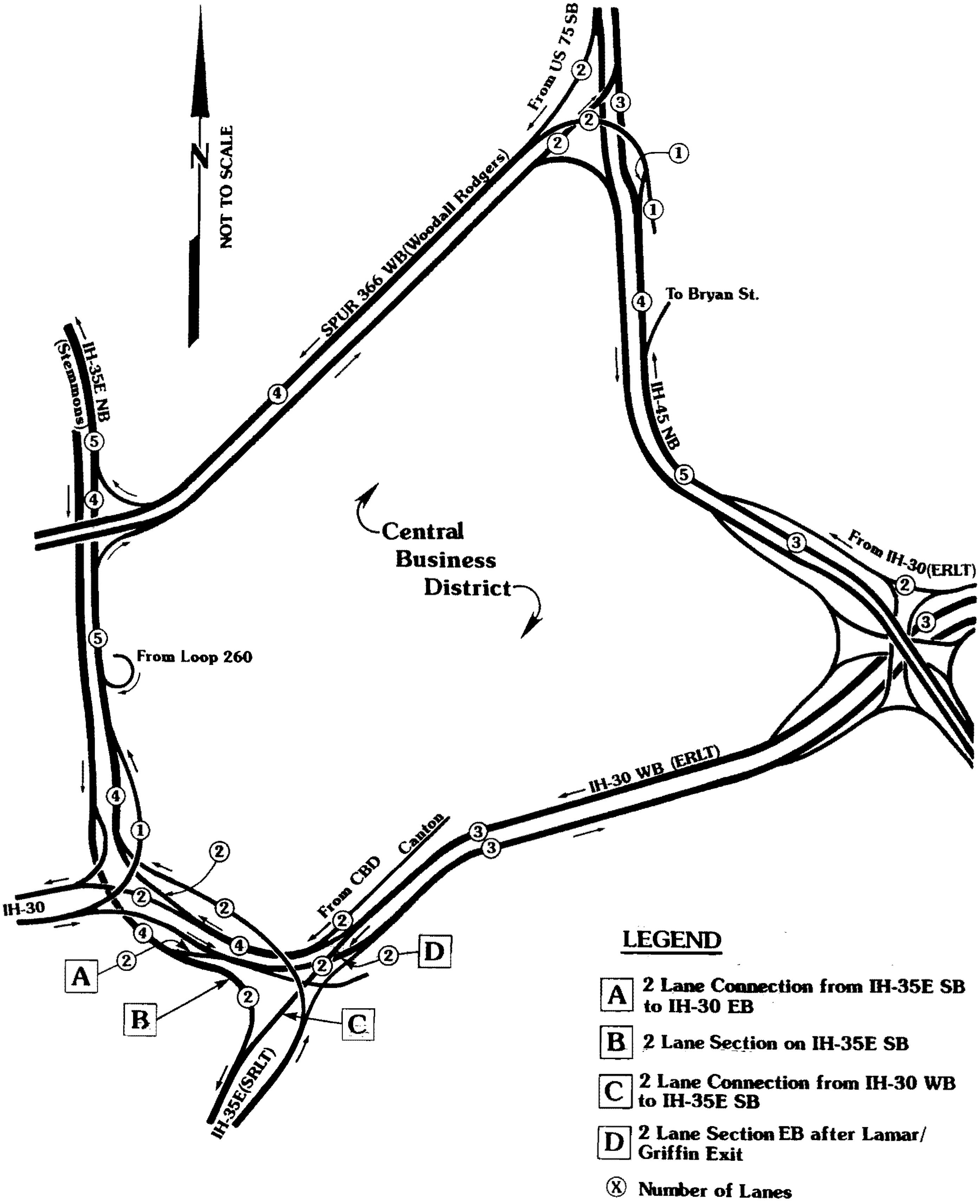


Figure 3. Evening Constraints Around Central Business District

RIGHT-OF-WAY CONSTRAINTS

Right-of-way constraints can also be a controlling factor in the viability of options for recommended improvements. Land development where right-of-way is required may have progressed to the point where purchasing the land (including buildings, houses, etc.) is not feasible. An example of this is US 75 between the CBD and IH 635.

US 75 between the CBD and IH 635 is one of the oldest and most congested freeways in Dallas County. This section of freeway is under construction and will be widened to eight lanes with an adjacent light-rail transit facility. There is little or no right-of-way available to add any additional capacity due to development adjacent to the freeway.

OPERATIONAL CONSTRAINTS

Operational constraints, such as ramp junctions and weaving areas, are also a significant concern in the Dallas System Planning Study. Locations where freeway operations are hindered must be addressed before capacity improvements throughout the corridor can be implemented. Such sections can constrict the traffic flow and limit the amount of traffic that can pass a given section of freeway. The problem of an existing weave that causes the freeway to operate poorly may be exacerbated by the addition of another lane to the freeway. The weaving problem will still exist and any additional capacity will most likely be wasted or not utilized.

This situation occurs on IH 30 near Fair Park. The westbound lanes of IH 30 were experiencing a significant amount of congestion during the morning peak period and a closer investigation revealed that one of the operational problems originated in the area of the westbound First Avenue entrance ramp. TTI conducted an origin-destination study (at the request of TxDOT) to identify the problem. The origin-destination study consisted of obtaining license plate information for vehicles utilizing the ramp during the morning peak period and mailing out postage-paid surveys to these individuals. The results of the study revealed that vehicles were leaving the freeway several kilometers (miles) upstream, traveling along the principal arterials, and entering at the front of the queue at the First Avenue entrance ramp. These entering vehicles caused a weaving problem by entering the freeway, weaving across the outside lanes, and conflicting with vehicles on the freeway mainlanes that were trying to get to the two-lane exit ramp to IH 45 located 0.8 kilometers (0.5 miles) downstream. Specifics of this origin-destination study were documented in a technical memorandum supplied to TxDOT (8).

Changing the geometrics within a corridor may create operational conditions which hinder the freeway. Every effort has, therefore, been made to identify these problem areas and incorporate modifications prior to implementation. Merging, diverging, and weaving sections have been analyzed using the procedures in the Highway Capacity Manual on all existing freeways with potential bottlenecks (9). The operational analysis of the Dallas freeway and HOV system for year 2015 volumes is discussed in Chapter X.

ENVIRONMENTAL CONSTRAINTS

Environmental constraints are especially critical where new facilities are proposed. Areas where wetlands, historical landmarks, or parks may be encroached upon due to the alignment of a proposed facility must be identified. Because highway location and design decisions affect adjacent area developments, it is important that environmental variables be given full consideration. The proposed Trinity Parkway alignment parallels the Trinity River. The Corps of Engineers must, therefore, be consulted to ensure that adverse effects to the river and the surrounding environment do not occur. TxDOT provided preliminary engineering information on corridors where these issues had been investigated.

OTHER CONCERNS

The effort described in this report is a system-level assessment of the cost and operation of the Dallas area freeway corridors in the year 2015. A significant amount of work remains to be done before this system can be implemented. One important part of that effort will be to obtain input from the residents and businesses in the Dallas area. The concerns and suggestions from the public, as well as future financial and design considerations, are elements that may require recommended system modifications over the next 25 years. That effort is more appropriately addressed at the corridor level during decisions on implementation of individual projects. As projects are approved, the system should be re-evaluated to determine the effect of any changes; however, at this time, no attempt was made to do this.

VI. CORRIDOR ALTERNATIVES ANALYSIS

Once the system constraints were determined, the research team analyzed the individual corridors for the "best" alternative. The alternatives analysis for each corridor consists of development and evaluation of several cross sections. The alternatives analysis for the entire freeway system was an iterative process based on the constraints that would control where traffic could be loaded and unloaded to other facilities and the demand for each portion of the corridor.

The cross sections evaluated for each corridor (where appropriate) included the existing cross section, the NCTCOG Mobility Plan cross section, an all general-purpose lane cross section, and cross sections including express lanes, a 2-or-more (2+) person HOV lane, and a 3-or-more (3+) person HOV lane. In many cases, variations of each cross section were evaluated such as the number of HOV or express lanes, at-grade versus elevated HOV or express lanes, and combinations of HOV lanes and express lanes.

The highest ranking alternative (based on lowest total cost) for each corridor was superimposed on the system to check for compatibility. At locations where corridor components were not compatible, the next-best alternative was evaluated for system compatibility. This process continued until the number of lanes and level of congestion were balanced for the freeway system.

HOV RIDERSHIP ADJUSTMENT FOR CONGESTION

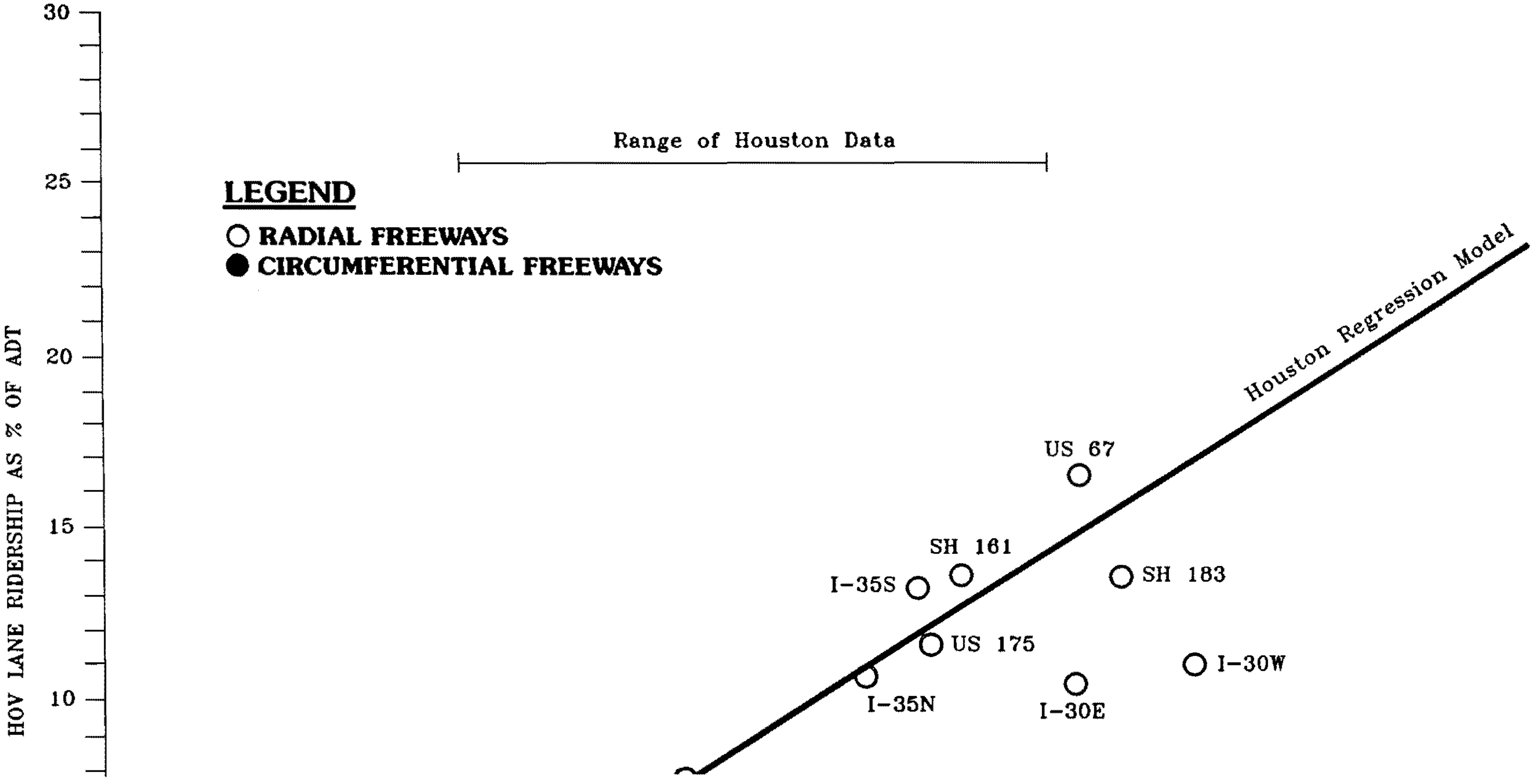
As described earlier, design hour vehicle and person volumes were derived for each freeway section from the NCTCOG assignment. The total person demand in a corridor was held constant for the various alternatives being evaluated. Different facilities would, however, handle different vehicle volumes based on the peak-hour congestion patterns in the corridor. A model, therefore, was needed to relate carpool and bus ridership with freeway congestion levels.

Any HOV or express lane treatment derives its benefit from a travel time advantage over congested regular general-purpose lanes. The HOV lane gives priority treatment to vehicles with the designated occupancy level, and express lanes give priority treatment to vehicles with specific trip destinations. The basic user group of the HOV lane is the vehicles that are eligible because of the number of occupants before the HOV treatment is opened. If the general-purpose facility is congested, however, people with similar trip patterns will form carpools or ride buses to take advantage of the time savings. This will have the effect of increasing the average vehicle occupancy of the traffic stream. The express lanes typically will not encourage the same increase in carpool and bus ridership because there are no restrictions on vehicle occupancy. The express lanes will provide time savings only when the congestion level is less than the mainlanes, which can be achieved if the access points are limited.

While there may be several travel corridor characteristics that might have an impact on the decision to use an HOV facility, travel time savings over congested general-purpose lanes is the primary motivation for most commuters to change modes of travel and utilize an HOV facility. To predict the increase in ridership on an HOV lane, TTI analyzed the data collected on the Houston HOV lanes. Because the Houston HOV system is the most extensive in the nation and demographic and land development characteristics are similar in Houston and Dallas, data from the Houston facilities were used as a gauge to estimate HOV facility ridership in the Dallas System Planning Study.

Daily traffic volume per lane is a measure of the amount of vehicle travel per section of roadway. While this does not directly measure peak-hour congestion, there is a close relationship between this variable and peak period HOV ridership. In the Dallas System Planning Study methodology, HOV ridership is expressed as a percentage of freeway average daily traffic based on data from the NCTCOG projections. For each corridor, the NCTCOG ridership projections (as a percent of average daily traffic) were plotted against the daily traffic volume per lane (congestion). These data points were plotted against the best fit line developed from the Houston data (Figure 4). The locations on radial facilities in Dallas (shown with circles) have good correlation with the Houston equation. The circumferential facilities in Dallas do not correlate well with the Houston model, which is not too surprising given that the Houston data are from radial facilities.

Figure 4. Relationship Between HOV Ridership and Congestion Level



The coefficient of determination (R^2) for the relationship between ridership and congestion level in Houston was 0.67, indicating a close correlation between the two factors. The majority of the NCTCOG HOV ridership estimates are associated with congestion levels similar to those in Houston (between 20,000 and 28,000 daily vehicles per lane), which was important if the Houston regression equation was to be useful to the Dallas System Planning Study effort. The Dallas average daily traffic per lane values are within 10 percent of the upper and lower ends of the Houston data, which, when combined with the relatively high R^2 value, indicated that the Houston regression line could be used to develop ridership estimates for roadway configurations not included in the NCTCOG Mobility Plan.

COST CRITERIA USED FOR RANKING ALTERNATIVES

In determining the economic feasibility of a given project, it is standard procedure to examine the projected costs and benefits. If the annual benefits exceed the annual costs, the project is feasible; though a decision to implement may depend upon funding availability, project feasibility, community concerns including environmental effects, and competing priorities. Determining feasibility for a single project (comparing costs and benefits) can be done in a variety of ways, but as a summary: a project is feasible if the sum of costs (-) and benefits (+) is greater than zero, or if a benefit/cost ratio is greater than 1.0.

However, in the context of alternatives analysis, a more sophisticated process is required in order to maximize public gain from the money that is available for investment. Simply ranking alternatives with a benefit/cost ratio greater than 1.0 in order of numerical benefit/cost ratio may lead to erroneous conclusions (10). Incremental benefit/cost comparison is required where the alternatives with a benefit/cost ratio greater than one are examined to determine the benefit of each additional dollar of investment above the lowest cost alternative.

A less confusing method to deal with this problem is the net present worth comparison. The net present worth comparison consists of converting all costs over the life of the project to present worth, using an appropriate time frame and discount rate, as negative values and all benefits are brought back to present worth as positive values. In this case, the highest net present worth available (capped, of course, by the availability of sufficient investment dollars) is the optimum project.

The net present worth of the public cost was used to select the most cost-effective alternatives in the Dallas System Planning Study. However, in order to avoid the necessity of quantifying the absolute value of congestion delay relative to a "do nothing" scenario, the congestion delay itself is regarded as a cost. All components (capital, operating and maintenance, and congestion) are costs; therefore, the optimum net present worth alternative is the lowest total cost alternative. The net present worth (or net present cost) comparison is the cost criteria used for ranking alternatives in the study.

VII. COST ANALYSIS

For each alternative developed within each corridor, costs were determined for the total capital cost, operating and maintenance cost, and, if necessary, a congestion cost.

CAPITAL COSTS

For the purposes of the Dallas System Planning Study analysis, total capital cost included the three components of: 1) rehabilitation cost; 2) construction cost; and 3) right-of-way cost.

Rehabilitation

Several of the freeways in the Dallas System Planning Study are more than 20 years old and are currently in need of physical repair (e.g., the replacement of deteriorated pavement which has reached its design life). In order to provide additional capacity to the freeway, the entire facility (in some cases) must first be repaired. Freeway standards are continually revised to enhance motorist safety. In some instances, the existing facility must also be upgraded to current design standards; this would typically entail upgrading geometric design elements such as horizontal and vertical curvature and clearances.

Construction

The construction cost is associated with the addition of general-purpose lanes, HOV lanes, and/or express lanes to the freeway. Costs for construction of various possible roadways were investigated at the planning level of analysis. General-purpose lane, HOV lane, and express lane cost values reflect average unit bid prices from recent Houston and Dallas construction projects. HOV lane costs include park-and-ride support facilities (such as "T" ramps into lots, but not the lot itself), elevated interchanges, and associated street and freeway improvements necessary to operate the HOV lane. Table 2 shows the unit cost values used in the construction cost estimates.

Table 2. Unit Construction Costs

Construction Item	Width Meters (Feet)	Cost - $ Million Per Kilometer (Per Mile)
Mainlane (one lane at grade)	3.7 m (12')	$1.6 per km ($2.5 per mile)
Mainlane (one lane elevated)	3.7 m (12')	$2.2 per km ($3.5 per mile)
HOV lane w/ramps (one lane at grade)	6.1 m (20')	$3.1 per km ($5 per mile)
HOV lane w/ramps (one lane elevated)	6.1 m (20')	$4.3 per km ($7 per mile)
HOV lanes w/ramps (two lanes at grade)	12.2 m (40')	$4.3 per km ($7 per mile)
HOV lanes w/ramps (two lanes elevated)	12.2 m (40')	$6.2 per km ($10 per mile)
Express lanes (two lanes at grade)	12.2 m (40')	$3.7 per km ($6 per mile)
Express lanes (two lanes elevated)	12.2 m (40')	$5.6 per km ($9 per mile)
Express lanes (three lanes at grade)	17.1 m (56')	$6.2 per km ($10 per mile)
Express lanes (three lanes elevated)	17.1 m (56')	$9.3 per km ($15 per mile)
Surveillance, communication & control (SC&C)	N/A	$0.31 per km ($0.50 per mile)

Right-of-Way

The right-of-way cost is related to any additional land required for widening a freeway. The cost of land varies in each corridor. Data relative to right-of-way costs were obtained from TxDOT, which supplied very detailed information on land values adjacent to the freeways. TTI used a representative unit cost per corridor (see Table 3) in order to estimate the right-of-way cost for a given corridor based on required land and amount of development. These costs were principally used in the analysis of elevated facilities to determine which alternative produces a lower cost -- acquiring additional right-of-way or elevating a facility.

Table 3. Right-of-Way Costs

Corridor	Land Value $ per sq meter ($ per sq ft)	Corridor	Land Value $ per sq meter ($ per sq ft)
IH 20	$215 ($20)	US 75	$431($40)
IH 30 (East Thornton)	$323 ($30)	US 80	$269 ($25)
IH 30 West	$269 ($25)	US 175	$215 ($20)
IH 35E (Stemmons)	$323, $484 ($30, $45)[1]	SH 114	$323, $431 ($30, $40)[3]
IH 35E (South Thornton)	$323 ($30)	SH 161	$215 ($20)
IH 45	$215 ($20)	SH 183	$431 ($40)
IH 635 North	$323, $538 ($30, $50)[2]	SH 190	$215 ($20)
IH 635 East	$323 ($30)	Loop 12/Spur 408	$269 ($25)
US 67	$269 ($25)	Trinity Parkway	$323 ($30)

[1] $484 per sq. meter ($45 per sq. ft.) between SH 183 and downtown; $323 per sq. meter ($30 per sq. ft.) north of SH 183.
[2] $323 per sq. meter ($30 per sq. ft.) west of Stemmons and $538 per sq. meter ($50 per sq. ft.) east of Stemmons.
[3] $431 per sq. meter ($40 per sq. ft.) around Los Colinas and $323 per sq. meter ($30 per sq. ft.) everywhere else.

OPERATING AND MAINTENANCE COST

The operating and maintenance cost varies depending on the type of facility proposed. The cost of a surveillance, communication, and control (SC&C) system has been included in each corridor regardless of the cross section. The operating cost for alternatives with reversible lanes is the cost of opening and closing (or reversing) the lane on a daily basis -- this would pertain to express or HOV lanes. The operating cost for alternatives with HOV lanes also includes the cost of enforcing the lane on a daily basis. Table 4 shows the operating cost for the various alternatives analyzed. The operating and maintenance costs are estimated on a corridor basis.

Table 4. Operating Costs

Operating Item	Annual Cost ($ Million)
Enforcement for separated HOV lane	$ 0.05 per facility
Reversible lane (Express and HOV)	$ 0.20 per facility
Surveillance, communication & control (SC&C)	$ 0.10 per mile

CONGESTION COST

The congestion cost quantifies the cost of delay to motorists. As the peak-hour volume per lane approaches and exceeds capacity, the average travel speeds will decrease from free flow operation. The level of congestion is defined by the average estimated speed of freeway traffic. Minutes lost per person can be calculated from the difference between the estimated congestion speed and free flow speed. To arrive at an annual congestion cost, the time lost is multiplied by the value of person time (11), the working days per year, and persons per lane. The delay per vehicle used in the Dallas System Planning Study based on the level of congestion is shown in Table 5.

Table 5. Delay Associated with Level of Congestion[1]

System Congestion Level (vehicles per hour per lane)	Estimated Speed kph (mph)	Delay per Vehicle minutes/km (minutes/mile)	Annual Unit Congestion Cost per vehicle-km (per vehicle-mile)[2]
< 1,850	89 (55)	0.0 (0.0)	$0 ($0)
1,850 - 1,999	72 (45)	0.19 (0.3)	$7.5 ($12)
2,000 - 2,199	48 (30)	0.62 (1.0)	$25 ($40)
2,200 - 2,400	24 (15)	1.9 (3.0)	$75 ($120)

Notes: [1] Congestion levels and delays illustrated above are for system planning level analysis purposes only.
[2] 1990 value of time=$9.76 per hour per vehicle (11).

The freeway volume is capped at 2,400 vehicles per hour per lane in the peak-hour. If the demand exceeds the 2,400 vehicles per hour, the excess demand is shifted to the hours on either side of the peak-hour. The congestion in these hours is evaluated in the same manner.

VIII. ALTERNATIVE SELECTION

LOWEST COST ALTERNATIVE FOR CORRIDOR

The net present cost is broken down into construction cost, right-of-way cost, operation and maintenance cost, and congestion cost for each alternative. As discussed earlier, the highest ranking alternative for each corridor is the alternative with the lowest total public cost (referred to as the net present cost).

Previous regional planning efforts and freeway design have been predicated on the goal of achieving traffic flow speeds of 72 kph (45 mph) or better during the peak-hours of travel. On the other hand, the goal of the Dallas System Planning Study has been to find the lowest public cost alternative in each corridor for a given volume of person trips. The selection of the highest ranking alternative many times leads to an HOV alternative with congestion on the mainlanes. This implies the acceptance of congestion, and accompanying delay, during the peak-hour for mainlane traffic, but only when this congestion cost is less than the cost of constructing additional capacity. This is a change in traditional planning efforts in that future congestion is accepted on freeways where carpooling and transit usage can be encouraged through HOV lanes, and the total cost to the public is kept to a minimum.

ALTERNATIVE COMPATIBILITY WITH SYSTEM

The highest ranking alternative for each corridor was evaluated for its compatibility with adjoining and intersecting corridors. Lane balance and continuity between general-purpose lanes, HOV lanes, and/or express lanes at each freeway-to-freeway interchange are critical. Therefore, in some instances, the second highest ranking alternative (i.e. the alternative with the second lowest net present cost) may be chosen as the recommended alternative over a lower cost alternative that is not compatible.

EXAMPLE CORRIDOR

The following is an example of the methodology used for a typical Dallas freeway. Typical freeway characteristics for a radial freeway in Dallas are:

- Freeway ADT (average daily traffic) = 260,000; HOV ADT = 7,000;
- K = 0.085; D = 0.60; Percent trucks = 3 percent;
- Existing cross section = 8 lanes with frontage roads; and
- ROW allows for maximum of 12 lanes with frontage roads.

The next step is to develop multiple alternatives as follows.

Table 6. Number of Lanes for Various Alternatives

Alternative	Number of Lanes		
	General-Purpose	Express	HOV
1. No Action	8	0	0
2. All General-Purpose (G-P)	16	0	0
3. G-P + Express	10	2R	0
4. G-P + HOV (1 lane)	12	0	1 R
5. G-P + HOV (2 lanes)	10	0	2 R

Notes: R = Reversible
Alternatives in this example assume 2+ HOV

Peak-hour volumes are then developed for each of the alternatives. The HOV alternative would be analyzed for formation of new carpools based on congestion level as discussed in Chapter VI. Table 7 shows the resulting critical peak-hour lane volumes.

Table 7. Critical Peak-Hour Lane Volumes

Alternative	Critical Volume Per Lane			Vehicle Volume in Critical Section
	General-Purpose	Express	HOV	
1. No Action	3,610	0	0	14,500
2. All General-Purpose (G-P)	1,810	0	0	14,500
3. G-P + Express	2,090	2,000	0	14,500
4. G-P + HOV (1 lane)	2,040	0	1,800	14,000
5. G-P + HOV (2 lanes)	2,000	0	1,430	11,400

The annual cost for each of the alternatives is calculated and the following selection process is used. Table 8 shows this example results in the selection of Alternative 5.

- Rank alternatives by lowest total public cost.
- Check alternative compatibility with adjacent system components.
- If the alternative is incompatible, test the next lowest cost alternative.
- If costs of two or more alternatives are the same, pick the alternative providing best system continuity/flexibility.

This alternative has the lowest total cost as well as the lowest vehicle volume for the same number of persons moved

Table 8. Alternative Cost Analysis

Alternative	Annual Cost ($ M)				
	Construction	O&M	ROW	Congestion	Total
No Action	0.0	0.1	0.0	24.4	25.5
All General-Purpose (G-P)	5.1	0.1	1.8	0.0	7.0
G-P + Express	2.7	0.3	0.0	1.6	4.6
G-P + HOV (1 lane)	3.6	0.4	0.4	1.4	5.8
G-P + HOV (2 lanes)	2.8	0.4	0.0	1.1	4.3

IX. RESULTS

The recommended alternatives resulting from the analyses discussed previously are illustrated in Figures 5 and 6. Figure 5 highlights the major freeway sections for which express lanes and/or general-purpose lane additions were recommended, while Figure 6 features recommended locations for HOV facilities in the year 2015. Specific information associated with these alternatives (e.g., additional number of lanes and lane-kilometers) is included in Appendix C and Table 9. These alternatives reflect the least costly improvements that are compatible with adjoining freeway sections.

The acronyms used in Table 9 and Table 10 have the following meanings: 1) GP = general-purpose freeway lanes; 2) HOV (2+) = high-occupancy vehicle lane(s) with a two-or-more person minimum occupancy requirement; 3) X = express lanes; 4) R = reversible; 5) B = bi-directional (not reversible); and 6) E = elevated (as opposed to at-grade) construction. The results of this analysis indicate that by the year 2015, there will be a need for an increase of approximately 40 percent in general-purpose freeway capacity, as well as 347 lane-kilometers (216 lane-miles) of HOV facilities and 32 lane-kilometers (20 lane-miles) of express facilities. The recommended HOV lane system includes 186 centerline-kilometers (116 centerline-miles) of which 129 kilometers (80 miles) are two-lane facilities and 58 kilometers (36 miles) are one-lane facilities.

The costs associated with these recommended alternatives are summarized in Table 10. All of the costs included in Table 10 are in 1990 dollars. The rehabilitation cost reflects the funds required to upgrade existing freeways to current design standards. As alluded to previously, this rehabilitation cost becomes necessary whenever capacity is added to an existing freeway that has inadequate design characteristics (e.g., inadequate vertical curvature). The construction costs shown in Table 10 include rehabilitation costs (where applicable) and the cost of installing a surveillance, communication, and control (SC&C) system.

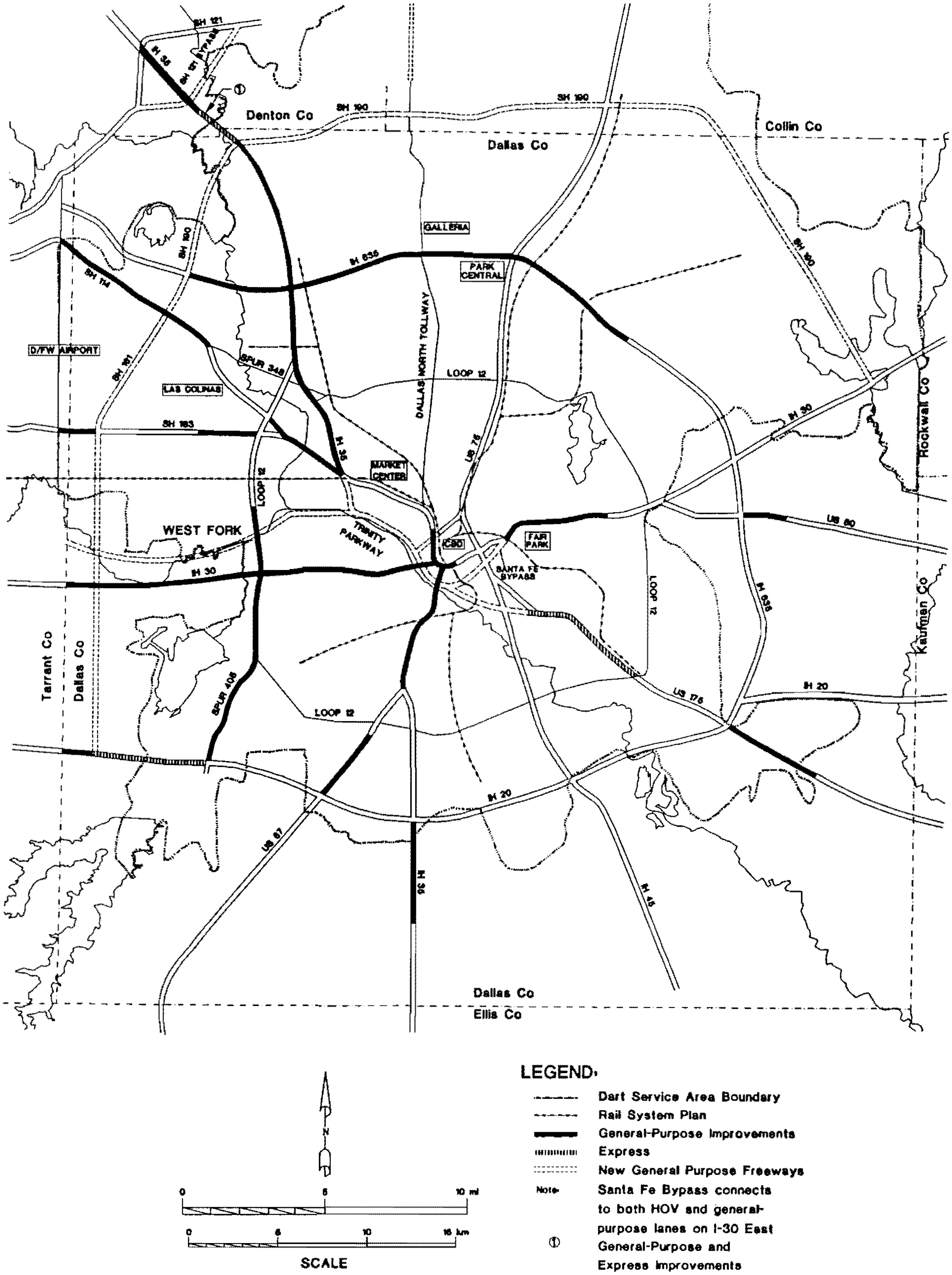
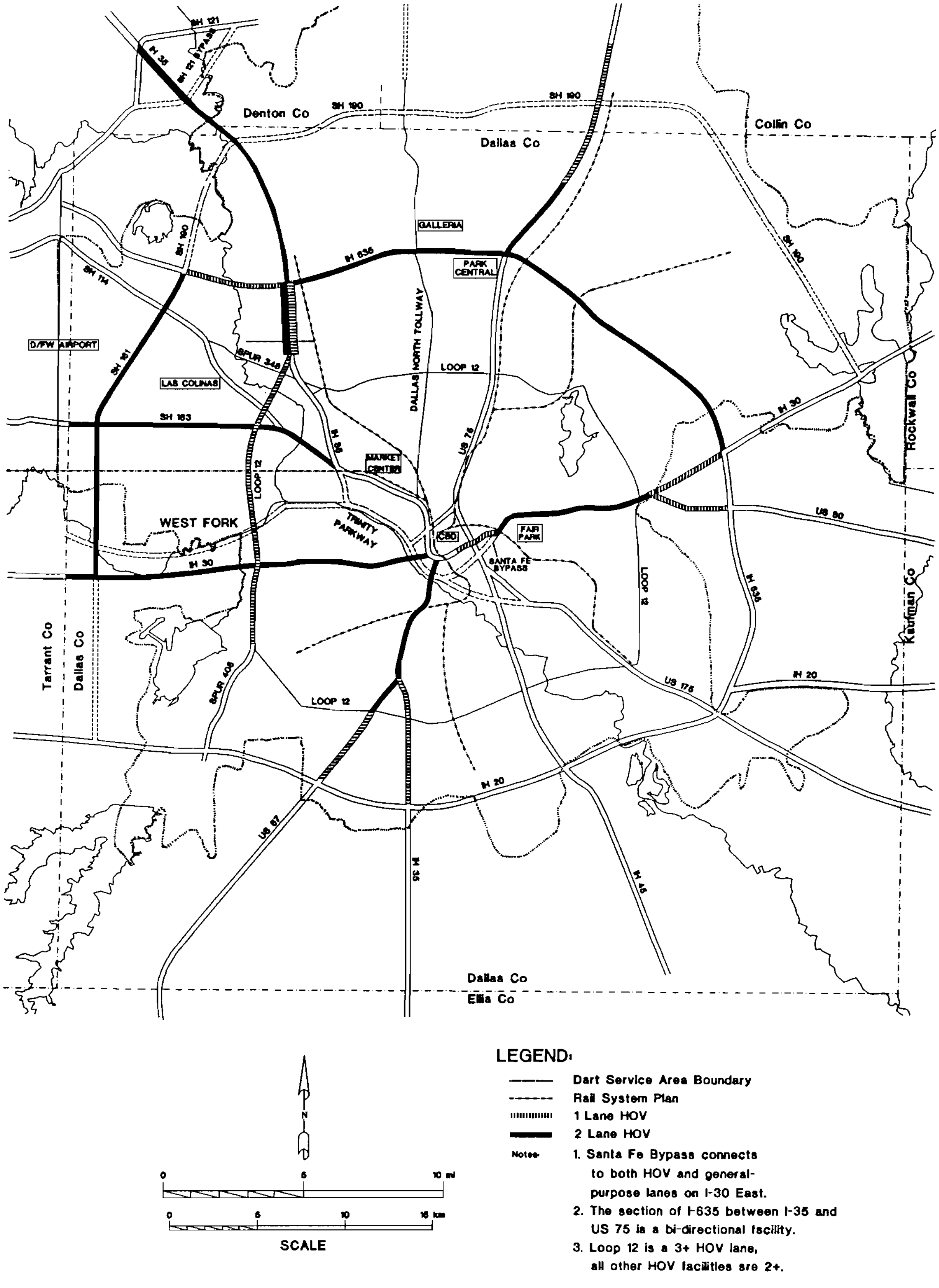


Figure 5. Recommended System for Dallas in the Year 2015, General-Purpose and Express Improvements



Notes:
1. Santa Fe Bypass connects to both HOV and general-purpose lanes on I-30 East.
2. The section of I-635 between I-35 and US 75 is a bi-directional facility.
3. Loop 12 is a 3+ HOV lane, all other HOV facilities are 2+.

Figure 6. Recommended System for Dallas in the Year 2015, HOV Lane Improvements

Table 9. Additional Lanes, Kilometers, and Lane-Kilometers of Facilities in Recommended Dallas System, Year 2015

Freeway Corridor	Study Limits[1]	Existing General-Purpose Lanes	Existing General-Purpose Ln-Km (Ln-Mi)	Additional Lanes[2] for Recommended Alternative			Additional Kilometers and Lane-Kilometers for Recommended Alternative					
				General Purpose	HOV[3]	Express	Gen-Purpose		HOV		Express	
							Kilometers (Miles)	Ln-Km (Ln-Mi)	Kilometers (Miles)	Ln-Km (Ln-Mi)	Kilometers (Miles)	Ln-Km (Ln-Mi)
IH 20	Co. Line to Belt Line	8	381 (237)	2	0	2	2 (1)	4 (2)	0 (0)	0 (0)	8 (5)	16 (10)
IH 30E/Santa Fe	CBD to Belt Line	8/6	156 (97)	2	2/1	0	6 (4)	13 (8)	19 (12)	26 (16)	0 (0)	0 (0)
IH 30W	SH 360 to IH 35E	6[4]	126 (78)	6/4/2	2	0	23 (14)	79 (49)	23 (14)	45 (28)	0 (0)	0 (0)
IH 35N	DNT to SH 121	10/8/6	259 (161)	6/4/2	2/1	2	34(21)	117 (73)	21 (13)	47 (29)	3 (2)	6 (4)
IH 35S	IH 30 to Belt Line	8/6/4	124 (77)	2	2/1	0	13 (8)	26 (16)	14 (9)	23 (14)	0 (0)	0 (0)
IH 45	IH 30 to Belt Line	10/6	126 (78)	0	0	0	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
IH 635N	Co. Line to US 75	8/6/4	174 (108)	4/2	4B/1R[5]	0	19 (12)	43 (27)	19 (12)	56 (35)	0 (0)	0 (0)
IH 635E	US 75 to IH 20	8	238 (148)	2	2	0	5 (3)	10 (6)	18 (11)	35 (22)	0 (0)	0 (0)
US 67	IH 35E to Belt Line	6/4	80 (50)	2	2/1	0	5 (3)	8 (5)	6 (4)	11 (7)	0 (0)	0 (0)
US 75	IH 635 to Parker	8	216 (134)	0	2/1	0	0 (0)	0 (0)	12 (7)	18 (11)	0 (0)	0 (0)
US 80	IH 30 to Belt Line	4	29 (18)	2	1	0	3 (2)	6 (4)	5 (3)	5 (3)	0 (0)	0 (0)
US 175	IH 45 to Belt Line	6/4	105 (65)	2	0	2	6 (4)	11 (7)	0 (0)	0 (0)	6 (4)	13 (8)
SH 114	SH 183 to Co. Line	6	95 (59)	2	0	0	11 (7)	21 (13)	0 (0)	0 (0)	0 (0)	0 (0)
SH 161	IH 20 to IH 635	None	0 (0)	8/6/4	2	0	27 (17)	169 (105)	18 (11)	35 (22)	0 (0)	0 (0)
SH 183	IH 35E to Co. Line	6	95 (59)	2	2	0	13 (8)	24 (15)	16 (10)	32 (20)	0 (0)	0 (0)
SH 190	IH 635 to IH 30	None	0 (0)	6	0	0	51 (32)	307 (191)	0 (0)	0 (0)	0 (0)	0 (0)
Loop 12/408	IH 35E to Camp Wisdom	6/4	132 (82)	2	1	0	10 (6)	18 (11)	16 (10)	16 (10)	0 (0)	0 (0)
Trinity Pkwy	US 175 to IH 35E	None	0 (0)	8/6/4	0	0	21 (13)	61 (38)	0 (0)	0 (0)	0 (0)	0 (0)
		None	0 (0)	5/4/3/2	0	0		48 (30)	0 (0)	0 (0)	0 (0)	
Totals	——	——	2,336 (1,451)	——	——	——	249 (155)[6]	965 (600)[7]	186 (116)[8]	347 (216)[9]	17 (11)	35 (22)

Note: Construction for recommended alternatives is at-grade unless otherwise noted.

[1] The limits represent the study limits of the Dallas urban area. For more detail of included limits of general-purpose and express lane improvements see Figure 5 and for HOV improvements see Figure 6.

[2] For exact number of lanes, see Appendix C.

[3] All HOV lanes are reversible unless noted otherwise.

[4] This section of IH-30 is planned to be reconstructed to 10 lanes between County Line and Loop 12 and 8 lanes between Loop 12 and IH-35E.

[5] R =Reversible; and B = Bi-directional (not reversible).

[6] Only 150 additional kilometers (93 miles) if new facilities are not included in this total.

[7] Only 380 additional lane-kilometers (236 lane-miles) if new facilities are not included in this total.

[8] 34 kilometers (21 miles) fall outside of the DART service area.

[9] 48 lane-kilometers (30 lane-miles) fall outside of the DART service area.

Table 10. Costs Associated with Recommended Alternatives for Dallas System

Freeway Corridor	Study Limits[1]	Recommended Alternative[2]	Rehab. Cost ($ M)	Construction Cost[3] ($ M)	R.O.W. Cost ($ M)	Total Capital Cost[4] ($ M)	Total Capital Cost w/o Rehab. ($ M)	Annual[5] O/M Cost ($ M)	Total Cost ($M)[6]
IH 20	Co. Line to Belt Line	GP + XR	0	45.3	0	45.3	45.3	0.30	68.7
IH 30E/Santa Fe	CBD to Belt Line	GP + HOV (2+)R	150.0	251.5	10.9	262.5	112.5	0.35	295.3
IH 30W	SH 360 to IH 35E	GP + HOV (2+)R	218.7	462.4	35.9	498.3	279.6	0.35	570.2
IH 35N	DNT to SH 121	GP + E HOV (2+)R+XR	368.7	931.1	68.7	999.8	631.1	0.35	1,109.2
IH 35S	IH 30 to Belt Line	GP + HOV (2+)R	212.5	342.2	15.6	357.8	145.3	0.35	418.7
IH 45	IH 30 to Belt Line	No Action	225.0	231.2	0	231.2	6.2	0.10	245.3
IH 635N	Co. Line to US 75	GP +E HOV (2+)B	176.5	559.3	51.6	610.8	434.3	0.35	690.5
IH 635E	US 75 to IH 20	GP + HOV (2+)R	406.2	514.0	0	514.0	107.8	0.35	574.9
US 67	IH 35E to Belt Line	GP + HOV (2+)R	121.9	170.3	0	170.3	48.4	0.10	190.6
US 75	IH 635 to Parker	E HOV (2+)R	0	57.8	0	57.8	57.8	0.35	100.0
US 80	IH 30 to Belt Line	GP + HOV (2+)R	51.6	78.2	0	78.2	26.6	0.10	87.5
US 175	IH 45 to Belt Line	GP + XR	168.7	242.1	6.2	248.3	79.7	0.30	264.0
SH 114	SH 183 to Co. Line	ALL GP	151.5	189.0	0	189.0	37.5	0.10	190.6
SH 161	IH 20 to IH 635	GP + E HOV (2+)R	0	609.3	7.8	617.1	617.1	0.35	637.4
SH 183	IH 35E to Co. Line	GP + E HOV (2+)R	157.8	360.9	29.7	390.6	232.8	0.35	473.4
SH 190	IH 635 to IH 30	ALL GP	0	854.6	0	854.6	854.6	0.10	867.1
Loop 12/408	IH 35E to Camp Wisdom	GP + HOV (3+)R	213.4	321.2	0	321.2	107.8	0.35	371.2
Trinity Pkwy	US 175 to IH 35E	GP	0	257.8	4.7	262.5	262.5	0.30	285.9
Totals			2,622.5	6,478.2	231.1	6,709.3	4,086.9	4.9	7,440.5

Note: All costs shown are in 1990 dollars and reflect at-grade construction, unless otherwise noted.

[1] The limits represent the study limits of the Dallas urban area. For more detail of included limits of general-purpose and express lane improvements see Figure 5 and for HOV improvements see Figure 6.

[2] GP = General-purpose freeway lane(s); HOV (2+) = High-occupancy vehicle lane(s) with a minimum occupancy requirement of two-or-more persons; (3+) = three-or-more persons; X=Express lanes; E = Elevated (as opposed to at-grade) construction; R = Reversible; B = Bi-directional; and No Action = No improvements beyond those already scheduled for construction.

[3] Includes costs associated with surveillance, communication, and control systems (SC&C) and rehabilitation costs (where applicable).

[4] Sum of rehabilitation cost, construction cost, and right-of-way cost.

[5] Annual operating and maintenance cost for freeway corridor.

[6] Sum of rehabilitation, construction, right-of-way, and congestion and operating cost.

As Table 10 indicates, the estimated total capital cost of the recommended system in the Dallas System Planning Study depicted in Figures 5 and 6 (including rehabilitation costs) is $6.7 billion. If rehabilitation costs are not included, this estimate becomes $4.1 billion. The estimated total cost of the system with operating and congestion cost is $7.5 billion. It should be noted that the annual operation and maintenance costs are approximately $4.7 million. Figure 7 shows a ranking of the congested corridors based on the average annual congestion cost per kilometer (mile). The congestion cost in this figure is presented as the average annual congestion cost per kilometer (mile) in order to compare the level of congestion being experienced on the different facilities.

In many of the congested corridors, HOV facilities are planned to provide an alternate to save time over general-purpose lanes. The estimated bus and carpool levels are shown in Table 11. It is estimated that a total of 375,000 persons per day will be using the recommended HOV system by the year 2015. The vast majority of these persons (90 percent) will be in the form of carpools. The relatively low percentage of bus ridership is due to the presence of rail lines in most corridors listed in Table 11. For purposes of this study, it was conservatively assumed that DART would not provide significant express-bus service adjacent to rail lines. Therefore, the HOV demand was primarily served by carpools.

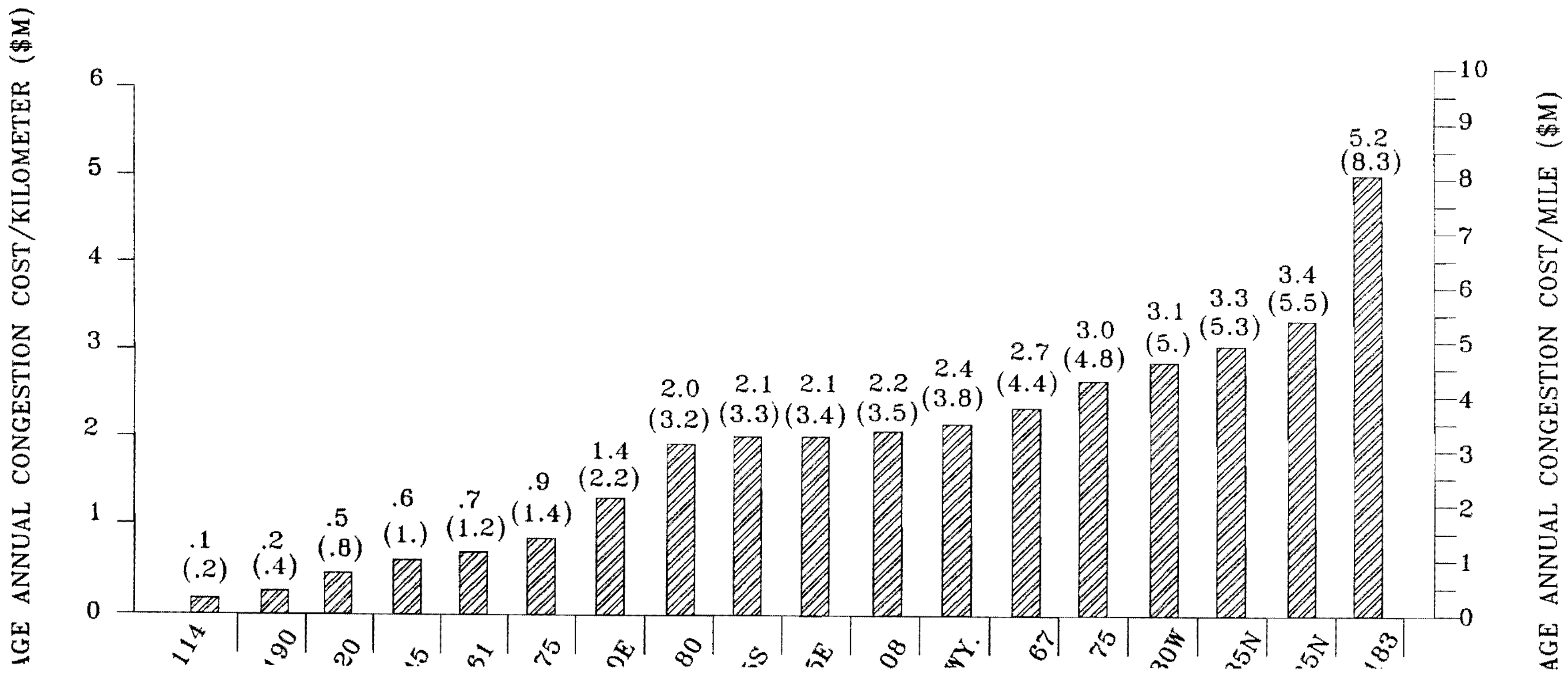
Table 11. Estimated Ridership for Recommended HOV Facilities, Year 2015

		Estimated Number of Persons Utilizing Respective HOV Facilities					
		Carpools		Buses		Total	
Freeway Corridor	Recommended Alternative[1]	Peak Hour[2]	Daily	Peak Hour[2]	Daily	Peak Hour[2]	Daily
IH 30E	HOV (2+)R	8,400	33,600	4,300	17,200	12,700	50,800
IH 30W	HOV (2+)R	8,800	35,200	1,500	6,000	10,300	41,200
IH 35N	HOV (2+)R	8,000	32,000	400	1,600	8,400	33,600
IH 35S	HOV (2+)R	8,800	35,200	1,200	4,800	10,000	40,000
IH 635N	HOV (2+)B	8,800	35,200	1,200	4,800	10,000	40,000
IH 635E	HOV (2+)R	6,000	24,000	500	2,000	6,500	26,000
US 67	HOV (2+)R	4,800	19,200	25	100	4,825	19,300
US 75	HOV (2+)R	8,800	35,200	900	3,600	9,700	38,800
US 80	HOV (2+)R	2,300	9,200	0	0	2,300	9,200
SH 161	E HOV (2+)R	8,400	33,600	0	0	8,400	33,600
SH 183	HOV (2+)R	8,300	33,200	0	0	8,300	33,200
Loop 12	HOV (3+)R	2,400	9,600	0	0	2,400	9,600
Totals		83,800	335,200	10,025	40,100	93,825	375,300

[1] HOV (2+)=High-occupancy vehicle lane(s) with a minimum occupancy requirement of two-or- more persons; R=Reversible; B=Bi-directional (not reversible); and E=Elevated (as opposed to at-grade) construction.

[2] 25 percent of the daily ridership is estimated to occur during the peak-hour.

Figure 7. Average Annual Congestion Cost per Kilometer (Mile) for Dallas Freeways



A comparison of how the recommended system compares with a more traditional planning method without HOV treatment is shown in Table 12. The all general-purpose system consists of freeway sections designed to handle the person demand in single occupant vehicles. The capital cost, total cost, and number of vehicles moved are lower for the recommended system, while the average vehicle occupancy is greater for the recommended system.

Table 12. Comparison of Recommended System to an All General-Purpose System

Item	All General-Purpose System	Recommended System	% Difference Between Recommended System and All G-P System
Capital Cost	$ 8.9 billion	$ 6.7 billion	- 24%
Total Cost	$ 9.2 billion	$ 7.5 billion	- 19%
Average Vehicle Occupancy Rate	1.22	1.34	+ 10%
Sum of Critical Peak-Hour Vehicle Volume on Facilities with HOV[1]	171,000	151,000	- 12%

NOTE: [1]Calculated from critical sections from 12 corridors.

Another comparison of the recommended system with results from a more traditional planning approach is shown in Table 13. The corridors are ranked by the daily vehicle volume. General-purpose lane improvements are effective in the low daily volume range; express lanes are effective in corridors with high directionality in the medium daily volume range, and HOV lanes are effective in the high daily volume range.

As alluded to previously, one of the major constraints associated with implementing freeway improvements is funding limitations. It is recognized that the recommended system outlined previously is rather ambitious in consideration of the current state (and probable future) of the economy. This recommended system can, however, be considered as a realistic identification of the infrastructure improvements required to efficiently meet the peak-hour travel demands in the Dallas urban area in the year 2015.

Table 13. Range of Year 2015 24-Hour Volumes and Recommended Alternatives

Critical Section in Corridor	24-Hr. Vehicle Volume	Alternative Recommended[1]	Basic No. of Lanes - Traditional Method[2]
SH 190 (US 75 - Coit)	94,000	6 GP	8
US 80 (IH 635 - Belt Line)	105,000	6 GP	8
SH 114 (SH 161 - County Line)	109,000	8 GP	10
US 67 (Hampton - IH 35E)	128,000	6 GP + 2 HOV[3] (2+) R	10
US 175 (2nd Ave - Bypass)	140,000	6 GP + 2 XR	14
IH 45 (US 175 - IH 30)	143,000	10 GP[4]	14
IH 20 (SH 161 - Spur 408)	166,000	8 GP + 2 XR	14
Loop 12 (Spur 408 - IH 30)	185,000	8 GP + 1 HOV (3+)[5] R	14
SH 161 (IH 635 - Belt Line)	215,000	8 GP + 2 HOV (2+)R	16
SH 183 (MacArthur - Loop 12)	230,000	8 GP + 2 HOV (2+)R	16
IH 30 E (East Grand - Peak)	252,000	10 GP + 2 HOV (2+)R	20
IH 635 E (Skillman - US 75)	300,000	10 GP + 2 HOV (2+)R	18
IH 30 W (SH 360 - SH 161)	311,000	12 GP + 2 HOV[6] (2+)R	22
IH 35 S (Ewing - Trinity Pkwy)	321,000	10 GP + 2 HOV (2+)R	22
IH 35 N (SH 121 - SH 190)	339,000	10 GP + 2 HOV (2+)R	22
US 75 (Spring Valley - IH 635)	344,000	8 GP + 2 HOV[7] (2+) R	20
IH 635 N (DNT - US 75)	423,000	10 GP + 4 HOV (2+)B	22

Notes: [1] GP = General-purpose freeway lane(s); HOV (2+) = High-occupancy vehicle lane(s) with a minimum occupancy requirement of two-or-more persons; X - Express lanes; E = Elevated (as opposed to at-grade) construction; R = reversible; and B = Bi-directional.

[2] Based on service flow rate per lane of 1650 vph (midpoint of LOS D), System Planning Study K and D factors (Table 1), 5 percent trucks, and peak-hour factor of 0.95.

[3] US 67 has high HOV ridership and connects to a congested corridor (IH 35E).

[4] IH 45 recommended alternative is the existing cross section.

[5] Loop 12 has low HOV ridership and lane balance at IH 35E influenced the recommended alternative.

[6] IH 30 West has minimal bus service.

[7] US 75 has high right-of-way costs, low K and D factors, and high demand over a short distance.

X. IMPLEMENTATION ISSUES

Implementation of the System Planning Study will require changes in the traditional planning process as well as in planning and design policy. The state and local agencies do not have the funding capability nor the legislative support to build the number of general-purpose lanes needed to serve peak-hour vehicle demand. The System Planning Study has identified this constraint and presented a method to serve the peak-hour person demand. The costs of building additional capacity and the costs of congestion were treated equally in the analysis of the total cost of an alternative. The System Planning Study uses a methodology which could affect the design of freeway sections, the mode-choice model process, and the operational analysis of freeway elements such as ramps and weaving sections. **In order to implement the Dallas System Planning Study, TxDOT and representatives of federal and local agencies need to discuss these planning and design issues and choose to accept or reject the associated changes involved.**

DESIGN OF FREEWAY SECTIONS

One of the greatest concerns of TxDOT was to design a system with the ability to connect all the freeways being planned for the future with proper lane balance through the interchanges while eliminating existing and future bottlenecks so that new capacity could be utilized to the greatest extent possible.

In order to evaluate operational efficiency of the system, researchers need to analyze peak-hour volumes. The peak-hour person volumes are calculated from the daily vehicle volumes provided by NCTCOG. The peak-hour person volume is used to test alternatives to determine the optimum combination of general-purpose, express, and HOV lanes. The HOV ridership model is used to estimate the increases in ridership on HOV lanes in freeway corridors where construction of general-purpose facilities will not meet peak-hour demand. The HOV ridership model also checks the peak-hour volume per lane so that congested conditions will not exist on the priority lanes.

The highest ranking alternative for each corridor (alternative with the lowest total public cost) is also evaluated for its compatibility with connecting and intersecting corridors. Continuity between express lanes and HOV lanes is important to the operation of these systems. At the same time, there must be lane balance between the general-purpose lanes at the freeway-to-freeway connections.

These checks on the operation through the interchanges are macroscopic in nature. A more refined step is needed to determine if individual ramps and weaving sections will operate at a reasonable level-of-service under the design volumes. This should be evaluated after review of the recommended system, sizing of freeways, and lane balance through the interchanges. This section presents a recommended methodology of this type.

PEAK PERIOD OPERATING CONDITIONS

Current design practice dictates that the level-of-service of the freeway elements (basic freeway segments, ramp junctions, and weaving areas) is required to be better than level-of-service (LOS) D in the peak hour, resulting in little congestion. In the System Planning Study, the selected alternative in a corridor is based on the total lowest cost to the public. In corridors where a sufficient number of general-purpose lanes cannot be reasonably built to serve the person demand, HOV facilities offer a high level-of-service for carpool and bus riders who take advantage of the time savings over congested general-purpose lanes. The model to estimate the increase in peak-hour carpool and bus riders due to congestion on general-purpose lanes is discussed in Chapter VI.

A comparison of the cross sections resulting from the traditional planning method and the System Planning Study was presented previously in Table 13. The System Planning Study handles the peak-hour person demand; however, the recommended alternative may result in peak period congestion on the general-purpose lanes if the congestion cost is less than the cost to construct additional capacity. **The acceptance of peak period congestion on the general-purpose lanes (coupled with providing HOV lanes to encourage use of transit and carpooling) is a change in planning policy that has governed the planning and design process.**

DESIGN HOUR VOLUME

Traditionally, the 30th highest hourly vehicle volume anticipated during the design year represents the design hour volume. In the System Planning Study, the 30th highest hour volume results in peak-hour congestion on the general-purpose lanes of selected alternatives in many corridors. It is inappropriate to over-design the other freeway elements for LOS D operations (using transitional design procedures) when the freeway is expected to be congested in the peak hour. A traditional design hour volume can be used in corridors where there can be provided sufficient general-purpose capacity to serve the peak-hour demand.

Corridors congested in the peak period typically experience a decrease in volumes outside the peak period. During these hours the freeway should operate efficiently without bottlenecks. This requires designing the freeway elements for an "off-peak" design hour volume (i.e. the highest anticipated hourly volume outside the peak period). In several corridors, an "off-peak" design hour volume is needed to perform an operational analysis. **The use of an "off-peak" design hour volume for operational analysis is a change in design policy which takes into account system effects.**

OPERATIONAL ANALYSIS

Designing improvements for existing and future bottlenecks in the freeway system requires a more detailed analysis at the corridor level. Once the sizing of the freeways and chosen alternatives of the study are reviewed and approved, the corridor analysis can be undertaken.

A detailed operational analysis of the ramps and weaving sections requires development of peak-hour volumes in both the morning and the evening. From these volumes, the operation of the critical junctions can be evaluated. The following methodology is recommended for this analysis:

1) Determine the peak-hour vehicle volume at the critical subsections using the design hour volume spreadsheet tool developed for the Dallas System Planning Study.

2) Determine the morning and evening peak-hour vehicle volumes on the ramps. Multiply the 24-hour volumes by the existing ramp "k"-factors (the peak-hour to daily volume ratio -- lowercase "k" is used to indicate the variable is based on vehicular traffic counts for each freeway ramp conducted during one week in 1989) to estimate peak-hour volumes.
3) Add and subtract ramp volumes from each critical freeway subsection to get general-purpose vehicle volumes for each subsection in the corridor.
4) Check to see whether the freeway peak-hour volumes match at the boundaries between major freeway sections.
    a) If the difference is less than 10 percent, go to step number 5.
    b) If the difference is more than 10 percent, look at 24-hour volume patterns, ramp "k"-factors, and growth rates to identify potential ramp volumes that might be adjusted to decrease the difference between sections to less than 10 percent.
5) Use the methods in the Highway Capacity Manual to check ramp merges, ramp diverges, and weaving sections for level-of-service.
    a) If the alternatives analysis results in a freeway operating better than level-of-service D, the ramps and weaving sections should be designed to operate at an equal level-of-service.
    b) If the alternatives analysis results in a freeway section operating at level-of-service F (speeds below 48 kilometers per hour (30 miles per hour)), it is not cost effective to design the ramp junctions to operate any better than the freeway. However, to avoid bottlenecks at these junctions during off-peak hours, the freeway volumes should be reduced to those required to allow level-of-service D operation and the ramp volumes reduced proportionately. This is the "off-peak" design hour volume described previously.
    c) The junctions should be re-evaluated for appropriate levels-of-service during periods other than the peak-hour.
6) Any ramp junctions and weaving sections that are estimated to operate at level-of-service F in the "off-peak" hour should be redesigned to operate at levels-of-service similar to that of the freeway in the same time period.

This step is planned to coincide with TxDOT's schedule of corridors in the Project Development Plan. A future report will be written to describe the improvements and ramp designs needed to give proper level-of-service to the ramp junctions and weaving sections under the year 2015 travel conditions.

XI. CONCLUSIONS

The Dallas System Planning Study was a coordinated effort of the Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART) and the North Central Texas Council of Governments (NCTCOG) with technical assistance from the Texas Transportation Institute (TTI). The study represents a balanced transportation system for the future which accommodates the projected travel demand at the lowest public cost.

The Dallas System Planning Study is technical in nature and does not address issues such as the programming responsibilities of the agencies involved, the staging or priority of projects within each corridor, or the source of funding for or the community concerns including environmental effects of recommended capacity improvements. The mission of the study is to provide an intermediate planning step between the macroscopic planning performed by NCTCOG and TxDOT's Regional Planning Office and the detailed corridor analysis performed during the design phase of a roadway improvement project. The proposed system is a set of recommendations to be considered and evaluated as part of the development of the Mobility 2010 Plan Update, the long-range transportation plan for the Dallas area.

The Dallas System Planning Study was developed using a methodology that focuses on peak-hour passenger travel demand for the freeways in Dallas and surrounding counties. The study analysis differs from other planning efforts in the region by its focus on peak-hour passenger travel demands and roadway operating conditions, the use of 2015 as the design year for the facilities, and, as explained below, the acceptance of congestion for some alternatives to induce travel in higher-occupancy modes. The intent of the effort was to provide a system that served the travel needs with a reasonable and balanced level of congestion.

It is important to note the change in public goals implied by the Dallas System Planning Study: *Future congestion is accepted on freeways almost everywhere in Dallas during peak- hours, and carpooling or use of transit is the solution offered to escape it.* This is a policy issue that transportation officials at the highest levels need to understand, debate, and accept or reject.

CONGESTION MANAGEMENT APPROACH

Freeway capacity improvements are becoming vastly more difficult to implement. In an era of increasing public involvement in issues ranging from air quality to noise, any transportation improvement which could be viewed as having detrimental environmental effects will be more and more closely scrutinized. Right-of-way is no longer readily available in heavily urbanized corridors, precluding some capacity improvements and driving up the cost of others. Construction costs are increasing partly because of the expense of construction under heavy traffic. Fewer projects can be implemented with a flow of funding from a fuel tax, which is declining as fuel efficiency increases. Under these constrained conditions, future travel demand will not be adequately served if reliance on the single occupant automobile continues undiminished and if travel demand continues to be heavily concentrated during only a few hours of the day.

Previous regional planning efforts and freeway design have been predicated on the goal of achieving freeway traffic flow speeds of 72 kph (45 mph) or better during the peak-hours of travel, assuming that low levels of vehicle occupancy continue. Conversely, the goal of the Dallas System Planning Study has been to find the lowest public cost alternative in each corridor, for a given volume of person trips. This framework views travel delay, construction, and operation of roadways as costs to the public. It also recognizes that some motorists will change their mode of travel when given the opportunity to avoid congestion, resulting in more transit and carpool use. This implies the acceptance of congestion, and attendant delay, during the peak-hour for mainlane traffic; high-occupancy vehicles are afforded greater speeds and are expected to draw a greater percentage of travelers into carpooling or transit usage; this in turn will decrease congestion through reduction in mainlane vehicle volumes as more people leave their vehicles at home or in a park-and-ride lot.

While travel time savings over congested general-purpose lanes is the primary motivation for most commuters to change modes of travel and utilize an HOV facility, other characteristics will also be important to the success of HOV facilities. These include active programs at employment sites such as financial incentives, preferential parking, and ride share programs. Aggressive marketing and public awareness efforts are also critical in gaining public support for HOV facilities, both before and after implementation. In addition, a successful HOV system needs sufficient support facilities such as convenient park-and-ride lots.

The study methodology uses an iterative process to examine congestion and the consequent shift in mode so that these two factors are consistent for an alternative. The proposed system balances money saved in construction against money lost in delay to find the optimum combination of mixed-flow, HOV, and express lanes necessary to move the demand.

TECHNICAL FINDINGS

The general technical findings from the alternatives analysis were as follows:

1) Corridors with low demand can typically be served by the existing design or by the existing design with some capacity improvements to the general-purpose lanes.

2) Corridors with moderate demand can typically be served by the existing design (sometimes with capacity improvements to the general-purpose lanes) and additional express lanes to serve the long-distance trips.

3) Corridors with high demand are best served by the existing design with some capacity improvements to the general-purpose lanes and an HOV facility. If a travel time advantage over the general-purpose lanes is created for HOVs, an HOV lane will reduce the total number of vehicle trips in the corridor because of the mode shift to high-occupancy vehicles.

The recommended system for Dallas includes more HOV facilities than the NCTCOG Regional Mobility Plan or the long-range transit system plan developed by DART. This difference is due to the fact that an HOV facility will induce the formation of new carpools to gain a travel time advantage which reduces the total number of vehicles to be served in a corridor. There must, however, be some congestion on the adjacent freeway to encourage this mode shift; otherwise, there is no incentive for individuals to change their mode of travel in order to meet the occupancy requirements of an HOV facility.

Express lanes provide no incentive for individuals to change mode of travel because they are open to single-occupant vehicles. It is, therefore, common for express lane alternatives to require construction of a greater number of total lanes in order to serve the same person demand as an HOV alternative. This is also the case in all general-purpose lane alternatives. There is no incentive for carpooling or riding transit; therefore, more lanes are needed to serve the greater number of vehicle trips.

RELATIONSHIP TO OTHER MOBILITY IMPROVEMENT PLANS

The Texas Department of Transportation (TxDOT), Dallas Area Rapid Transit (DART) and the North Central Texas Council of Governments (NCTCOG), as well as each city, have plans for the improvement of the roadway and transit systems in the Dallas area. While TxDOT and DART are responsible for the implementation of most of these programs and projects, NCTCOG is responsible for the funding prioritization among the projects to be constructed with federal aid.

The Dallas System Planning Study differs from the traditional, existing improvement plans in two areas. One area already discussed (the design of a system with congestion as part of the recommended alternative) represents a significant departure for TxDOT, DART, and NCTCOG. The use of an analysis process that attempts to optimize the movement of persons without respect to mode is another key difference between the recommended system and the existing plans for the implementing agencies.

The recommendations of the Dallas System Planning Study represent a guide for the long-range planning process of each transportation agency in the Dallas area. The elements of the recommended system were developed without regard for the budget of individual agencies. There is a significant amount of funding required for the completed recommended system configuration, a level that may not be possible for all agencies in the Dallas area to achieve.

A first step will be for each agency to study the recommendations of the study and compare them to the agency's plan. The recommendation for each corridor is interdependent with intersecting and parallel corridors; any shortfall in system improvement should be discussed between the agencies and plans agreed upon for addressing any deficiencies. This interagency cooperation in program and project development was begun with the Dallas System Planning Study effort and should continue through the implementation phase.

IMPLEMENTATION RESPONSIBILITY

One concern that should be addressed as projects are prioritized is the identification of the agency that will be responsible for turning the recommendations into actions. The construction and reconstruction of new highway facilities will probably continue to be the responsibility of TxDOT. Rail transit guideway construction will probably continue to be funded by DART. It is, therefore, the high-occupancy vehicle lane element of the recommended system in the Dallas System Planning Study that does not have a designated lead agency. HOV facilities are a significant part of the system, and their implementation is important to the successful operation of the Dallas area transportation system in the future.

The experience of operating HOV projects in Texas has been that transit agencies and TxDOT share the cost of HOV lane construction, and the transit agency is responsible for operating the facility. This combination is in place on the IH-30E (East R.L. Thornton) Contraflow Lane. HOV projects in other states have been constructed and operated by state departments of transportation. The method of funding and project oversight may vary for individual transportation projects in the Dallas area, but there is a need for the roadway and transit agencies to work together to insure that the available funds are spent on the most cost effective improvement projects.

This action will require that the area agencies continue to work in a cooperative manner so that the transportation improvements can be consistent with the limited areawide funding. Limits on funding may mean that not all elements recommended for a corridor can be implemented, but with a cooperative project development process the shortfall in person movement capacity from one element or mode may be addressed in another element.

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7. "1991 Annual Report, Permanent Automatic Traffic Recorders." Division of Transportation Planning, Texas Department of Transportation, 1992.

8. "Westbound First Avenue Entrance Ramp to IH 30E Origin-Destination Survey." Technical Memorandum prepared for the Texas State Department of Highways and Public Transportation, District 18, Dallas, Texas. Texas Transportation Institute, September, 1990.

9. "Highway Capacity Manual." Special Report 209. Transportation Research Board, 1985.

10. Collier, C.A, and W. B. Ledbetter. Engineering Cost Analysis. Harper and Row Publishers, New York, 1982.

11. McFarland, W. F., and M. Chui. "The Value of Travel Time: New Estimates Developed Using A Speed Choice Model." Research Report No. 396-2F, Texas Transportation Institute, 1985.

APPENDIX A - 24-HOUR CORRIDOR VOLUMES

Appendix A consists of 24-hour two-way volume plots for each freeway analyzed in the Dallas Freeway/HOV System Planning Study. The 24-hour volumes shown in Figures A-1 through A-18 include the 1989/1990 traffic counts collected by TTI, the base year NCTCOG 1986 assignment, the NCTCOG year 2010 assignment, and the NCTCOG year 2010 all-or-none assignment for each corridor. The all-or-none assignment is a free-flow assignment with no consideration given to the type of links or link capacities. All trips are loaded on the minimum path (based on time, distance, cost, or user impedances) of the highway network. Also shown on the plots are the permanent automatic traffic recorder (ATR) station volumes for the year 1990. TxDOT maintains the ATR stations which are located in freeways throughout Texas. Traffic data from the ATR stations are summarized annually by TxDOT.

The NCTCOG year 2010 two-way 24-hour volumes are the result of several computer model assignments performed for NCTCOG's Regional Mobility Plan, which includes a regional HOV, express lane, and light-rail system. While the NCTCOG volumes were forecast for the year 2010, TxDOT required a design year of 2015 for the Dallas System Planning Study. The NCTCOG volumes were, therefore, increased at a growth rate of two percent per year for five years for use in the study. The two percent growth per year is a typical historical annual growth rate in the Dallas urban area.

The year 2015 volumes were compared to the 1989/1990 traffic counts collected by TTI as well as the base year 1986 assignment by NCTCOG to ensure reasonable growth rates. Working with staff from all agencies, some adjustments to the year 2015 assignment were agreed upon in areas where the 1986 base assignment did not correlate well with the 1989/1990 TTI counts. Also, in some cases where existing ramps were not modeled in the NCTCOG assignment, other refinements had to be made to the year 2015 volumes to determine the freeway ramp volumes. Figure A-19 shows the adjusted year 2015 volumes for each corridor, which were used in the study.

Figure A-1. 24-Hour Volumes for IH 20

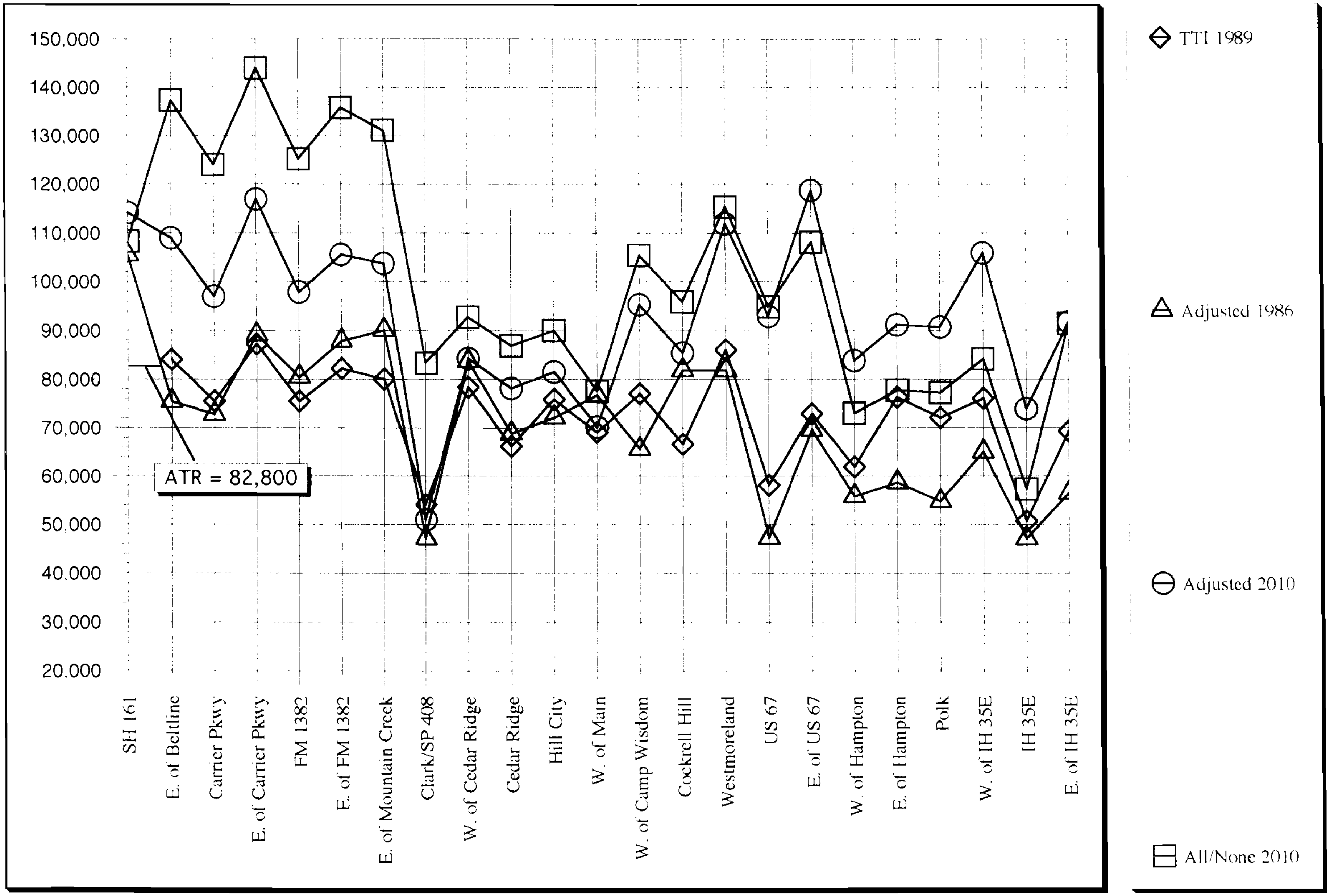


Figure A-1. 24-Hour Volumes for IH 20 (cont.)

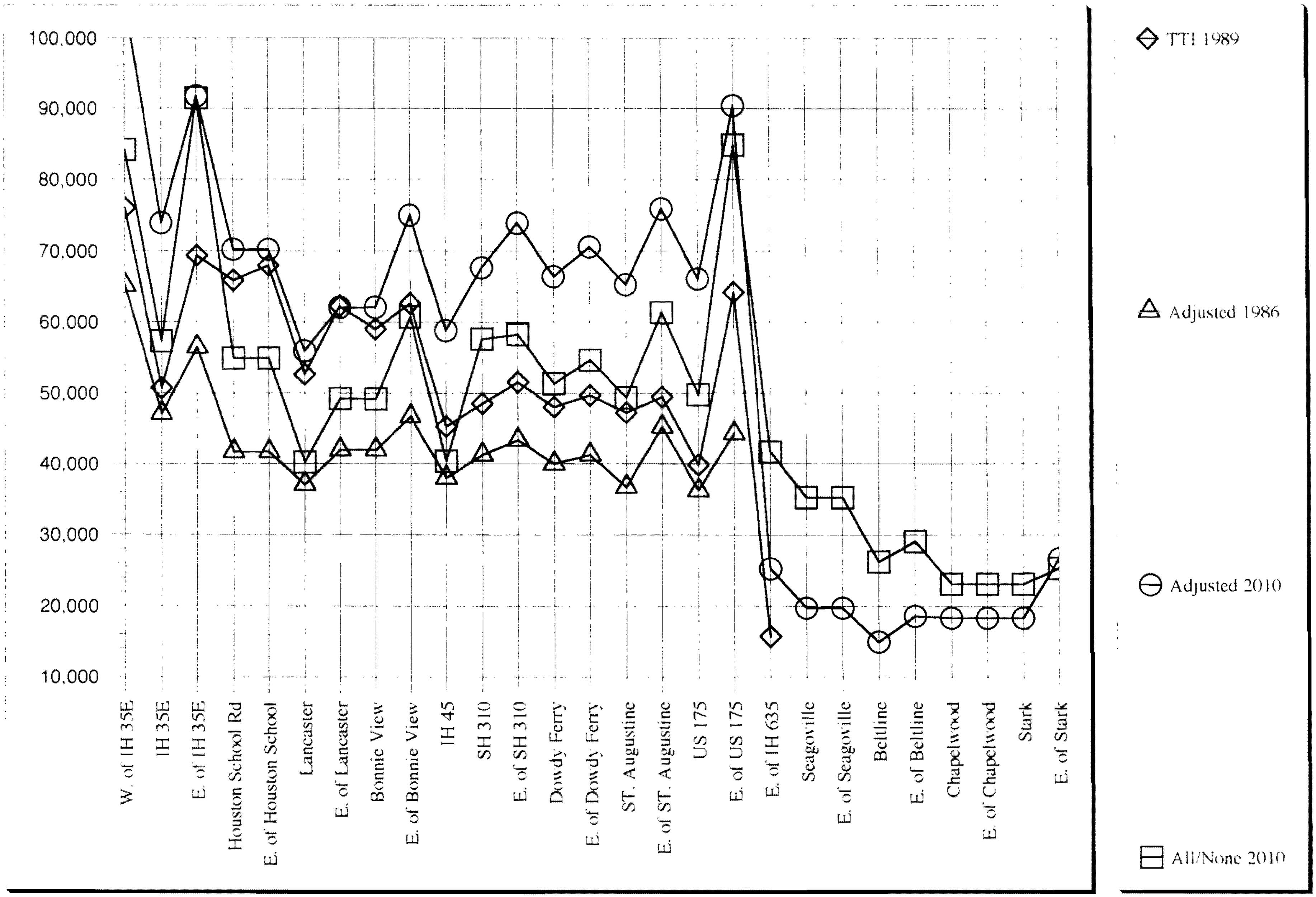


Figure A-2. 24-Hour Volumes for IH 30 East

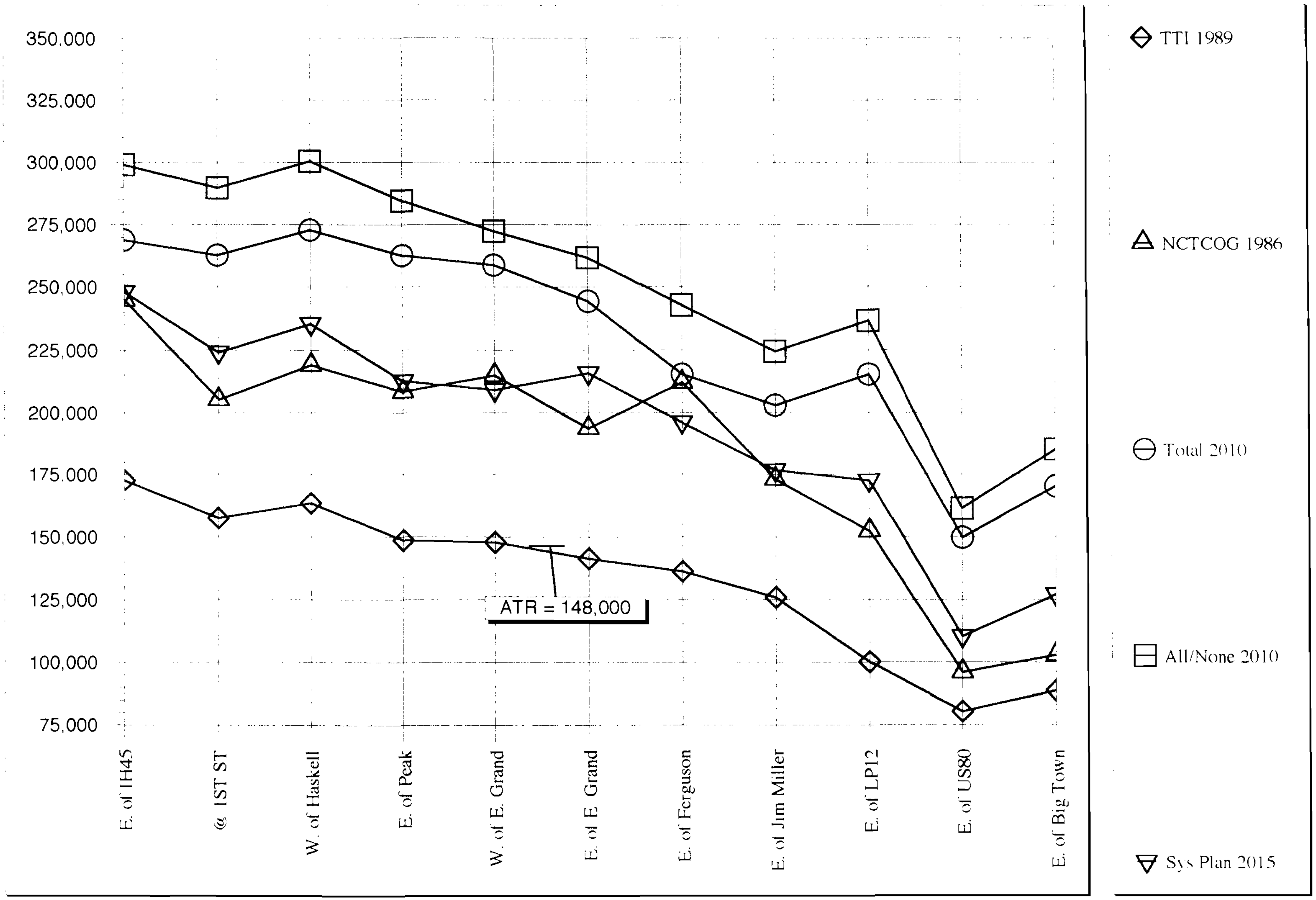


Figure A-3. 24-Hour Volumes for IH 30 West

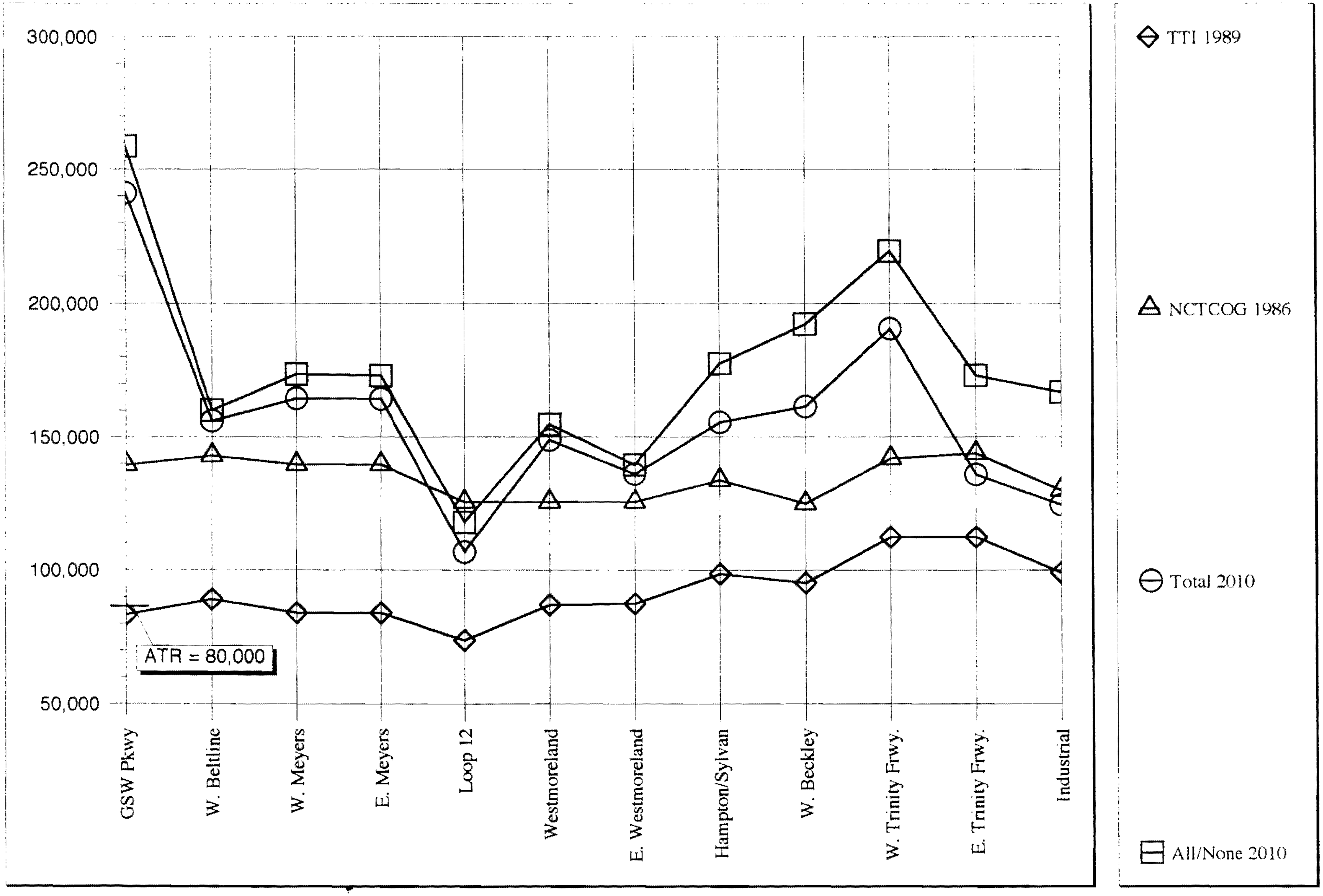


Figure A-4. 24-Hour Volumes for IH 35E North

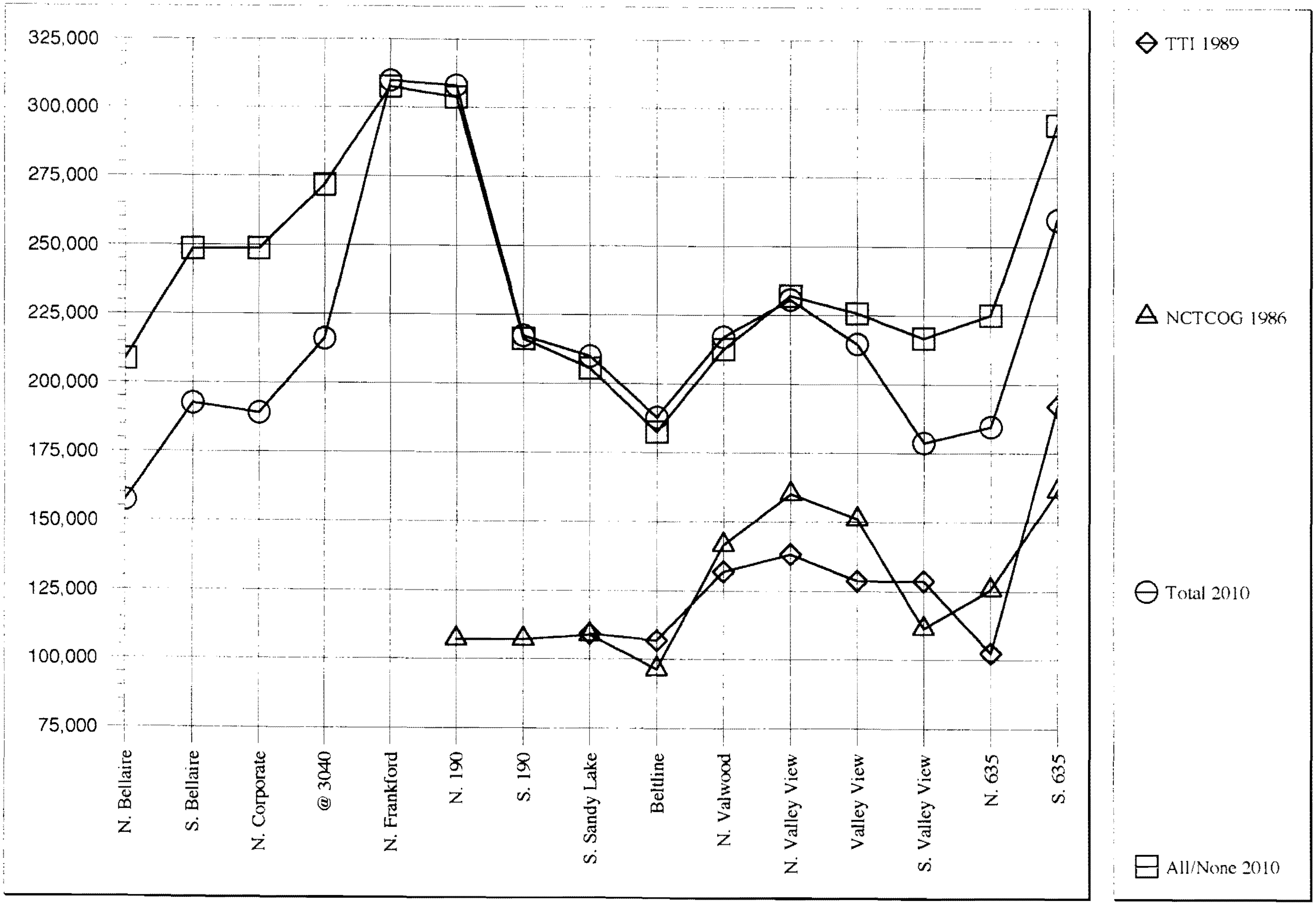


Figure A-4. 24-Hour Volumes for IH 35E North (cont.)

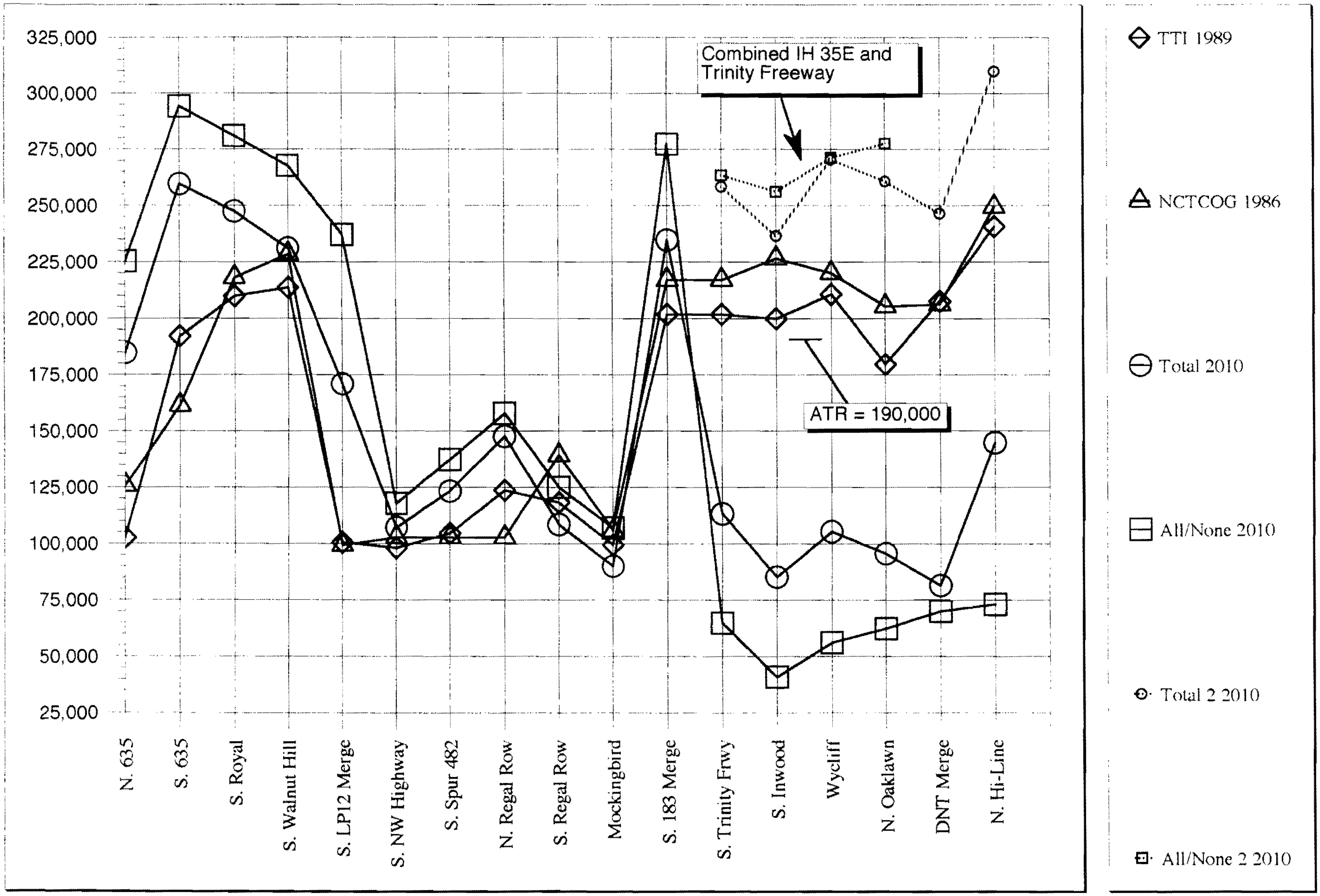


Figure A-5. 24-Hour Volumes for IH 35E South

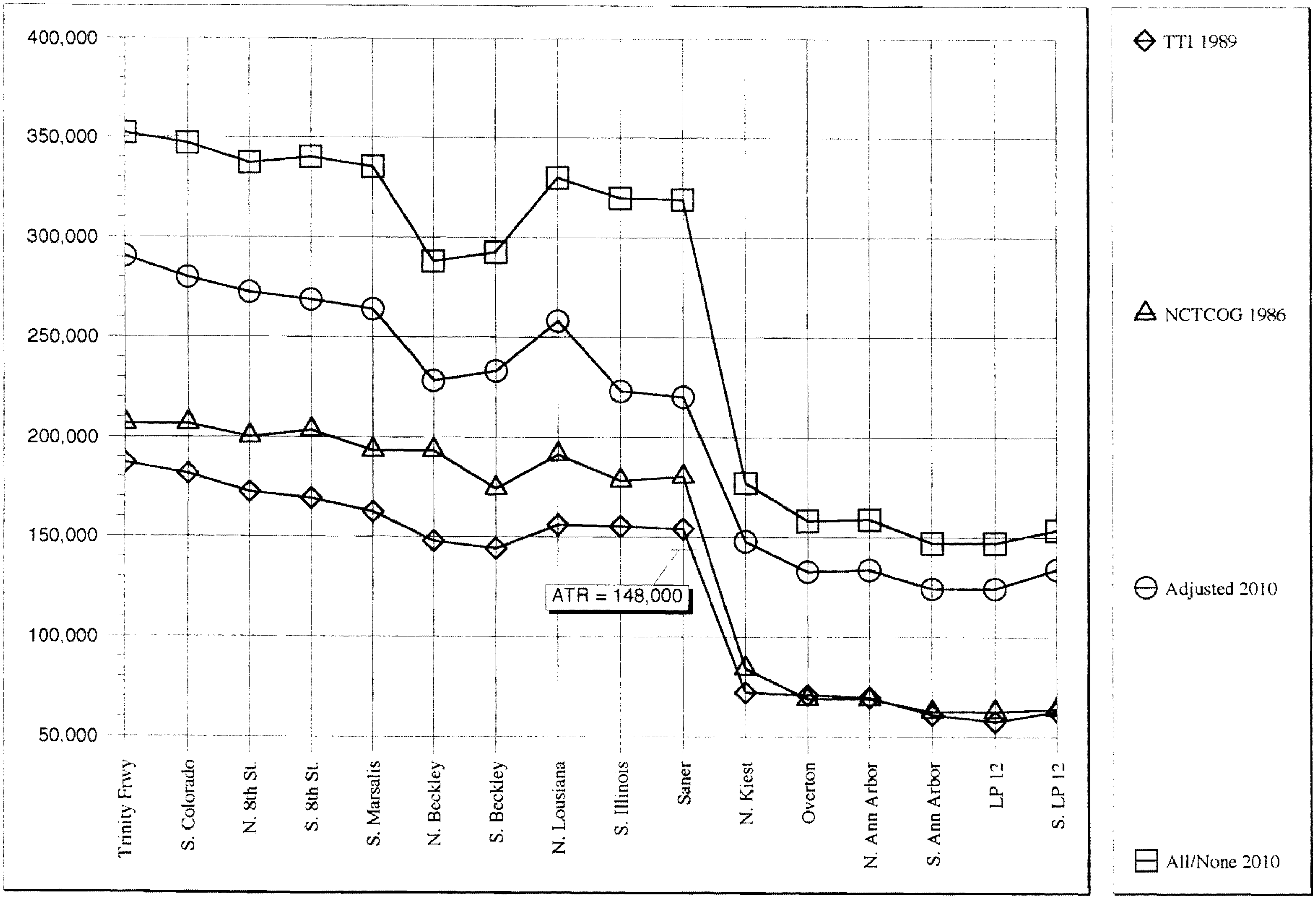


Figure A-5. 24-Hour Volumes for IH 35E South (cont.)

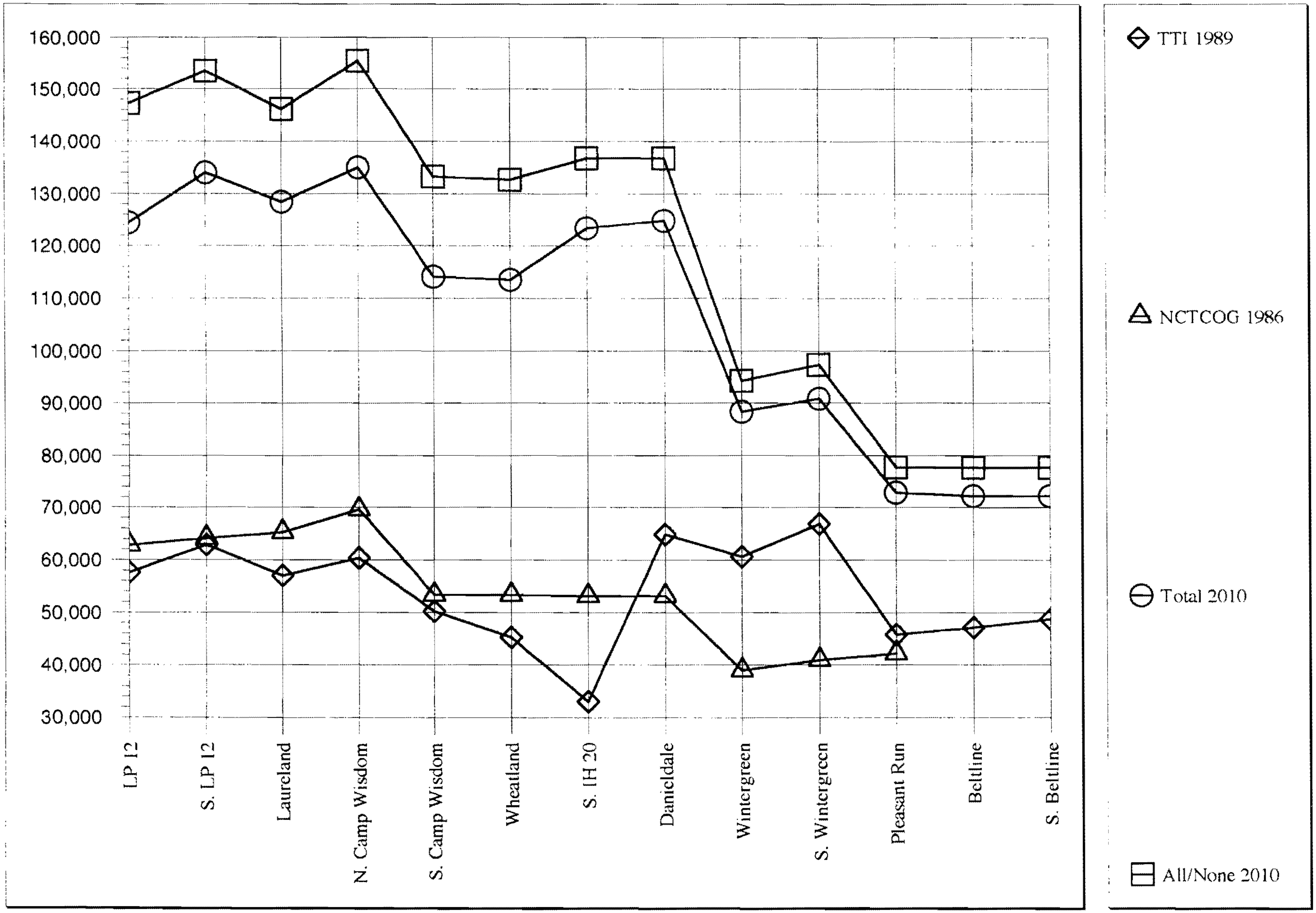


Figure A-6. 24-Hour Volumes for IH 45

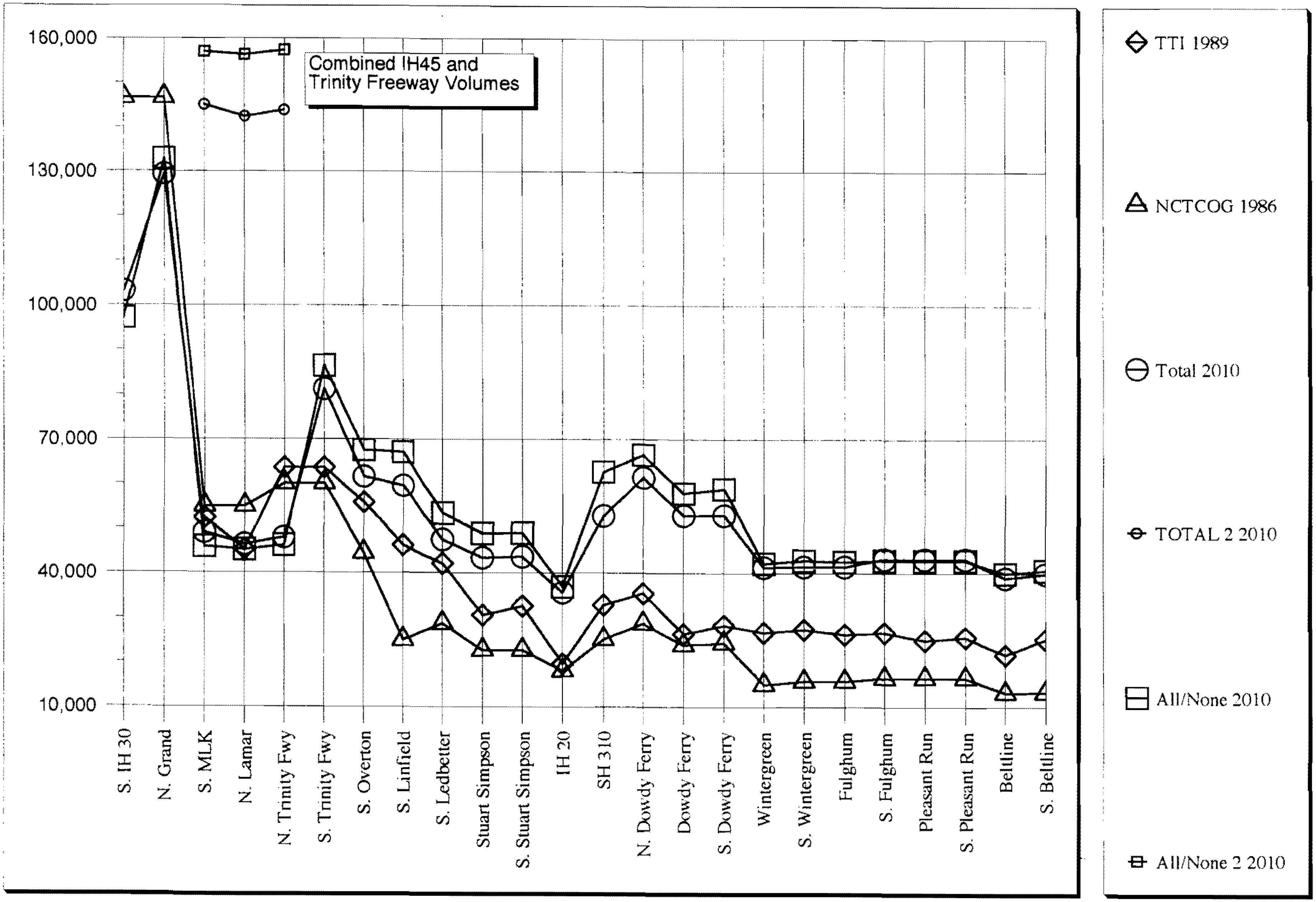


Figure A-7. 24-Hour Volumes for IH 635 East

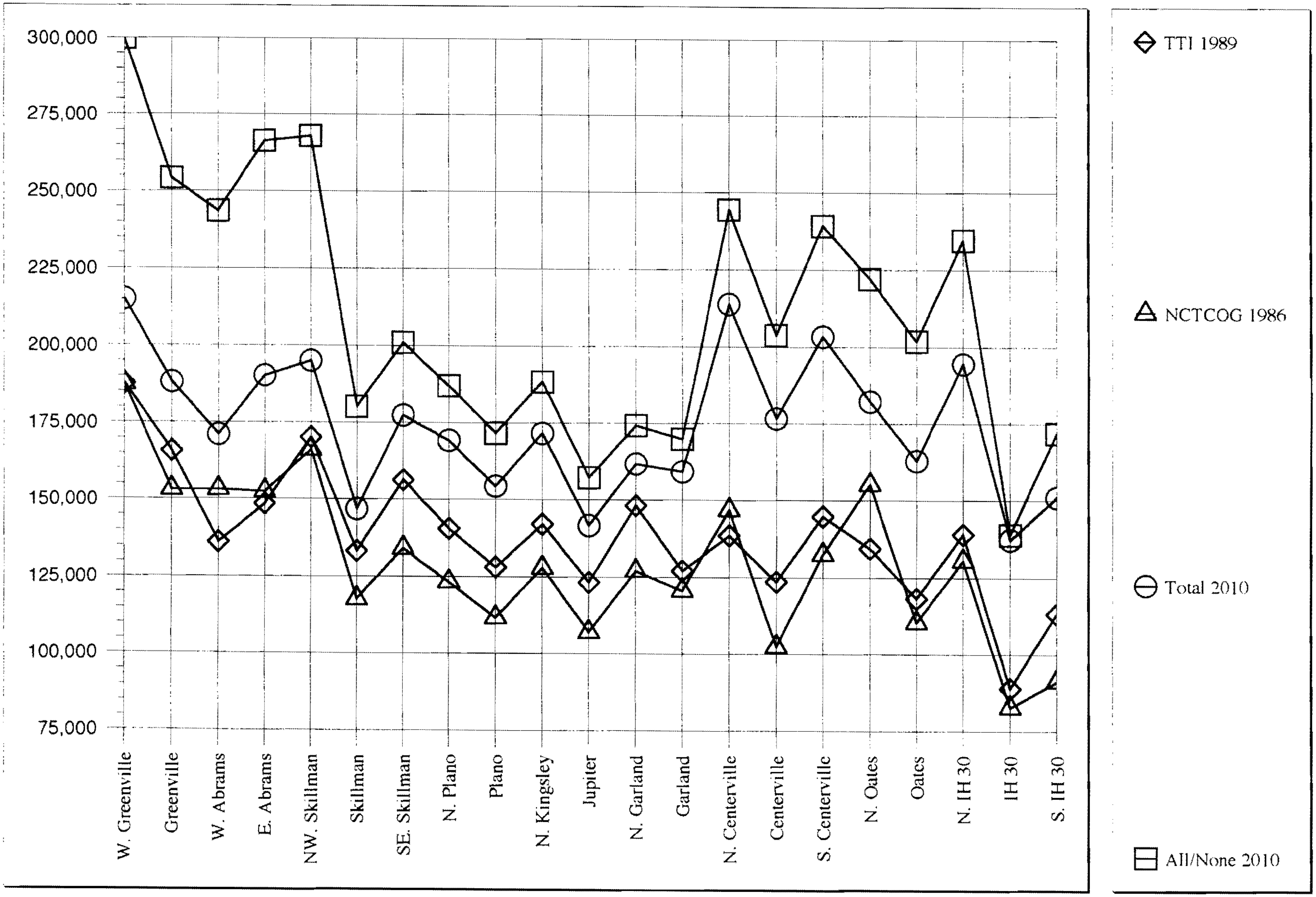


Figure A-7. 24-Hour Volumes for IH 635 East (cont.)

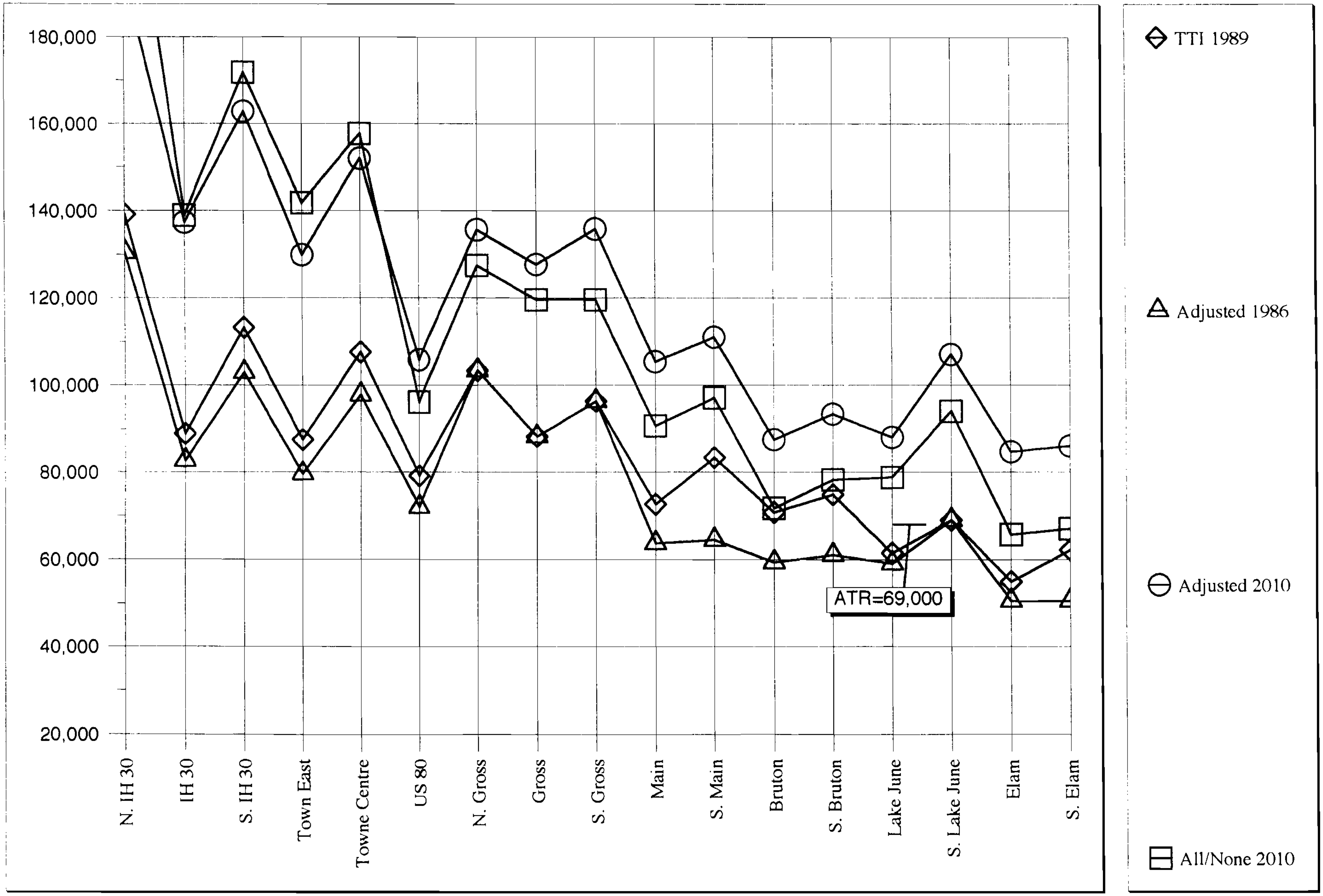


Figure A-8. 24-Hour Volumes for IH 635 North

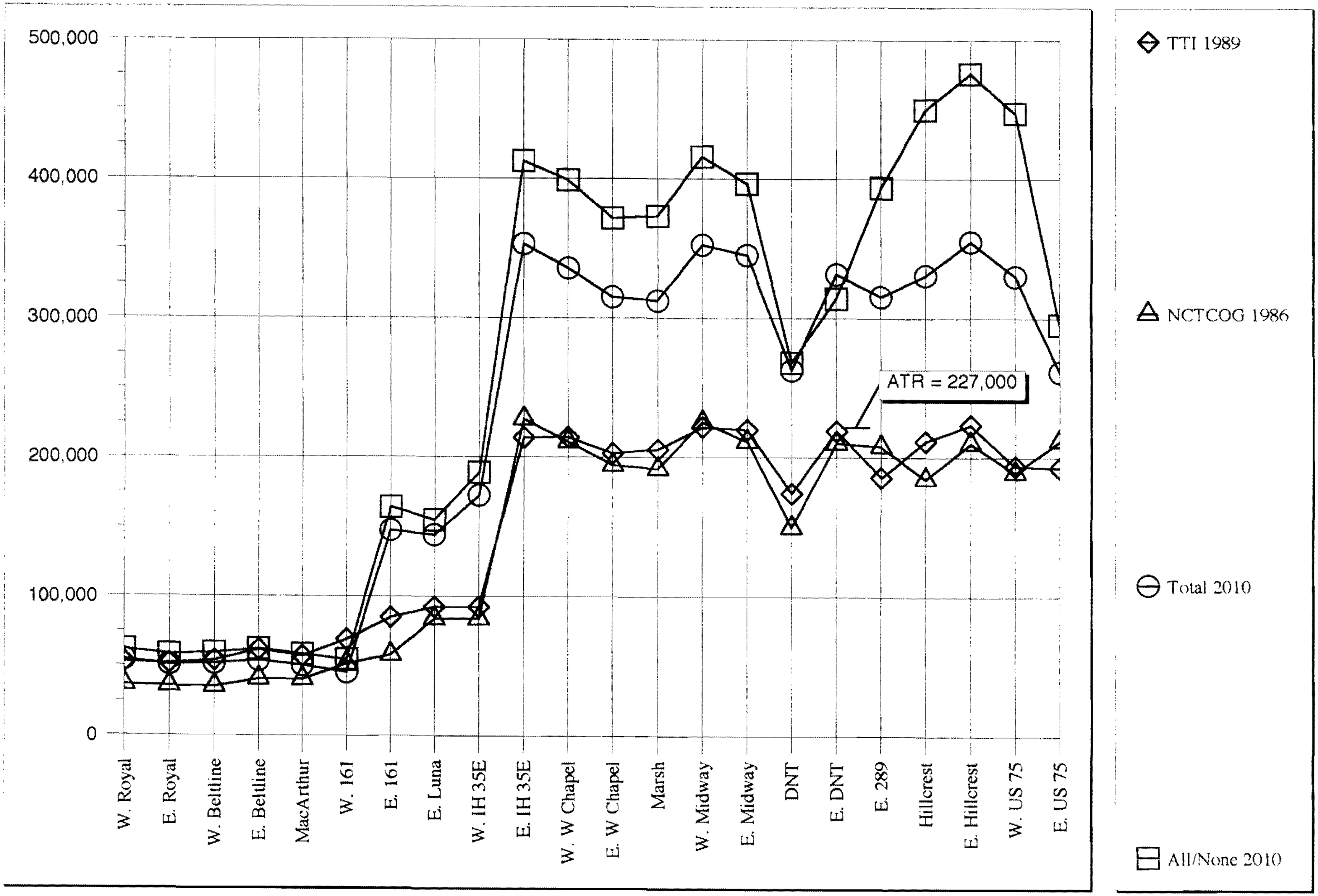


Figure A-9. 24-Hour Volumes for US 67

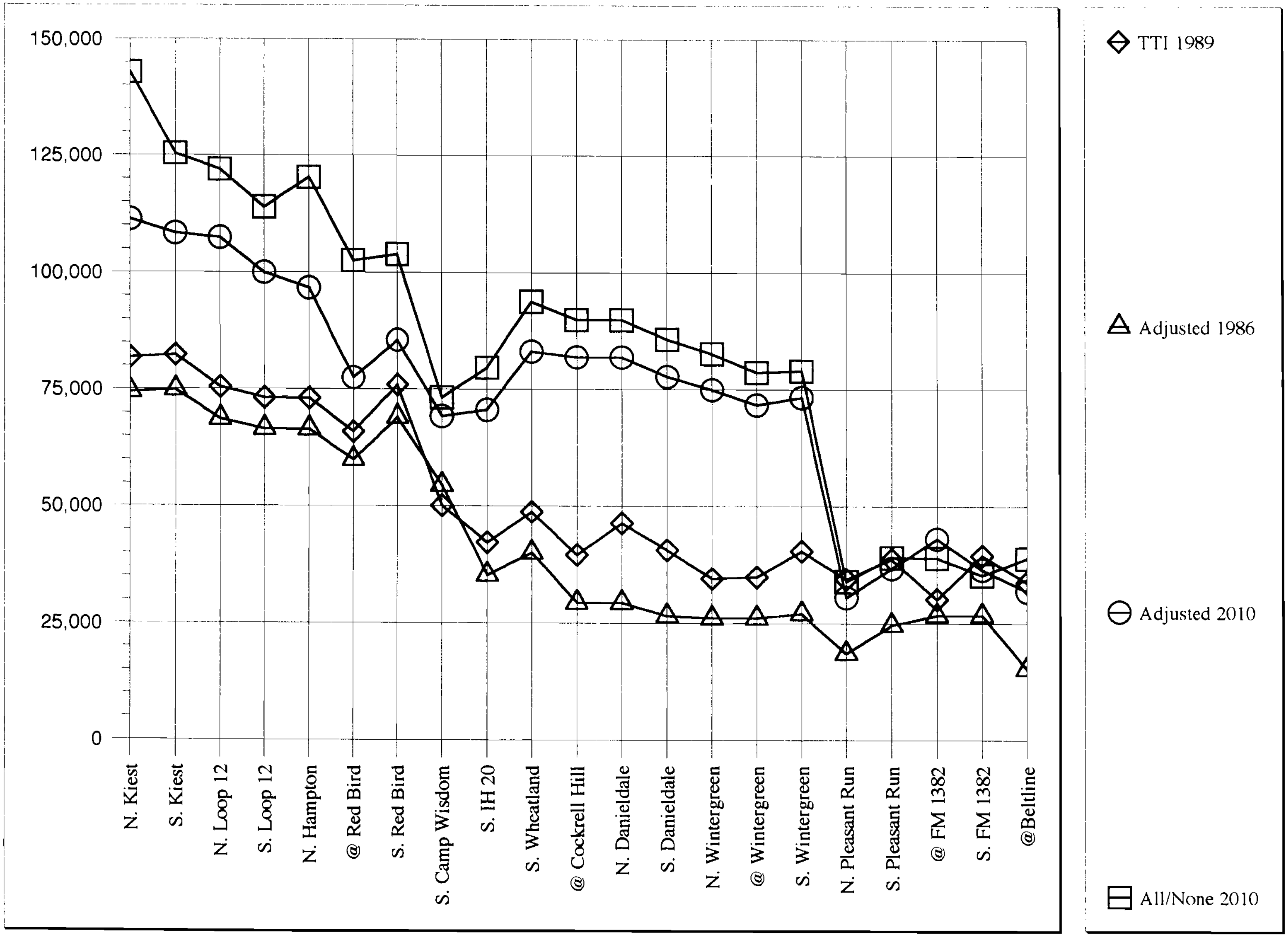


Figure A-10. 24-Hour Volumes for US 75

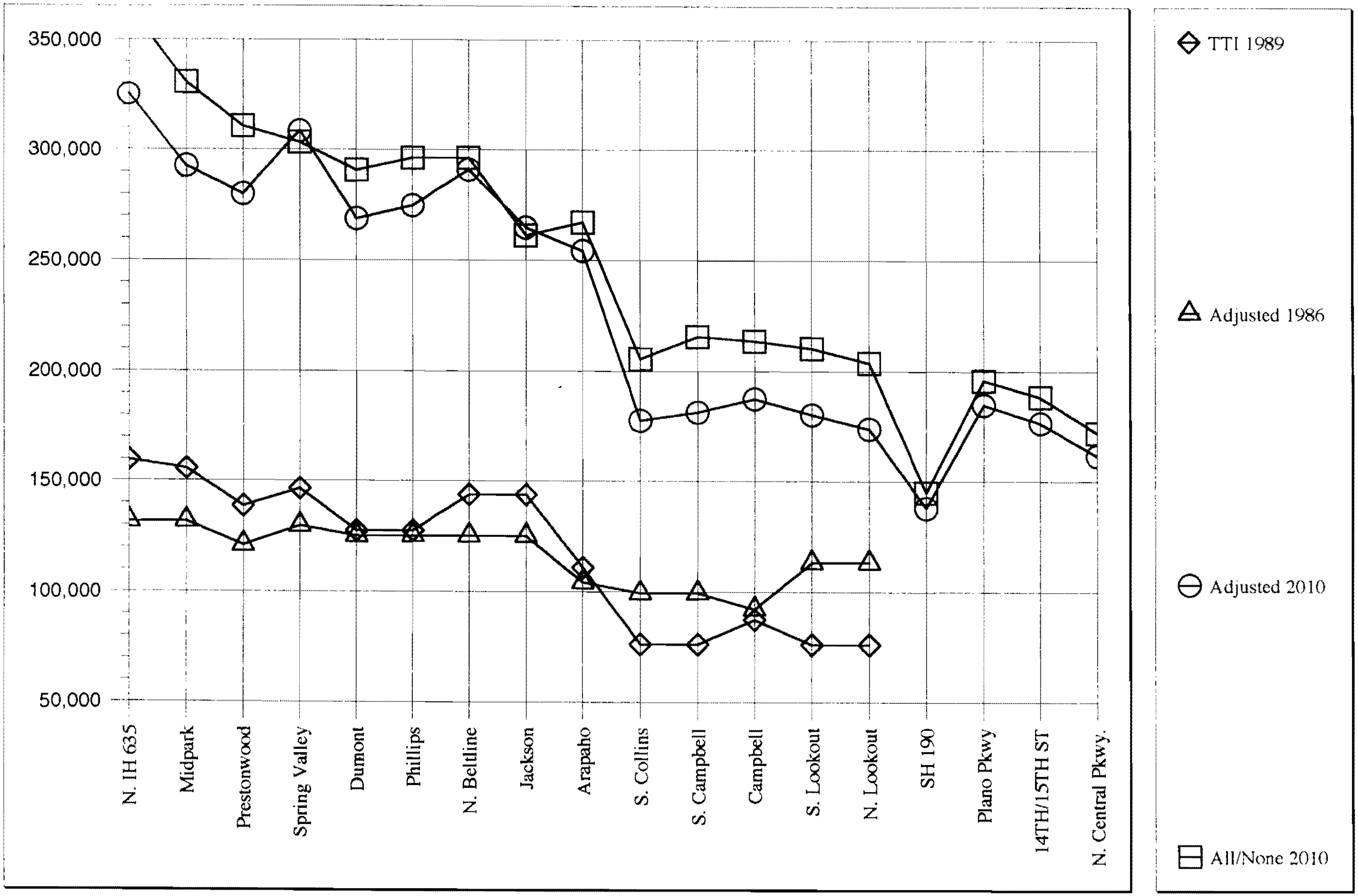


Figure A-11. 24-Hour Volumes for US 80

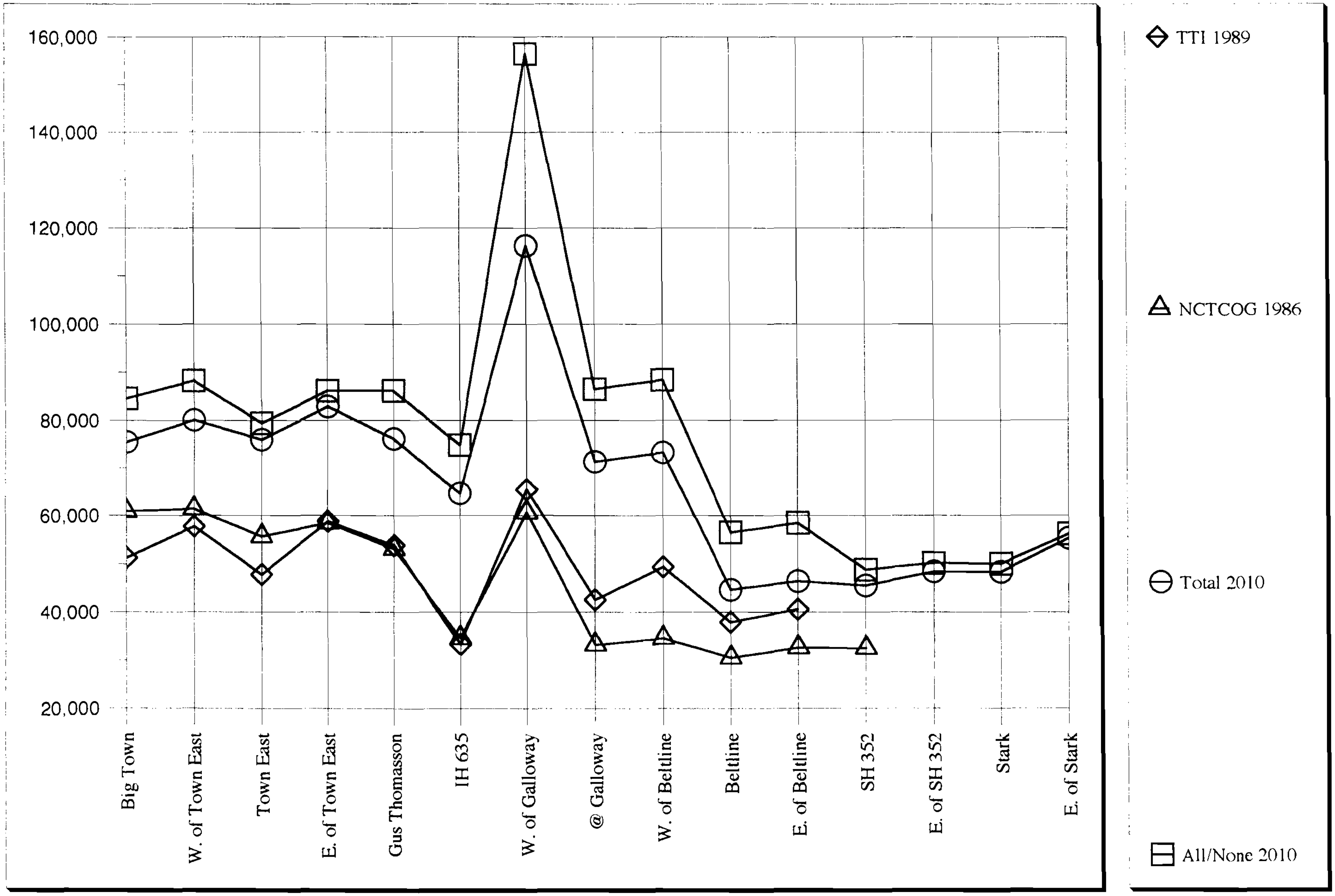


Figure A-12. 24-Hour Volumes for US 175

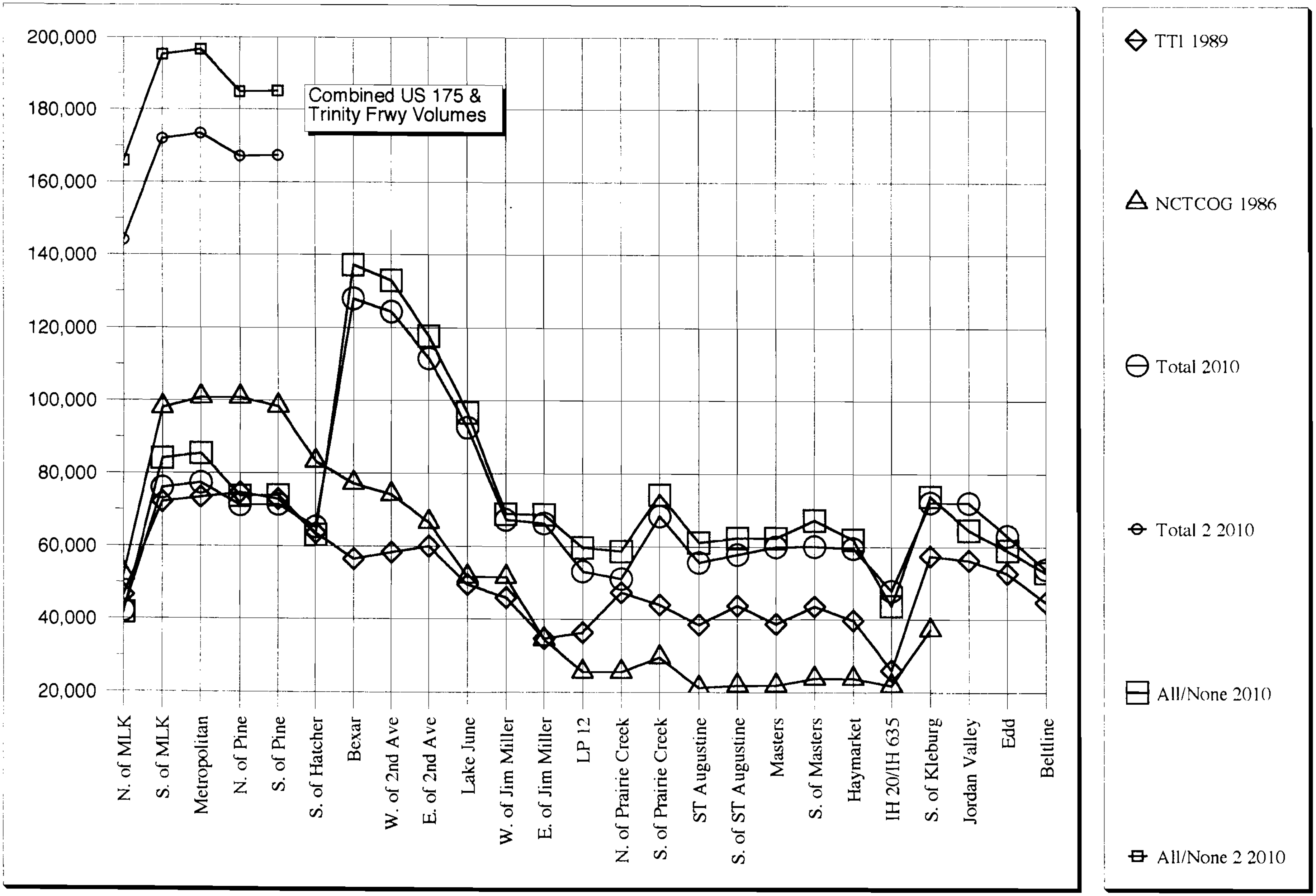


Figure A-13. 24-Hour Volumes for SH 114

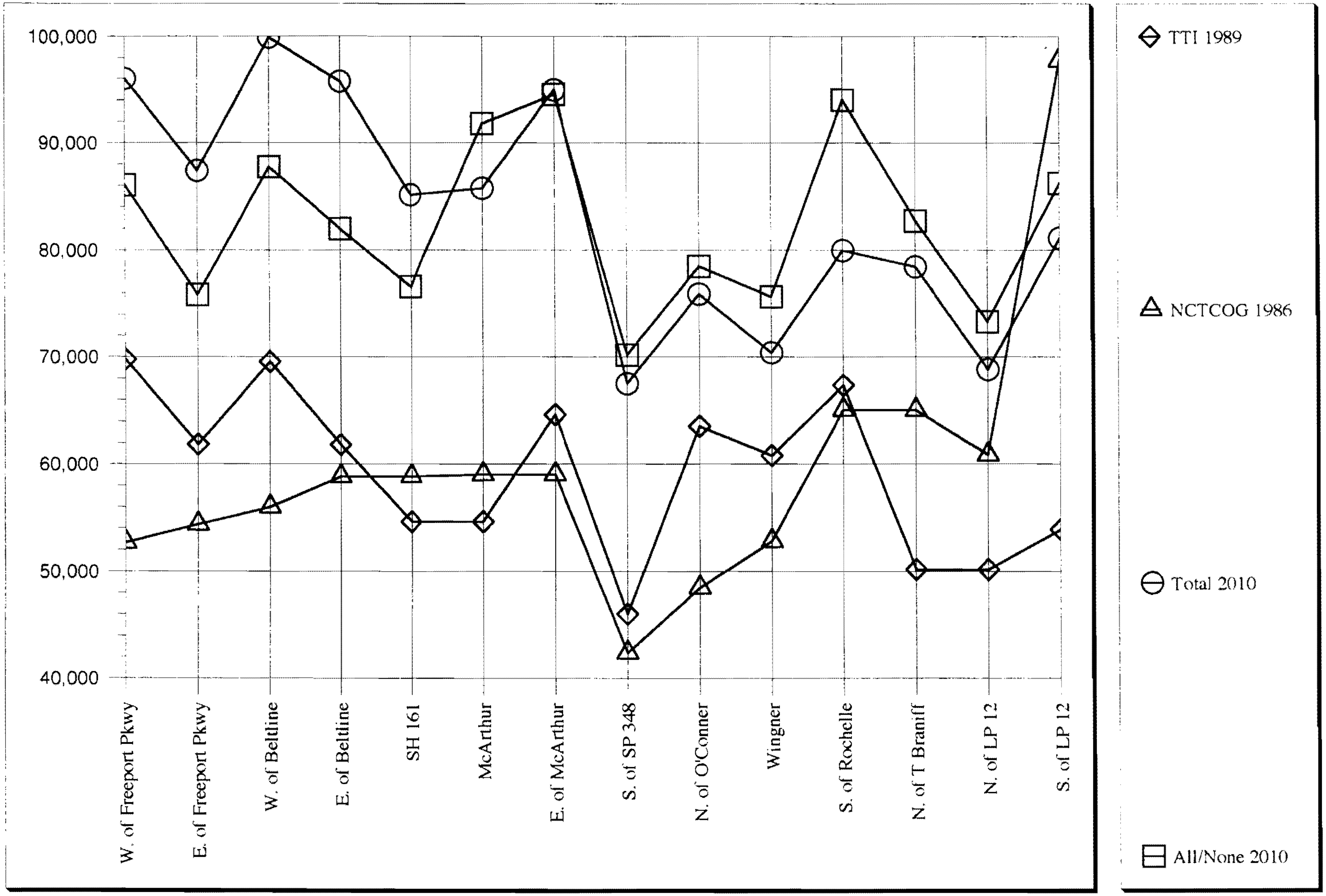


Figure A-14. 24-Hour Volumes for SH 161

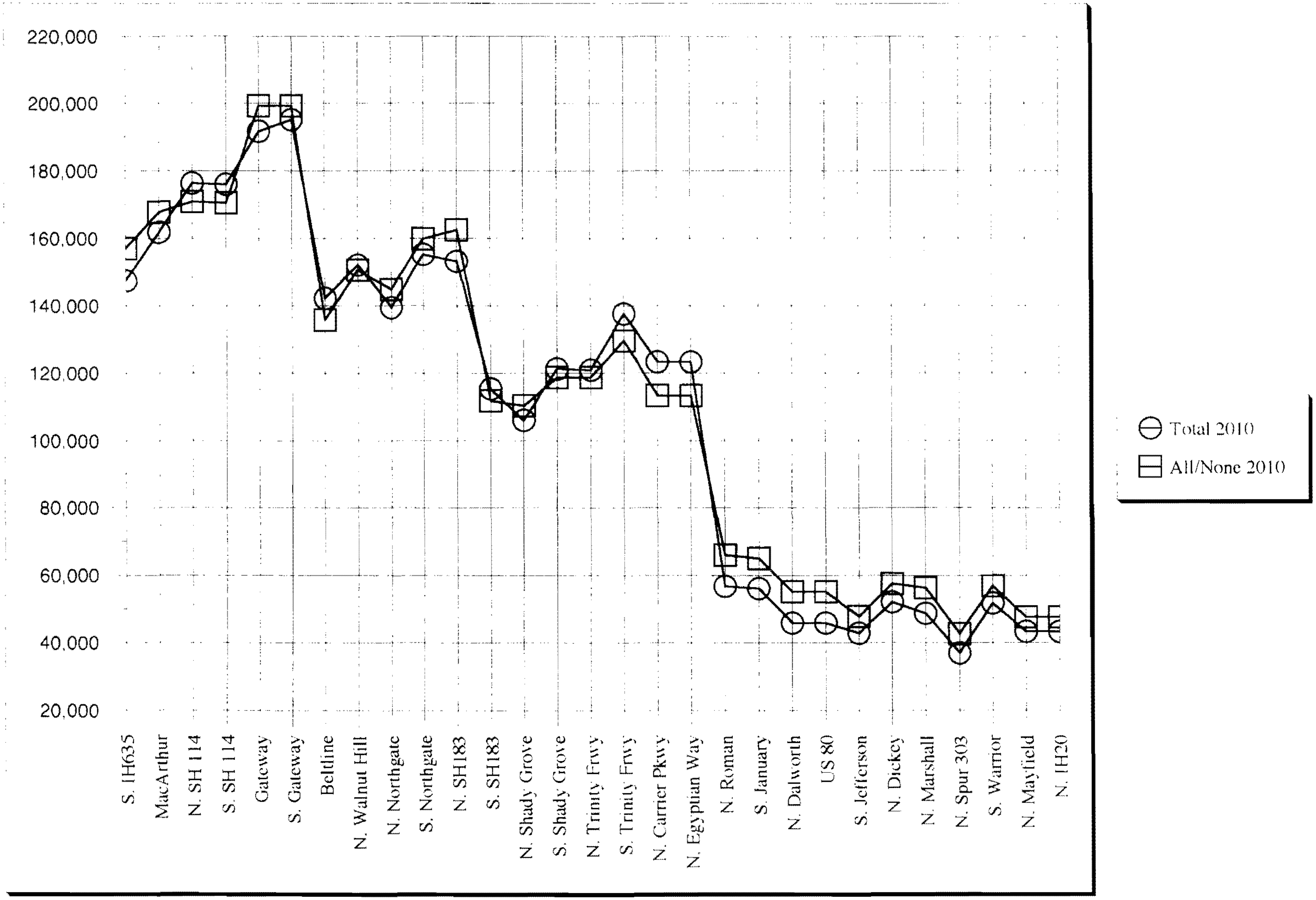


Figure A-15. 24-Hour Volumes for SH 183

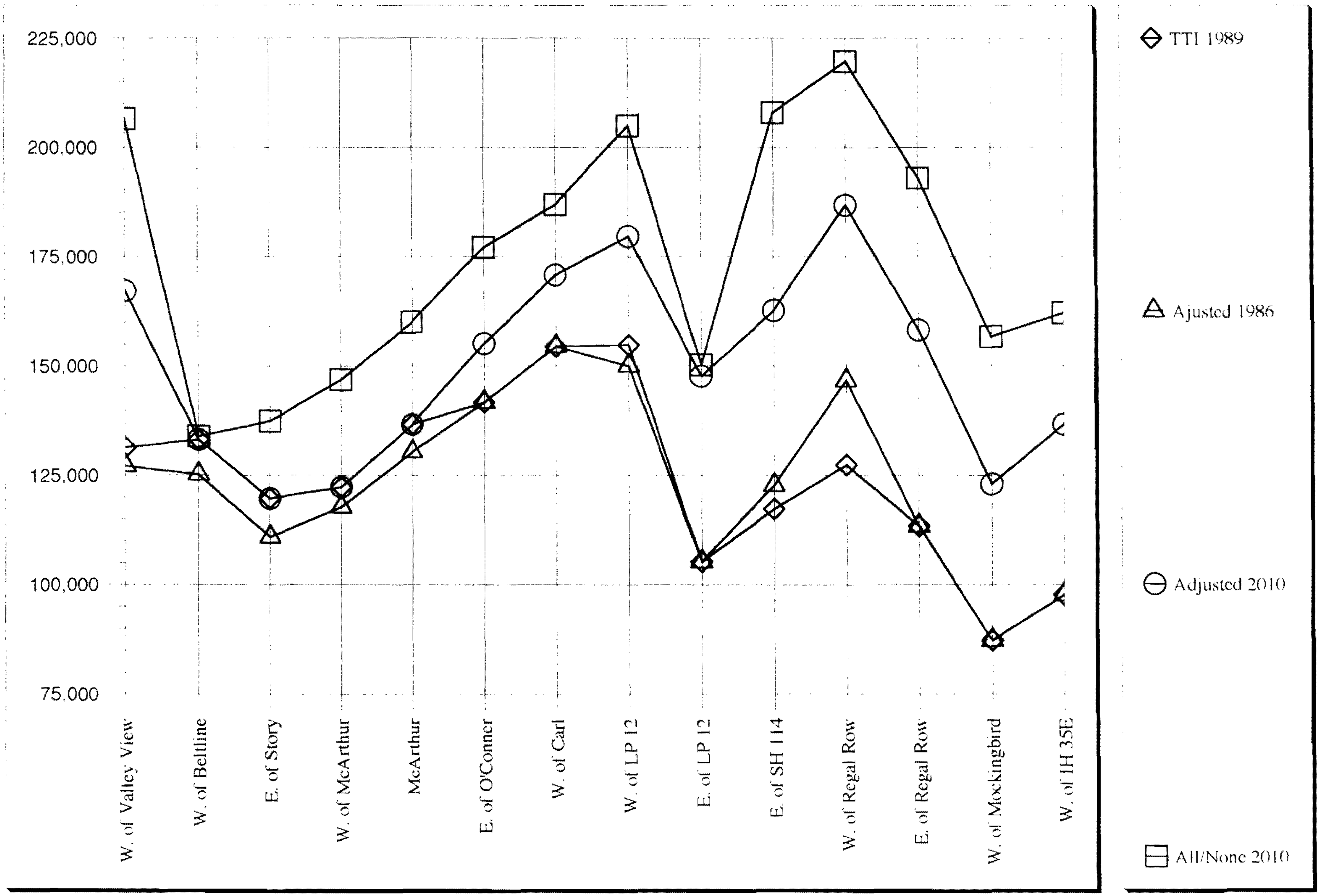


Figure A-16. 24-Hour Volumes for SH 190

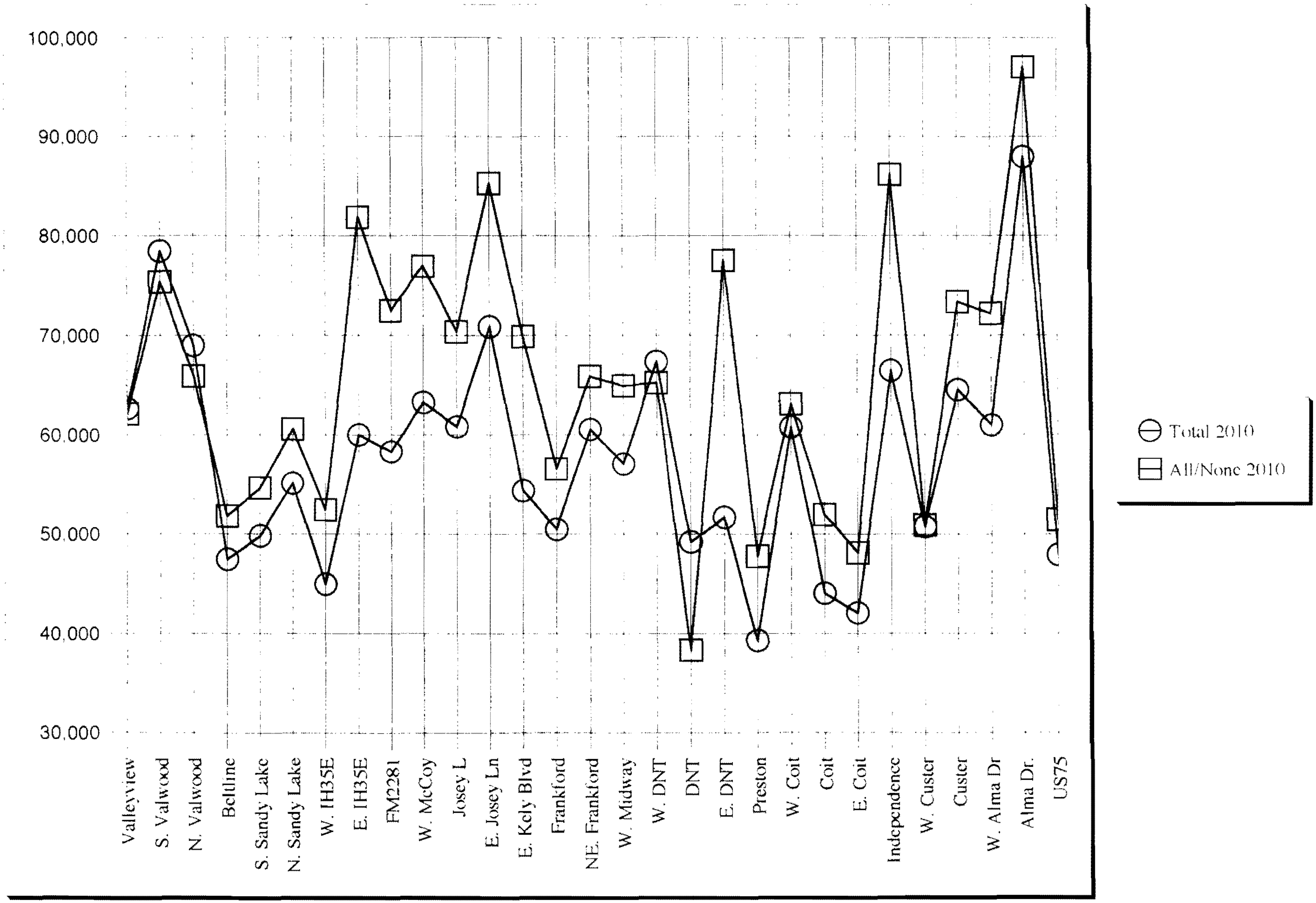


Figure A-16. 24-Hour Volumes for SH 190 (cont.)

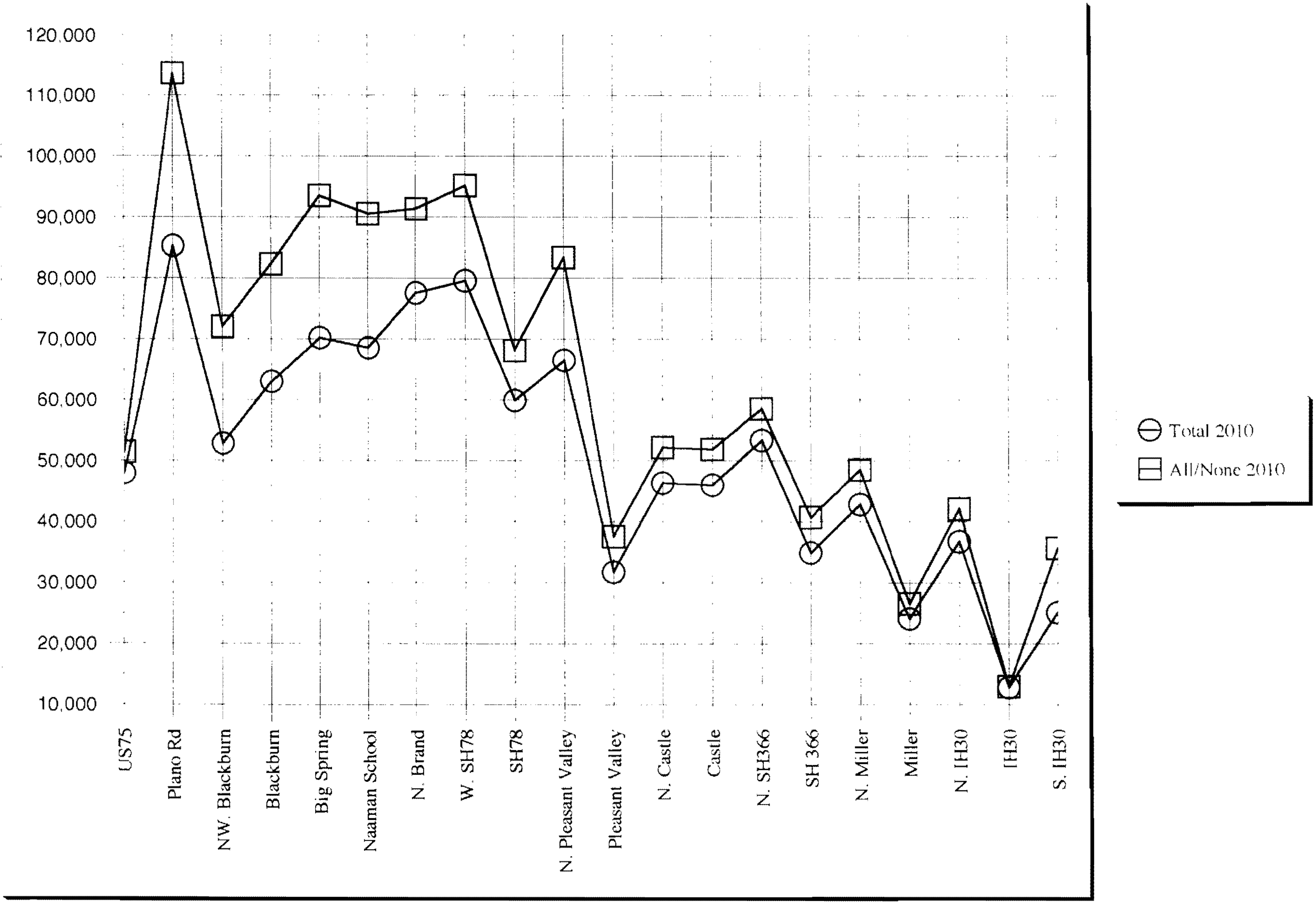


Figure A-17. 24-Hour Volumes for Loop 12/Spur 408

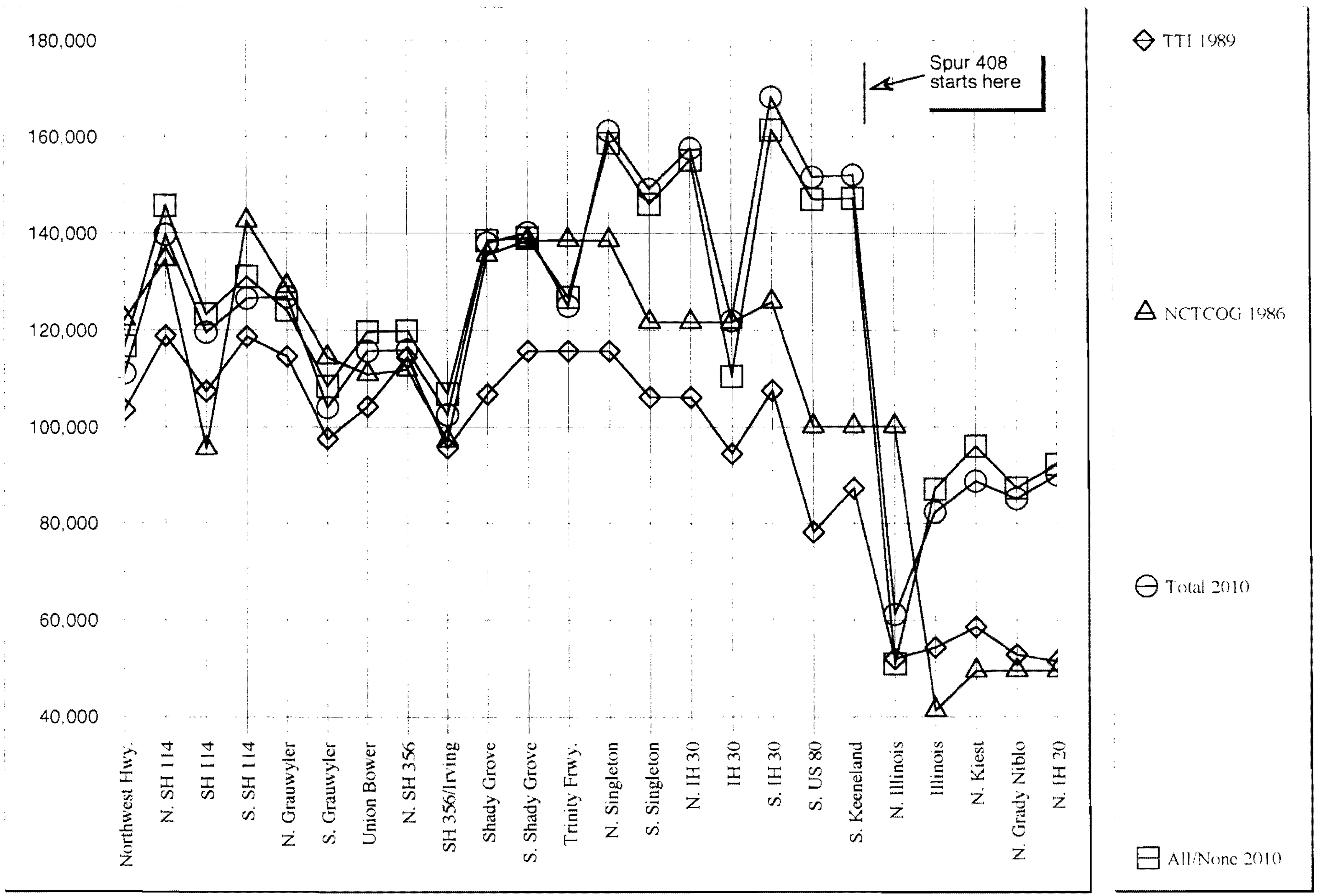
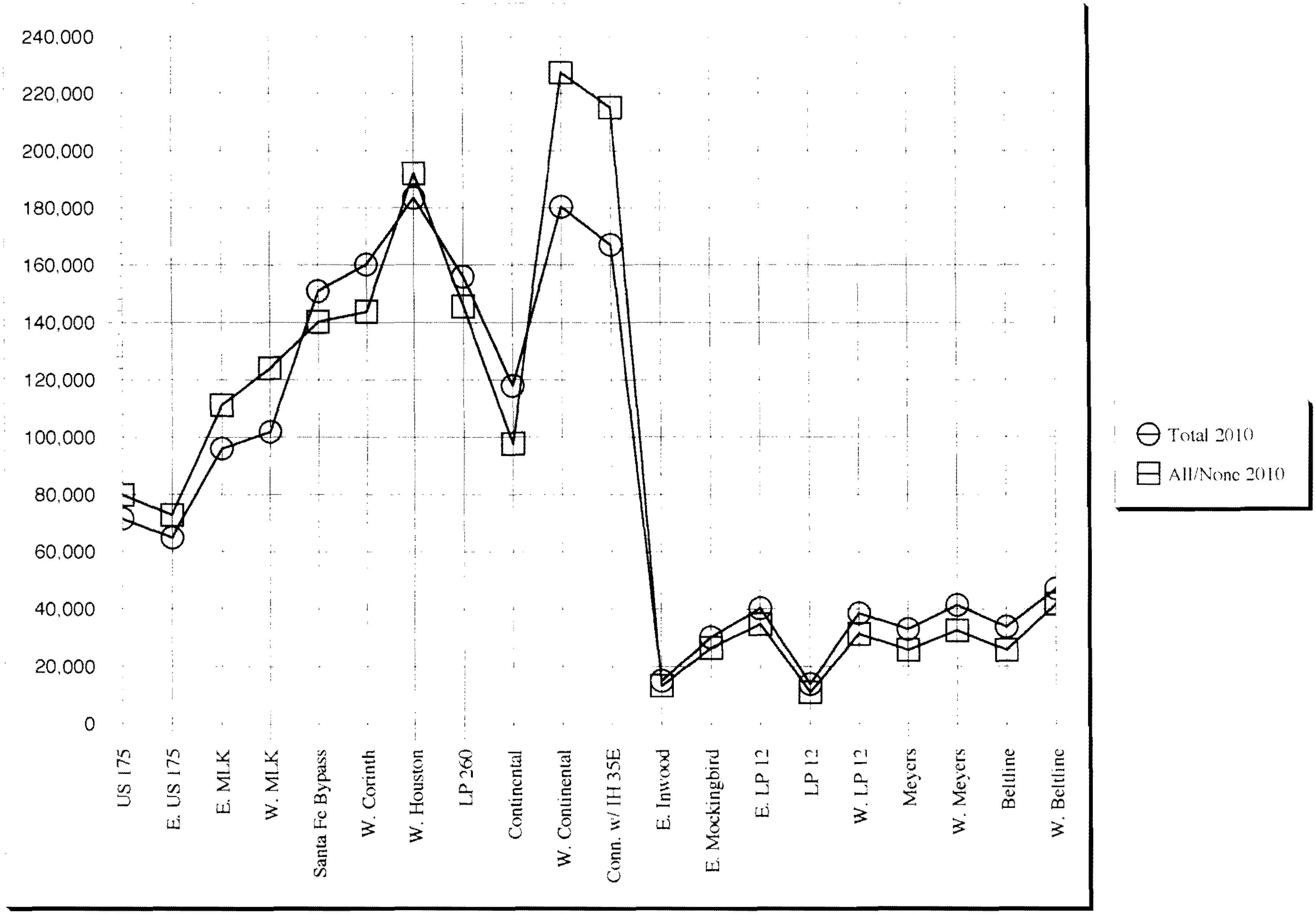


Figure A-18. 24-Hour Volumes for Trinity Parkway



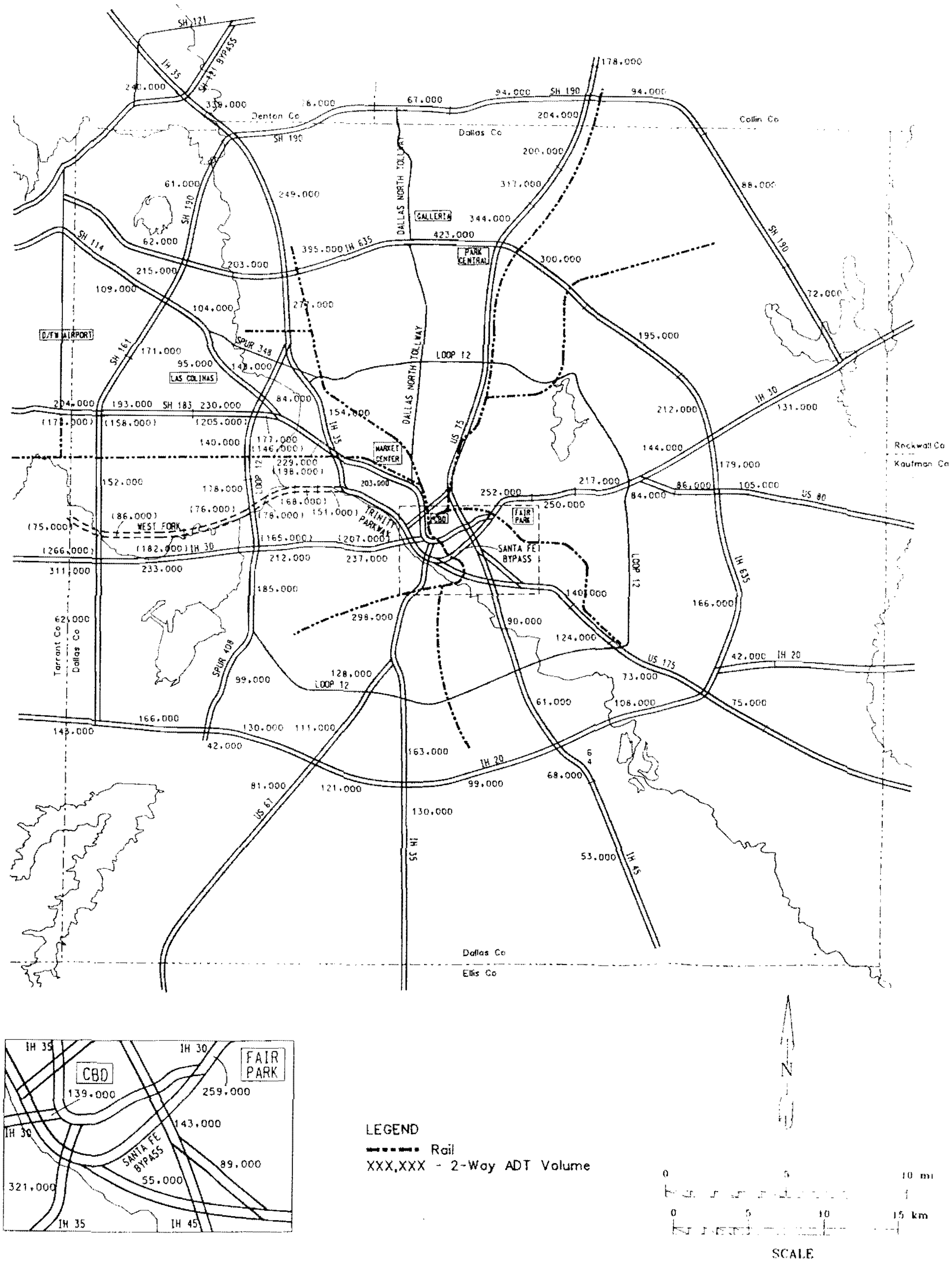


Figure A-19. 24-Hour Year 2015 System Planning Study Volumes

APPENDIX B - AVERAGE ANNUAL COST OF ALTERNATIVES

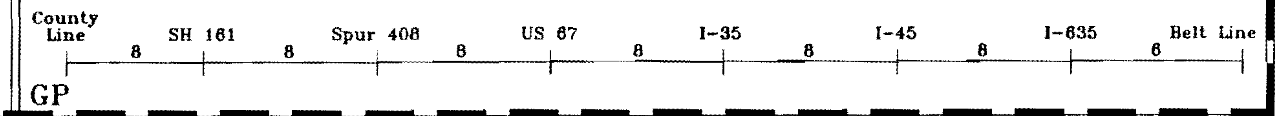
Appendix B consists of the alternative configurations analyzed for each freeway corridor and the corresponding average annual cost for the freeways in the Dallas Freeway/HOV System Planning Study. The alternatives analysis for each corridor consists of development and evaluation of several cross sections. The alternatives analysis for the entire freeway system was an iterative process based on the constraints that would control where traffic could be loaded and unloaded to other facilities and the demand for each portion of the corridor. The average annual cost includes rehabilitation, construction, right-of-way, operating and maintenance, and congestion cost. Rehabilitation cost is required in corridors where the existing pavement has reached its design life or where current design standards are not met.

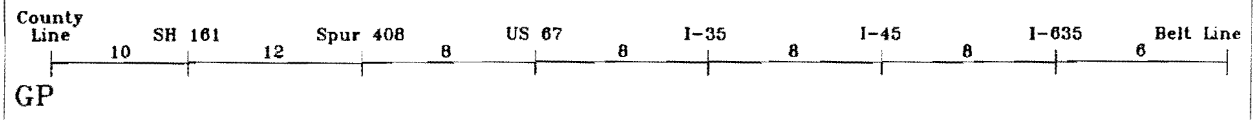
The cross sections evaluated for each corridor (where appropriate) included the existing cross section, the NCTCOG Mobility Plan cross section, an all general-purpose lane cross section, and cross sections including express lanes, a 2-or-more (2+) person HOV lane, and a 3-or-more (3+) person HOV lane. In many cases, variations of each cross section were evaluated such as the number of HOV or express lanes, at-grade versus elevated HOV or express lanes, and combinations of HOV lanes and express lanes.

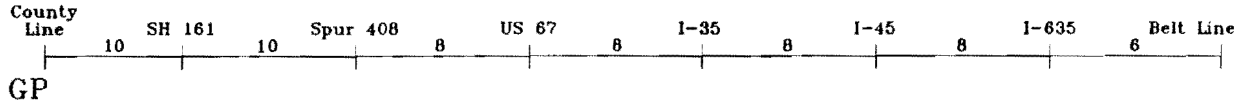
The costs shown in the following tables are the average annual cost, based on 1990 dollars, for the years 1990 through 2015. The alternative highlighted with a heavy solid line for each corridor is the recommended alternative for the System Planning Study. The alternative highlighted with a heavy dashed line is an example of one possible freeway and HOV system that operates with 3+ carpools and significantly constrained capital funding. The limited data on 3+ HOV facilities make estimations of ridership levels on this system more difficult than a 2+ HOV system and have less reliability than the recommended system.

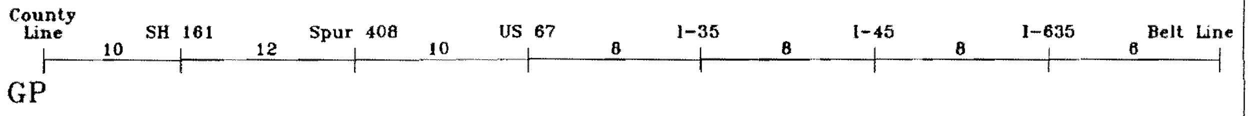
Table B-1. Average Annual Costs for IH 20
(1990-2015)

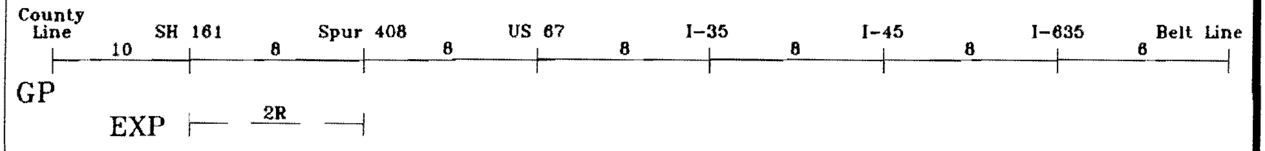
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.9	0.0	0.9	0.1	12.3	13.3
2 (COG Mobility Plan All G-P)	4.0	0.0	4.0	0.1	1.2	5.3
3 (All G-P)	2.6	0.0	2.6	0.1	2.6	5.3
4 (All G-P)	5.4	0.0	5.4	0.1	0.2	5.7
5 (G-P + Exp)	2.9	0.0	2.9	0.3	1.2	4.4
6 (G-P + HOV, 2+)	4.0	0.0	4.0	0.35	1.3	5.7

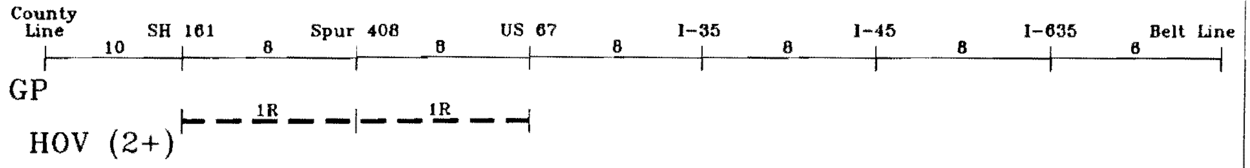










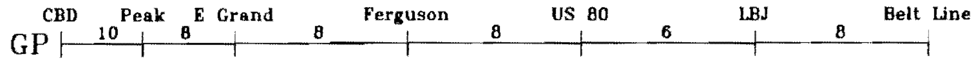


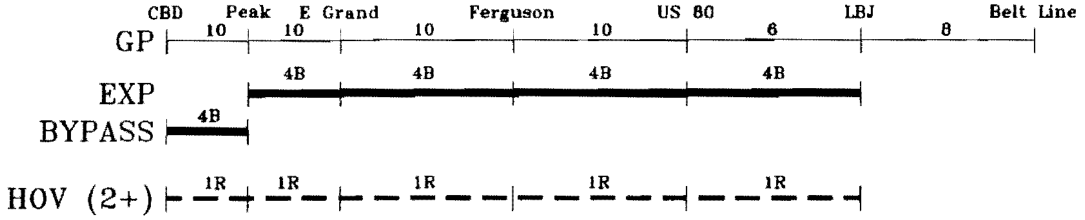
LEGEND

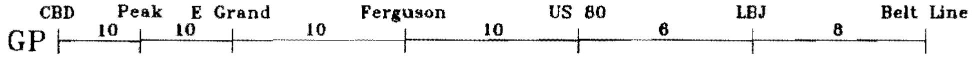
——— At-Grade GP	━━━ Elevated Express
— — At-Grade Express	■ ■ ■ ■ Elevated HOV
━ ━ ━ At-Grade HOV	R – Reversible
	B – Bi-Directional

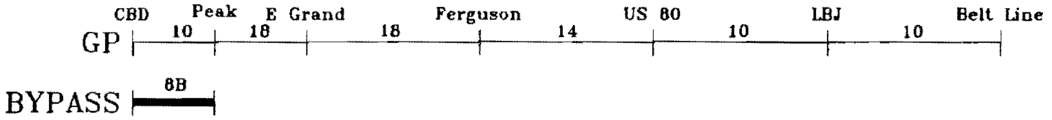
Table B-2. Average Annual Costs for IH 30 East (1990-2015)

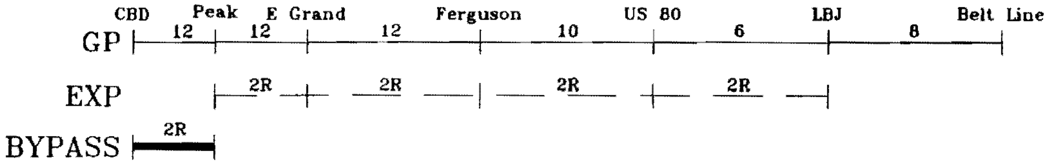
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.4	0.0	0.4	0.1	57.7	58.2
2 COG Mobility Plan (G-P + Exp + HOV, 2+)	21.2	1.1	22.3	0.35	2.6	25.3
3 (All G-P)	2.2	0.0	2.2	0.1	50.8	53.1
4 (All G-P)	16.8	3.7	20.5	0.3	0.9	21.7
5 (G-P + Exp)	10.6	1.9	12.5	0.3	4.0	16.8
6 (G-P + Exp)	10.3	1.3	11.6	0.3	4.4	16.3

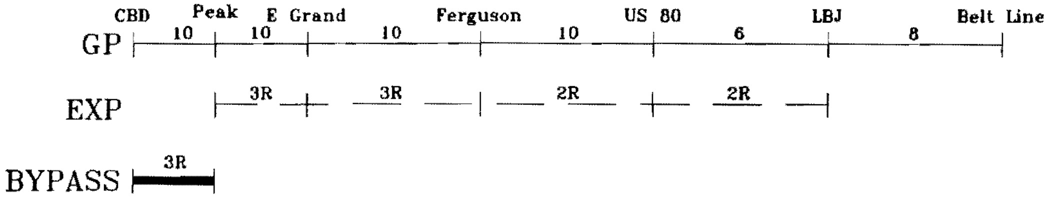












LEGEND

——— At-Grade GP

— — At-Grade Express

▬ ▬ ▬ At-Grade HOV

▬▬▬ Elevated Express

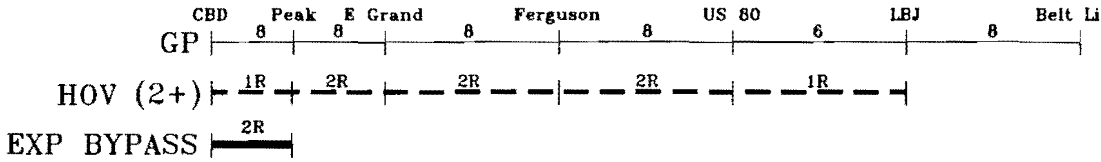
■ ■ ■ ■ Elevated HOV

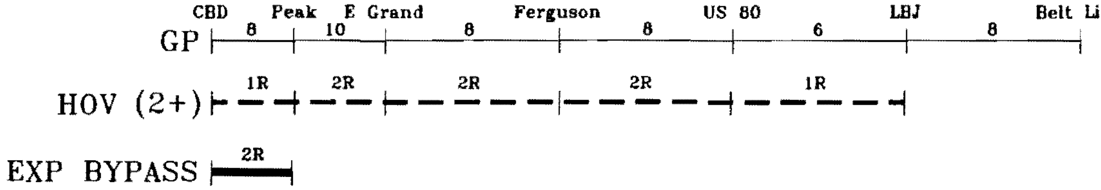
R – Reversible

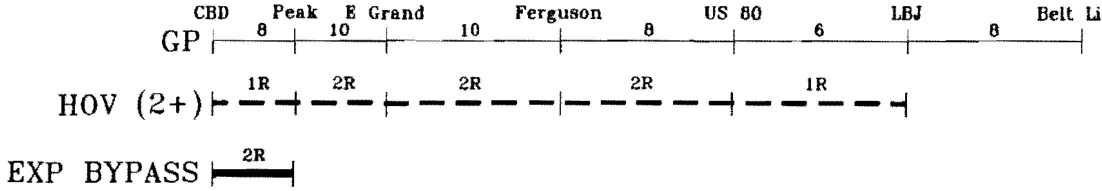
B – Bi-Directional

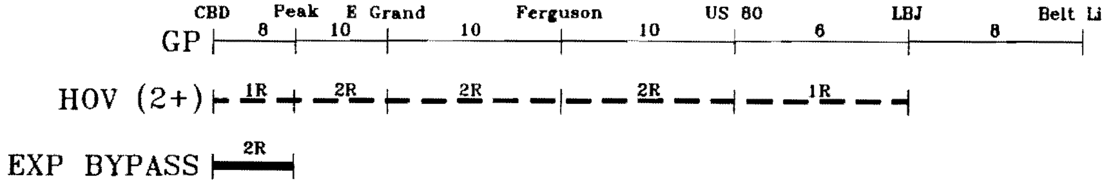
Table B-2. Average Annual Costs for IH 30 East (cont.)
(1990-2015)

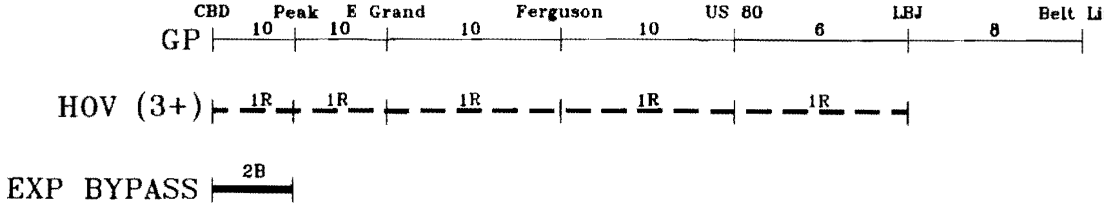
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
7 (G-P + HOV, 2+)	5.6	0.0	5.6	0.35	3.7	9.7
8 (G-P + HOV, 2+)	6.0	0.3	6.3	0.35	3.2	9.9
9 (G-P + HOV, 2+)	**6.5**	**0.7**	**7.2**	**0.35**	**1.7**	**9.3**
10 (G-P + HOV, 2+)	9.9	1.0	10.9	0.35	7.8	19.1
11 (G-P + HOV, 3+)	7.6	0.5	8.1	0.35	7.6	16.1







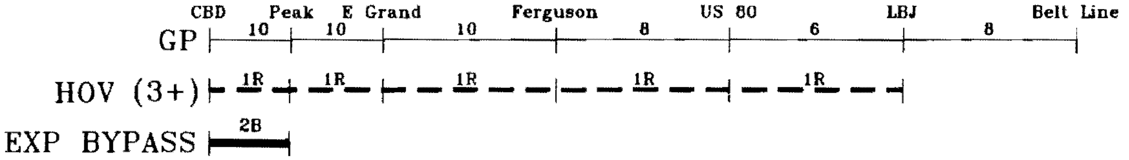
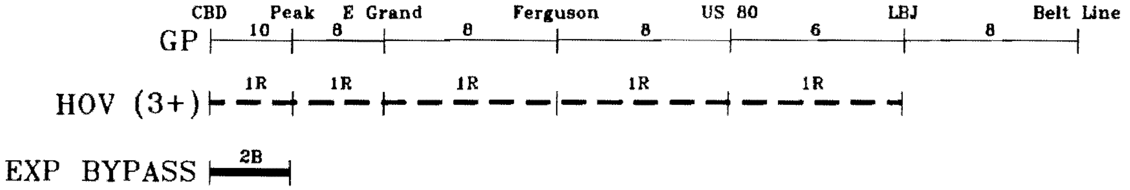




LEGEND

———	At-Grade GP	▬▬▬	Elevated Express
— —	At-Grade Express	▪ ▪ ▪ ▪	Elevated HOV
▬ ▬ ▬	At-Grade HOV	R	– Reversible
		B	– Bi-Directional

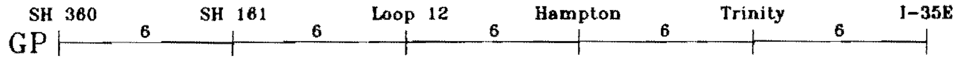
Table B-2. Average Annual Costs for IH 30 East (cont.) (1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
12	5.7	0.5	6.2	0.35	12.3	18.9
(G-P + HOV, 3+)						
13	4.7	0.1	4.8	0.35	19.1	24.3
Cons Budget (G-P + HOV, 3+)						

LEGEND

———	At-Grade GP	▬▬	Elevated Express
— —	At-Grade Express	▪ ▪ ▪ ▪	Elevated HOV
▬ ▬ ▬	At-Grade HOV	R	– Reversible
		B	– Bi-Directional

Table B-3. Average Annual Costs for IH 30 West (1990-2015)

<table>
<tr><th>Alt.</th><th>Constr Cost ($mill)</th><th>R.O.W. Cost ($mill)</th><th>Total Capital Cost ($mill)</th><th>O & M Cost ($mill)</th><th>Congest Cost ($mill)</th><th>Total Avg Annual Cost ($mill)</th></tr>
<tr><td rowspan="2">1
(No Action)</td><td>0.5</td><td>0.0</td><td>0.5</td><td>0.1</td><td>89.7</td><td>90.3</td></tr>
<tr><td colspan="6"> </td></tr>
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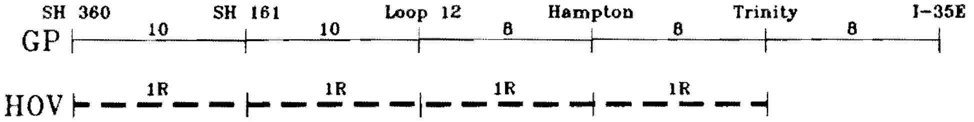
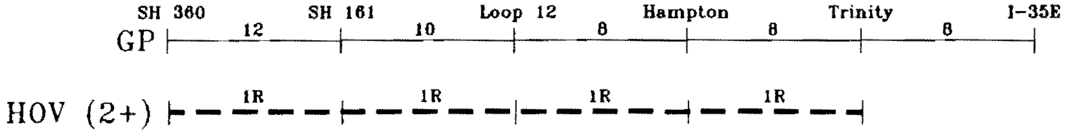
(TxDOT)</td><td>12.8</td><td>0.7</td><td>13.5</td><td>0.35</td><td>54.0</td><td>67.9</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">3
(COG Mobility Plan 1 G-P + HOV, 2+)</td><td>13.4</td><td>0.9</td><td>14.3</td><td>0.35</td><td>47.9</td><td>62.6</td></tr>
<tr><td colspan="6"> </td></tr>
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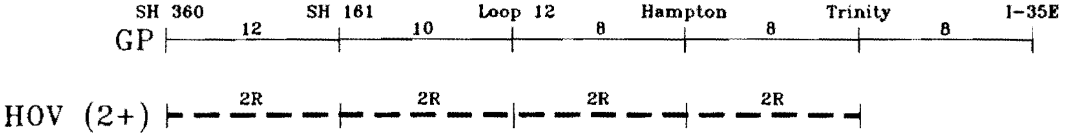
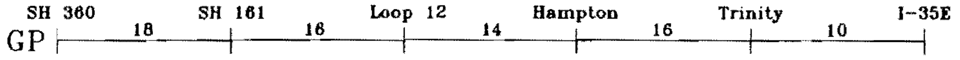
(COG Mobility Plan 2 G-P + HOV, 2+)</td><td>15.6</td><td>2.3</td><td>17.9</td><td>0.35</td><td>4.2</td><td>22.5</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">5
(All G-P)</td><td>23.6</td><td>8.5</td><td>32.1</td><td>0.1</td><td>1.7</td><td>33.9</td></tr>
<tr><td colspan="6"> </td></tr>
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LEGEND

—— At-Grade GP

— — At-Grade Express

▬ ▬ ▬ At-Grade HOV

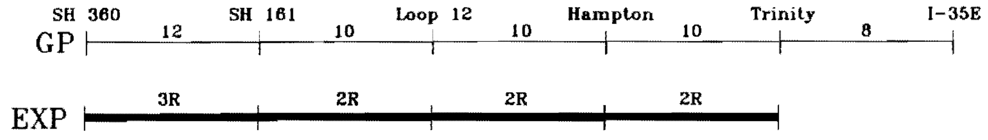
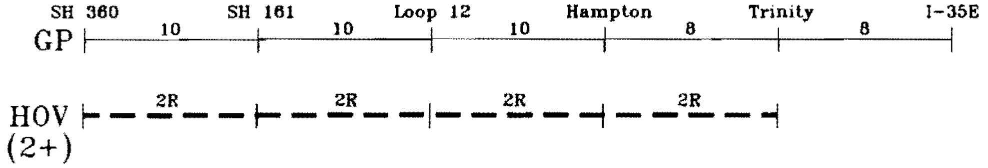
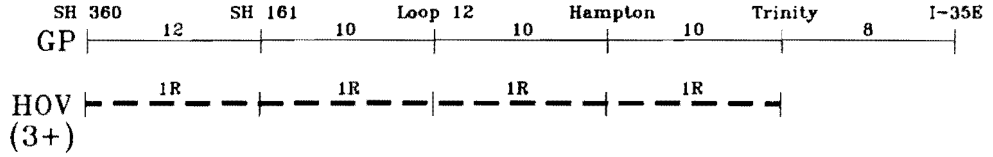
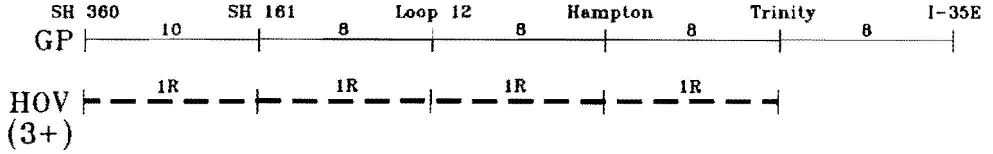
▬ Elevated Express

▪ ▪ ▪ ▪ Elevated HOV

R – Reversible

B – Bi-Directional

Table B-3. Average Annual Costs for IH 30 West (cont.)
(1990-2015)

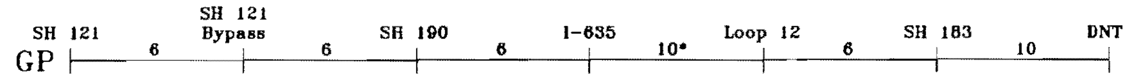
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
6 (G-P + Elev Exp)	19.4	2.0	21.4	0.3	5.2	26.9
						
7 (G-P + HOV, 2+)	16.0	2.6	18.6	0.35	6.0	25.0
						
8 (G-P + HOV, 3+)	15.2	2.0	17.2	0.35	13.1	30.7
						
9 Cons Budget (G-P + HOV, 3+)	10.6	0.0	10.6	0.35	41.0	52.0
						

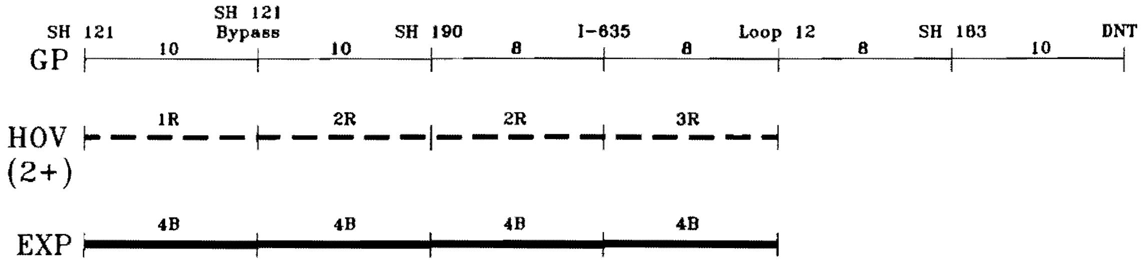
LEGEND

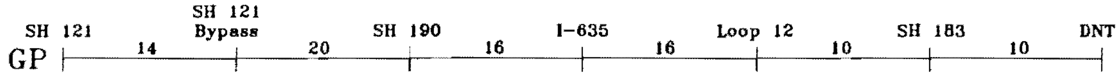
━━━ Elevated Express
──── At-Grade GP
▪ ▪ ▪ ▪ Elevated HOV
— — At-Grade Express
R – Reversible
▬ ▬ ▬ At-Grade HOV
B – Bi-Directional

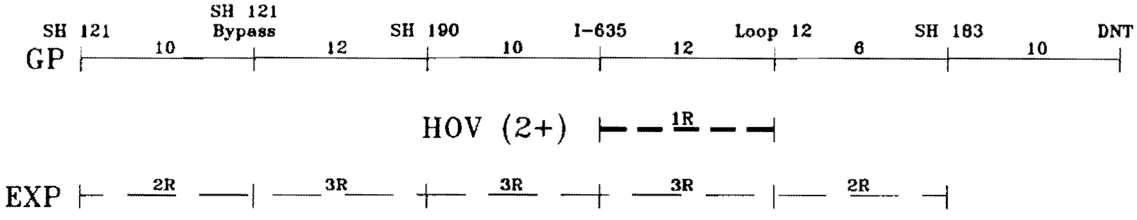
Table B-4. Average Annual Costs for IH 35E North (1990-2015)

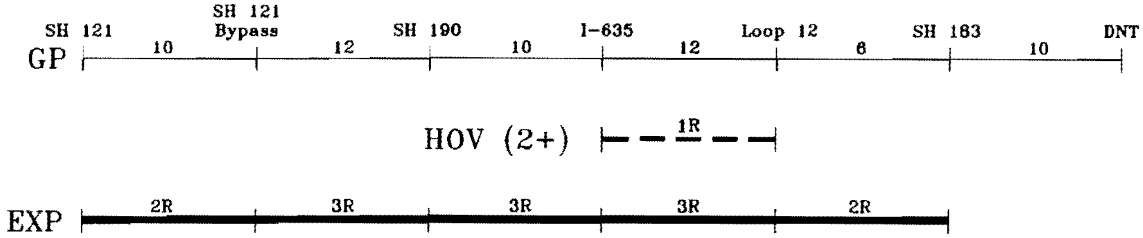
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.7	0.0	0.7	0.1	148.2	149.0
2 COG Mobility Plan (G-P + HOV, 2+ + Elev Exp)	37.8	0.8	38.6	0.35	12.9	51.9
3 (All G-P)	37.8	13.1	50.9	0.1	4.5	55.5
4 (G-P + Exp)	33.2	7.7	40.9	0.3	7.4	48.6
5 (G-P + Elev Exp)	38.0	4.0	42.0	0.3	7.4	49.7











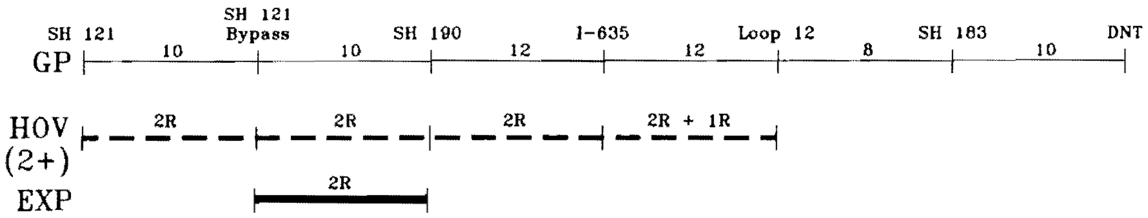
* Short Term Improvement

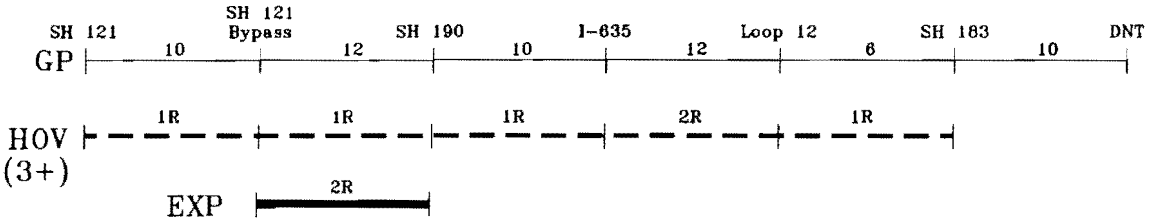
LEGEND

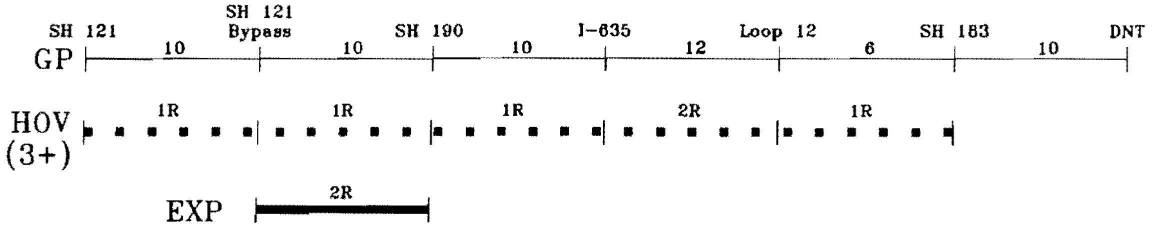
── At-Grade GP	━━ Elevated Express
— — At-Grade Express	▪ ▪ ▪ ▪ Elevated HOV
▬ ▬ ▬ At-Grade HOV	R – Reversible
	B – Bi-Directional

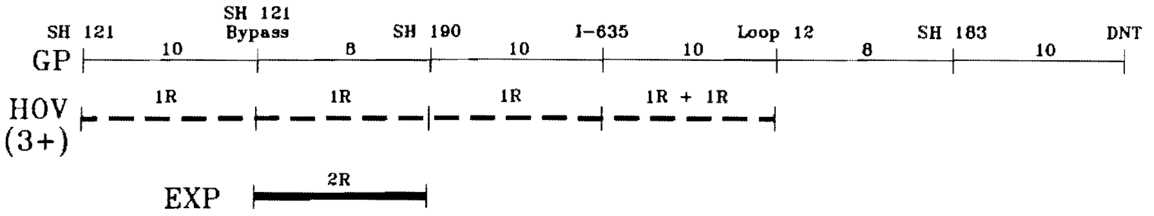
Table B-4. Average Annual Costs for IH 35E North (cont.) (1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
6 (G-P + HOV, 2+)	33.3	7.2	40.5	0.35	6.6	47.5
7 (G-P + Elev HOV, 2+)	36.0	4.4	40.4	0.35	6.6	47.4
8 (G-P + HOV, 3+)	29.5	3.6	33.1	0.35	15.2	48.7
9 (G-P + Elev HOV, 3+)	31.4	2.7	34.1	0.35	15.2	49.7
10 Cons Budget (G-P + HOV, 3+)	24.8	1.9	26.7	0.35	25.1	52.2





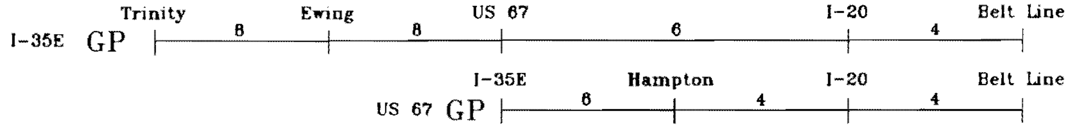
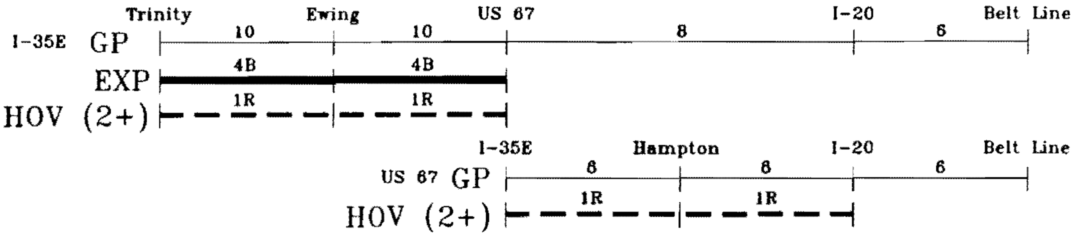
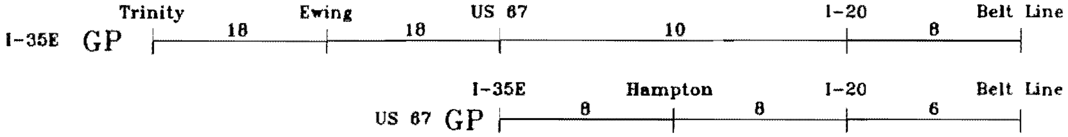
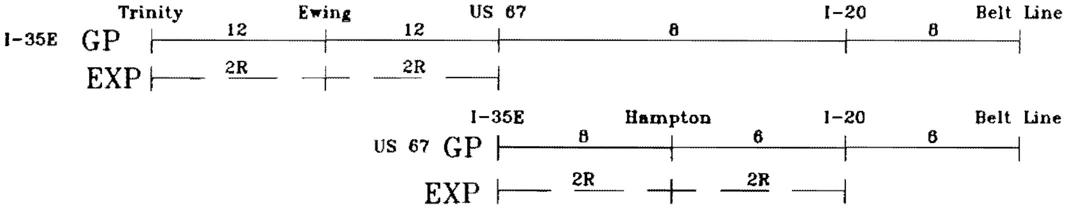
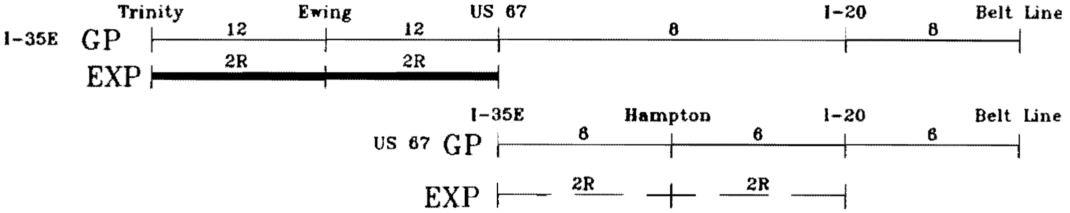
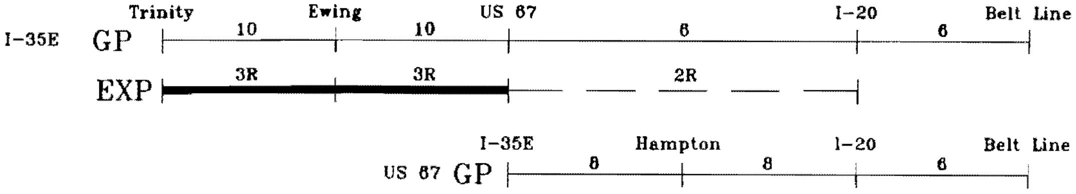




LEGEND

- ——— At-Grade GP
- — — At-Grade Express
- — — — At-Grade HOV
- ▬▬ Elevated Express
- ■ ■ ■ ■ Elevated HOV
- R – Reversible
- B – Bi-Directional

Table B-5. Average Annual Costs for IH 35E South/US 67
(1990-2015)

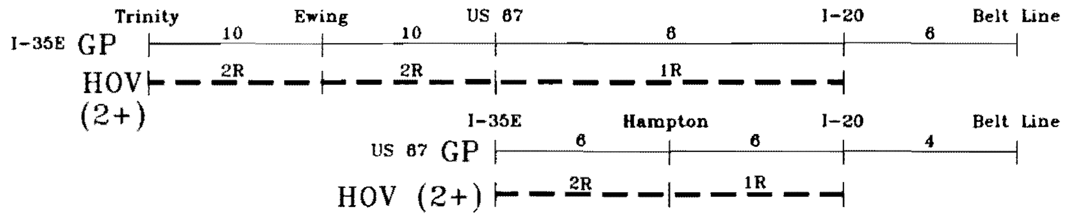
<table>
<tr><th>Alt.</th><th>Constr Cost ($mill)</th><th>R.O.W. Cost ($mill)</th><th>Total Capital Cost ($mill)</th><th>O & M Cost ($mill)</th><th>Congest Cost ($mill)</th><th>Total Avg Annual Cost ($mill)</th></tr>
<tr><td rowspan="2">1
(No Action)</td><td>0.9</td><td>0.0</td><td>0.9</td><td>0.1</td><td>77.9</td><td>78.9</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">2
COG Mobility Plan
(G-P + HOV, 2+ + Elev Exp)</td><td>17.9</td><td>1.0</td><td>18.9</td><td>0.35</td><td>12.4</td><td>31.7</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">3
(All G-P)</td><td>19.6</td><td>4.2</td><td>23.8</td><td>0.1</td><td>3.6</td><td>27.5</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">4
(G-P + 2-Lane Exp)</td><td>16.4</td><td>1.6</td><td>18.0</td><td>0.3</td><td>7.4</td><td>25.7</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">5
(G-P + 2-Lane Elev Exp)</td><td>15.7</td><td>2.1</td><td>17.8</td><td>0.3</td><td>7.4</td><td>25.5</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">6
(G-P + 3-Lane Elev Exp)</td><td>15.4</td><td>0.5</td><td>15.9</td><td>0.3</td><td>8.7</td><td>24.9</td></tr>
<tr><td colspan="6"> </td></tr>
</table>

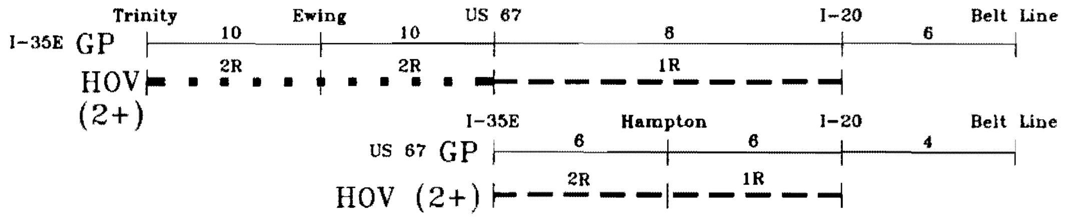
LEGEND

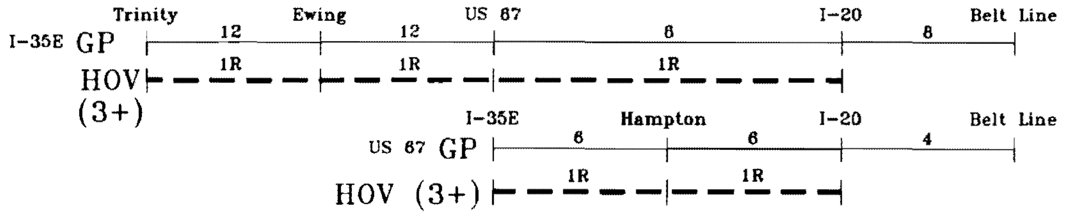
──── At-Grade GP	━━━━ Elevated Express
── ── At-Grade Express	▪ ▪ ▪ ▪ Elevated HOV
▬ ▬ ▬ At-Grade HOV	R – Reversible
	B – Bi-Directional

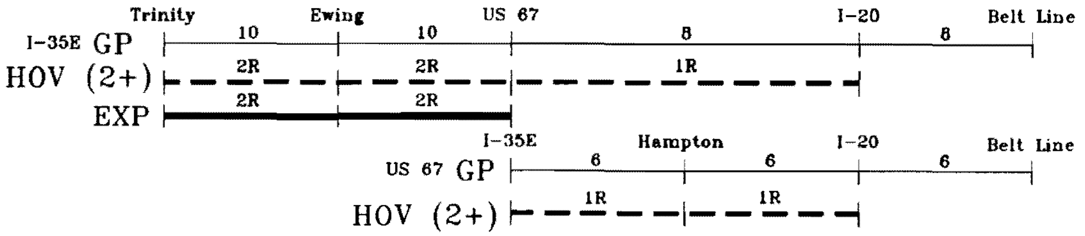
Table B-5. Average Annual Costs for IH 35E South/US 67 (cont.) (1990-2015)

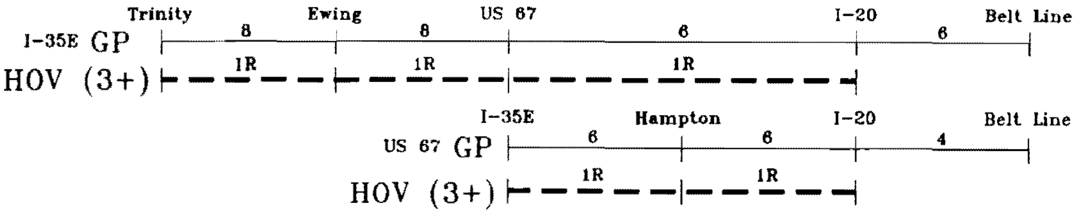
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
7 (G-P + HOV, 2+)	11.4	1.0	12.4	0.35	6.1	18.9
8 (G-P + Elev HOV, 2+)	12.0	0.5	12.5	0.35	6.1	19.0
9 (G-P + HOV, 3+)	14.7	1.6	16.3	0.35	4.5	21.2
10 (G-P + HOV, 2+ + Elev Exp)	23.0	1.6	24.6	0.35	2.1	27.1
11 Cons Budget (G-P + HOV, 3+)	7.6	0.0	7.6	0.35	17.7	25.7











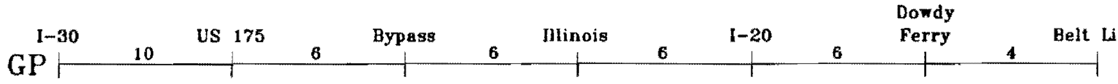
LEGEND

——— At-Grade GP
— — At-Grade Express
▬ ▬ ▬ At-Grade HOV
▬▬▬ Elevated Express
■ ■ ■ ■ Elevated HOV
R – Reversible
B – Bi-Directional

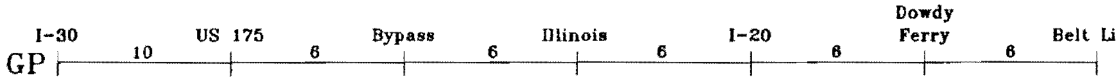
Table B-6. Average Annual Costs for IH 45 (1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (TxDOT)	0.4	0.0	0.4	0.1	0.8	1.3
2 COG Mobility Plan (All G-P)	1.9	0.0	1.9	0.1	0.6	2.6
3 (All G-P)	2.8	0.4	3.2	0.1	0.2	3.5
4 (G-P + Exp)	6.8	1.3	8.1	0.3	0.2	8.6
5 (G-P + HOV, 2+)	6.0	0.7	6.7	0.35	0.1	7.2

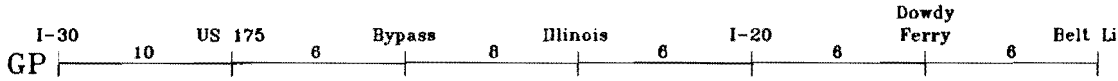
1 (TxDOT)



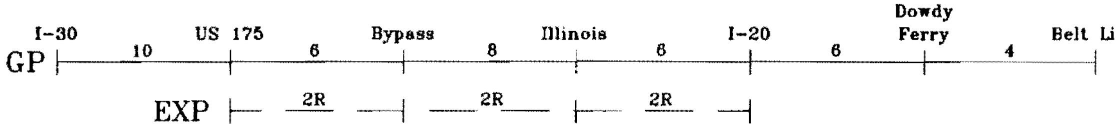
2 COG Mobility Plan (All G-P)



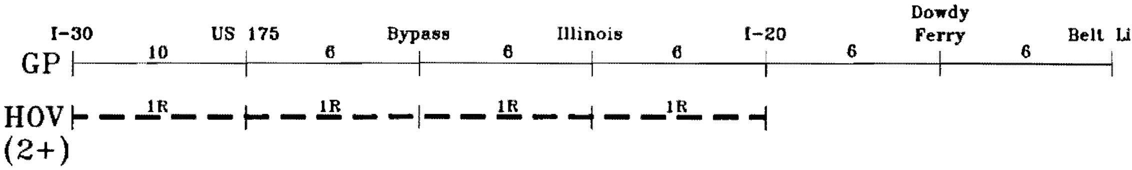
3 (All G-P)



4 (G-P + Exp)



5 (G-P + HOV, 2+)

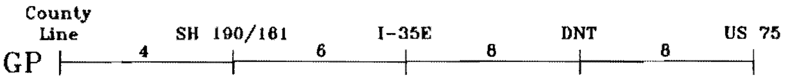


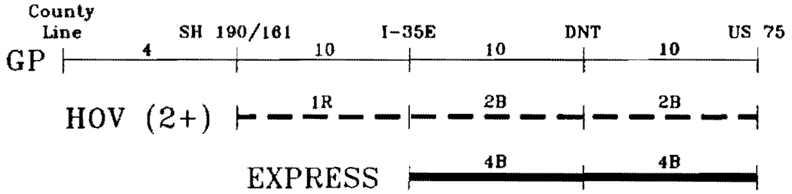
LEGEND

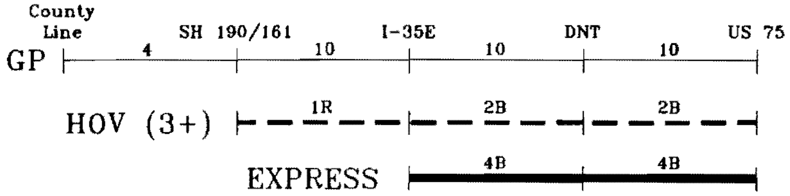
——— At-Grade GP
— — At-Grade Express
▬ ▬ ▬ At-Grade HOV
▬▬ Elevated Express
▪ ▪ ▪ ▪ Elevated HOV
R - Reversible
B - Bi-Directional

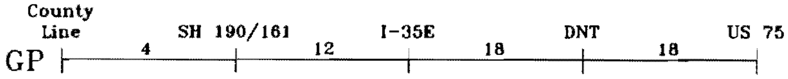
Table B-7. Average Annual Costs for IH 635 North (1990-2015)

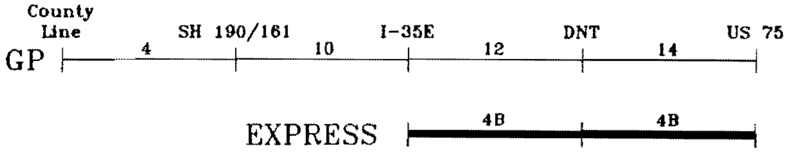
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.5	0.0	0.5	0.1	130.0	130.6
2 COG Mobility Plan 1 (G-P + HOV, 2+ + Elev Exp)	30.4	5.0	35.4	0.35	12.2	48.0
3 COG Mobility Plan 2 (G-P + HOV, 3+ + Elev Exp)	30.4	5.0	35.4	0.35	4.7	40.5
4 (All G-P)	27.4	13.6	41.0	0.1	1.2	42.3
5 (G-P + Elev Exp)	27.4	6.4	33.8	0.3	6.9	41.0











LEGEND

——— At-Grade GP

— — At-Grade Express

– – – At-Grade HOV

▬ Elevated Express

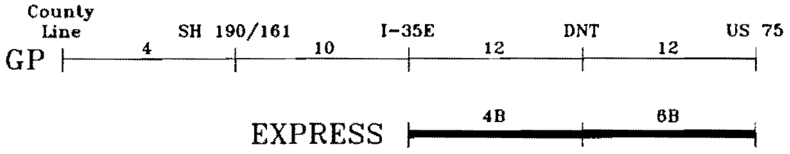
▪ ▪ ▪ ▪ Elevated HOV

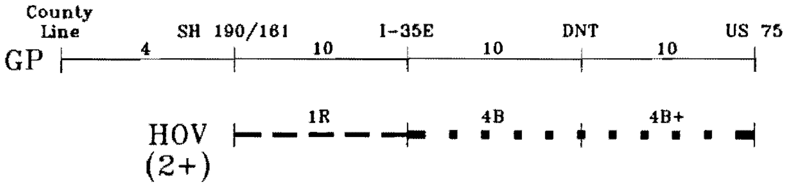
R – Reversible

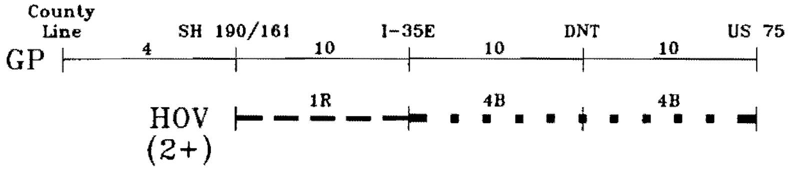
B – Bi-Directional

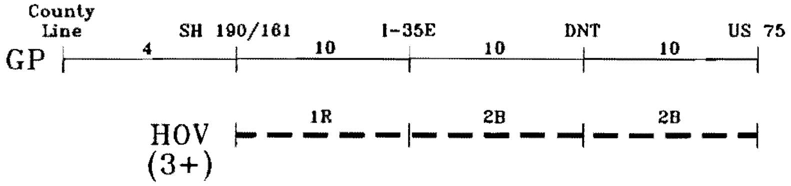
Table B-7. Average Annual Costs for IH 635 North (cont.) (1990-2015)

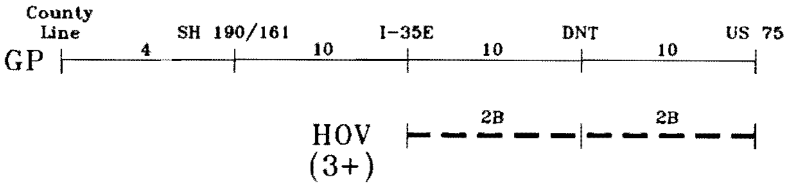
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
6 (G-P + Elev Exp)	28.5	5.0	33.5	0.3	7.1	40.9
7 (G-P + Elev HOV, 2+)	24.5	3.3	27.8	0.35	4.7	32.9
8 (G-P + Elev HOV, 2+)	24.5	3.3	27.8	0.35	9.4	37.6
9 (G-P + HOV, 3+)	18.1	3.3	21.4	0.35	35.8	57.6
10 Cons Budget (G-P + HOV, 3+)	17.1	3.3	20.4	0.35	38.7	59.5









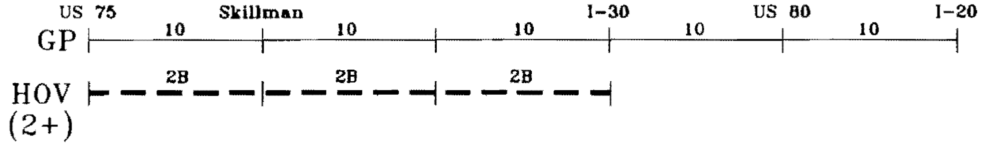


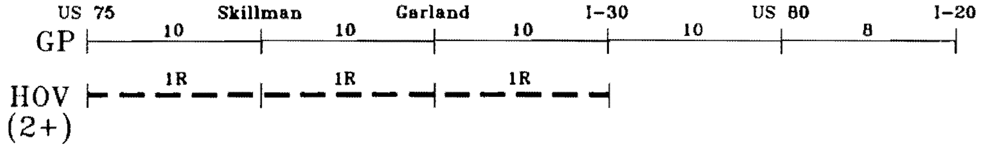
LEGEND

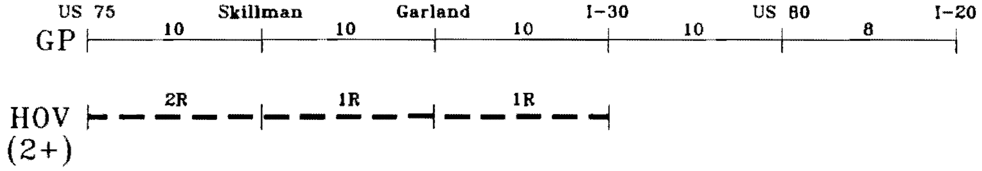
——— At-Grade GP
— — At-Grade Express
▬ ▬ ▬ At-Grade HOV
▬▬▬ Elevated Express
■ ■ ■ ■ Elevated HOV
R – Reversible
B – Bi-Directional

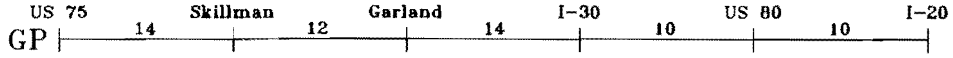
Table B-8. Average Annual Costs for IH 635 East (1990-2015)

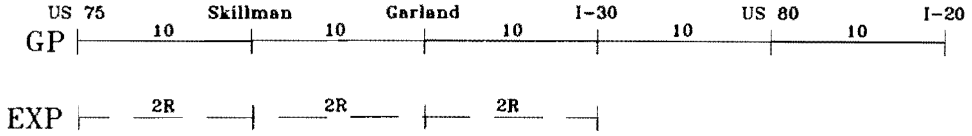
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.6	0.0	0.6	0.1	48.0	48.7
2 TxDOT (G-P + HOV, 2+)	12.0	0.0	12.2	0.15	5.5	17.9
3 COG Mobility Plan 1 (G-P + HOV, 2+)	8.4	0.0	8.4	0.35	7.1	15.9
4 COG Mobility Plan 2 (G-P + HOV, 2+)	8.8	0.0	8.8	0.35	2.1	11.3
5 (All G-P)	19.7	1.8	21.5	0.1	0.9	22.5
6 (G-P + Exp)	9.2	0.0	9.2	0.3	3.3	12.8







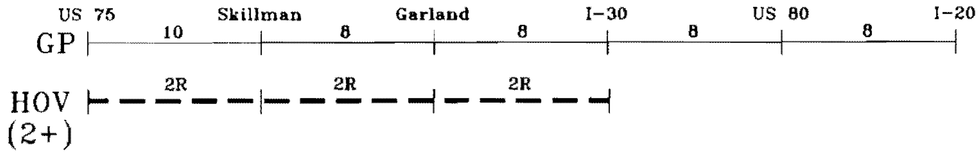
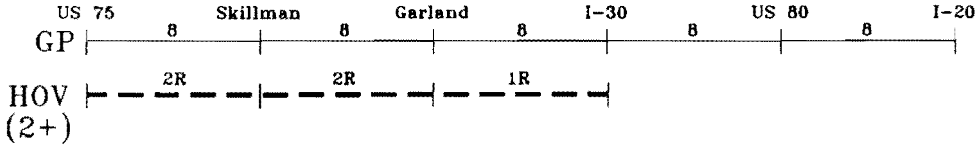
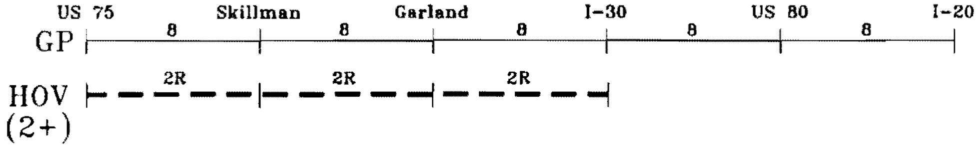
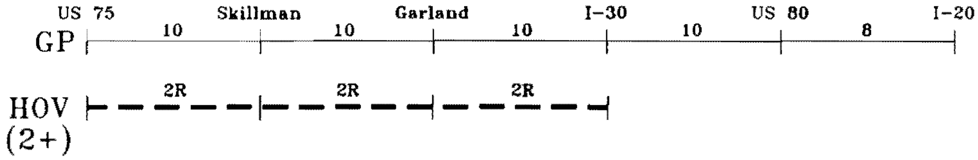
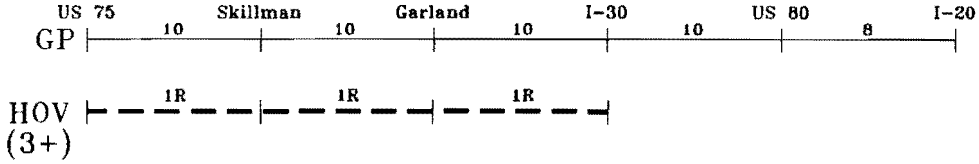
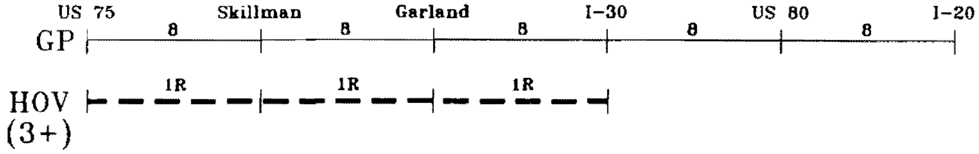




LEGEND

——— At-Grade GP
— — At-Grade Express
▬ ▬ ▬ At-Grade HOV
▬▬▬ Elevated Express
■ ■ ■ ■ Elevated HOV
R – Reversible
B – Bi-Directional

Table B-8. Average Annual Costs for IH 635 East (cont.) (1990-2015)

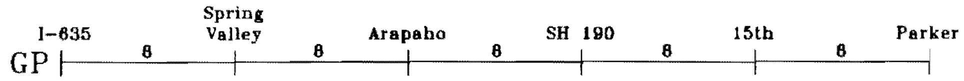
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
7	6.9	0.0	6.9	0.35	3.5	10.8
(G-P + HOV, 2+)						
8	4.6	0.0	4.6	0.35	10.7	15.7
(G-P + HOV, 2+)						
9	5.9	0.0	5.9	0.35	7.4	13.7
(G-P + HOV, 2+)						
10	10.1	0.0	10.1	0.35	1.8	12.3
(G-P + HOV, 2+)						
11	8.4	0.0	8.4	0.35	6.9	15.7
(G-P + HOV, 3+)						
12 Cons Budget	4.2	0.0	4.2	0.35	29.7	34.3
(G-P + HOV, 3+)						

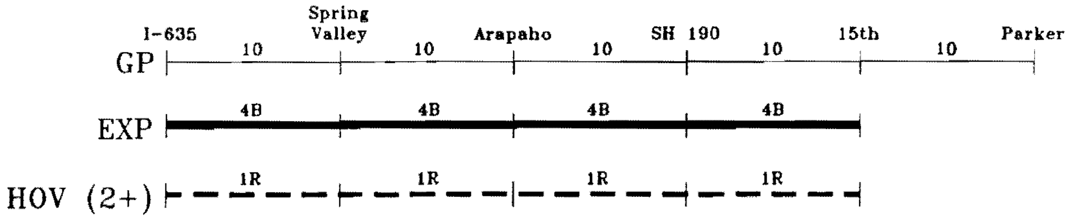
LEGEND

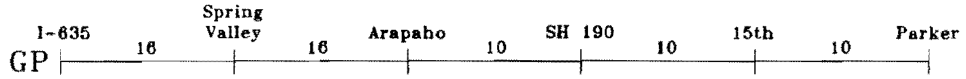
——	At-Grade GP	▬▬	Elevated Express
— —	At-Grade Express	■ ■ ■ ■	Elevated HOV
▬ ▬ ▬	At-Grade HOV	R	– Reversible
		B	– Bi-Directional

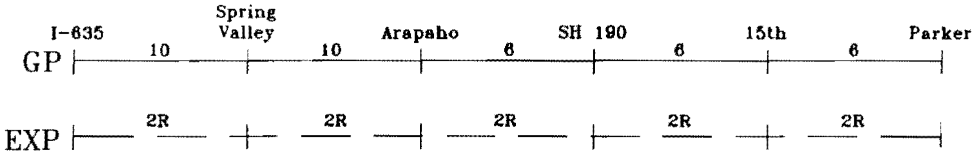
Table B-9. Average Annual Costs for US 75
(1990-2015)

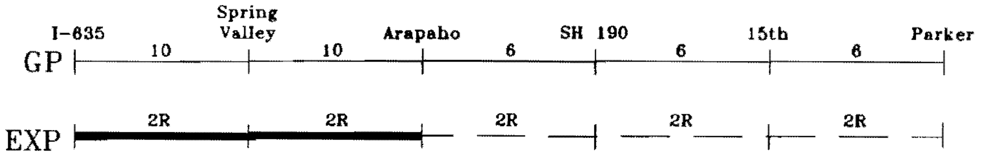
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.3	0.0	0.3	0.1	25.0	25.4
2 COG Mobility Plan (G-P + Elev Exp + HOV, 2+)	23.7	3.9	27.6	0.35	1.0	29.0
3 (All G-P)	14.7	4.4	19.1	0.1	0.6	19.7
4 (G-P + Exp)	5.8	1.5	7.3	0.3	3.2	10.8
5 (G-P + Elev Exp)	6.4	1.0	7.4	0.3	3.2	10.9







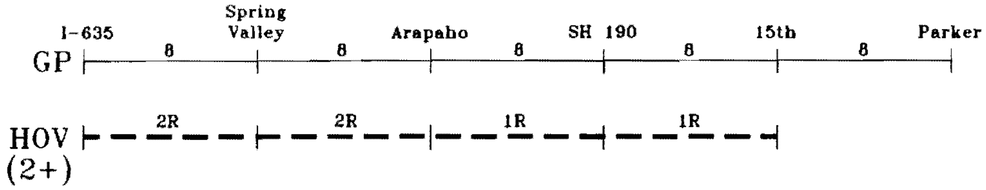
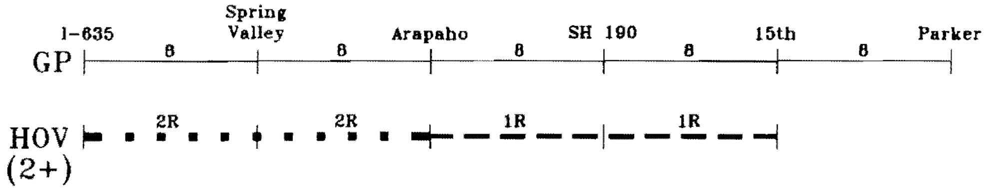
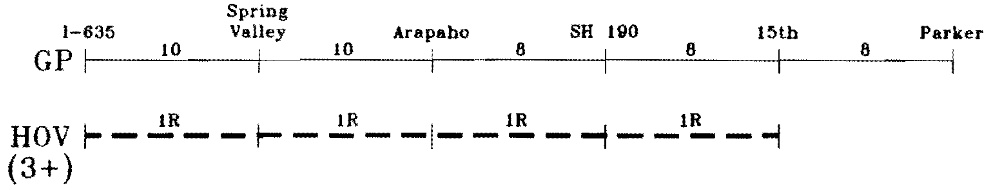
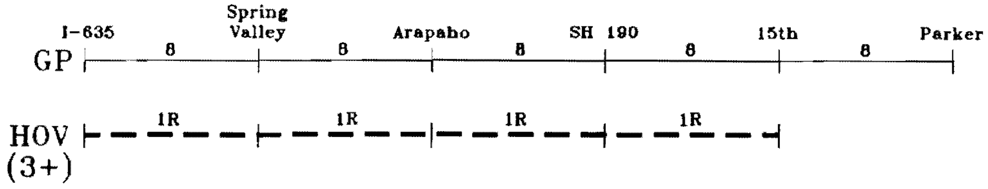




LEGEND

———	At-Grade GP	▬▬	Elevated Express
— —	At-Grade Express	▪ ▪ ▪ ▪	Elevated HOV
- - -	At-Grade HOV	R	– Reversible
		B	– Bi-Directional

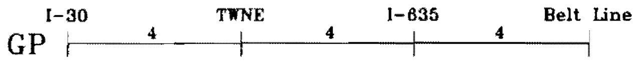
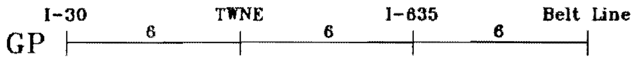
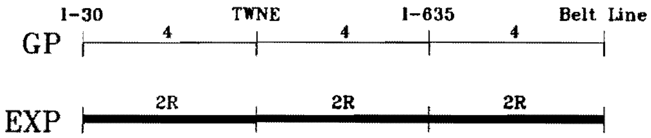
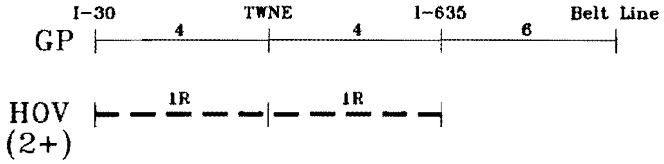
Table B-9. Average Annual Costs for US 75 (cont.) (1990-2015)

<table>
<tr><th>Alt.</th><th>Constr Cost ($mill)</th><th>R.O.W. Cost ($mill)</th><th>Total Capital Cost ($mill)</th><th>O & M Cost ($mill)</th><th>Congest Cost ($mill)</th><th>Total Avg Annual Cost ($mill)</th></tr>
<tr><td rowspan="2">6
(G-P + HOV, 2+)</td><td>6.1</td><td>0.5</td><td>6.6</td><td>0.35</td><td>2.3</td><td>9.3</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="2">7
(G-P + Elev HOV, 2+)</td><td>3.7</td><td>0.0</td><td>3.7</td><td>0.35</td><td>2.3</td><td>6.4</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="2">8
(G-P + Elev HOV, 3+)</td><td>6.7</td><td>1.0</td><td>7.7</td><td>0.35</td><td>7.6</td><td>15.7</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="2">9
Cons Budget
(G-P + HOV, 3+)</td><td>2.7</td><td>0.0</td><td>2.7</td><td>0.35</td><td>15.1</td><td>18.2</td></tr>
<tr><td colspan="6">
</td></tr>
</table>

LEGEND

────	At-Grade GP	━━━━	Elevated Express
── ──	At-Grade Express	■ ■ ■ ■	Elevated HOV
━ ━ ━	At-Grade HOV	R	– Reversible
		B	– Bi-Directional

Table B-10. Average Annual Costs for US 80 (1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.2	0.0	0.2	0.1	8.4	8.7
						
2 COG Mobility Plan (All G-P)	1.7	0.0	1.7	0.1	0.3	2.1
						
3 (All G-P)	4.0	0.4	4.4	0.1	0.0	4.5
						
4 (G-P + Elev Exp)	2.1	0.0	2.1	0.3	0.2	2.6
						
5 (G-P + HOV, 2+)	1.7	0.0	1.7	0.35	0.2	2.3
						

LEGEND

── At-Grade GP

— — At-Grade Express

▬ ▬ ▬ At-Grade HOV

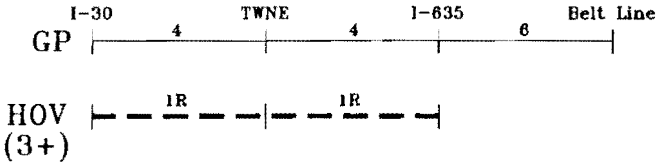
▬ Elevated Express

■ ■ ■ ■ Elevated HOV

R - Reversible

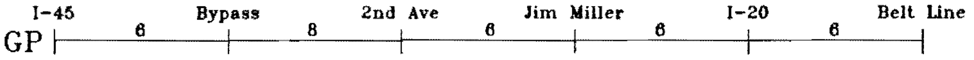
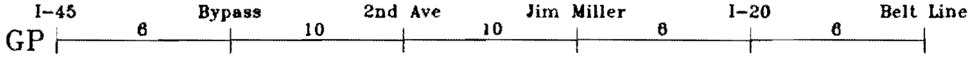
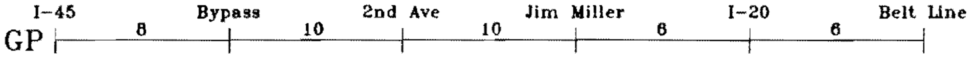
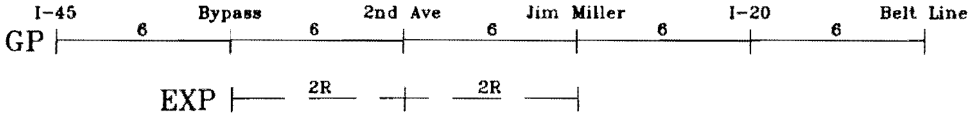
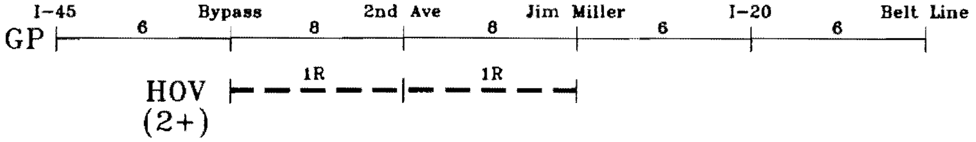
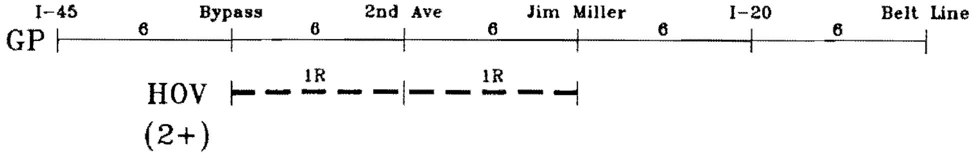
B - Bi-Directional

Table B-10. Average Annual Costs for US 80 (cont.)
(1990-2015)

<table>
<tr><th>Alt.</th><th>Constr Cost ($mill)</th><th>R.O.W. Cost ($mill)</th><th>Total Capital Cost ($mill)</th><th>O & M Cost ($mill)</th><th>Congest Cost ($mill)</th><th>Total Avg Annual Cost ($mill)</th></tr>
<tr><td rowspan="2">6
(G-P + HOV, 3+)</td><td>1.7</td><td>0.0</td><td>1.7</td><td>0.35</td><td>0.4</td><td>2.5</td></tr>
<tr><td colspan="6">
</td></tr>
</table>

LEGEND		▬▬▬	Elevated Express
———	At-Grade GP	▪ ▪ ▪ ▪	Elevated HOV
— —	At-Grade Express	R	– Reversible
▬ ▬ ▬	At-Grade HOV	B	– Bi-Directional

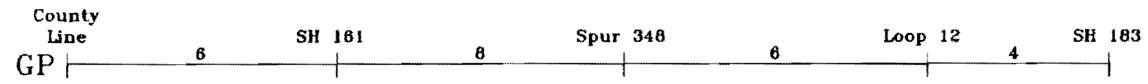
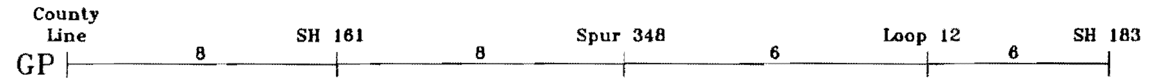
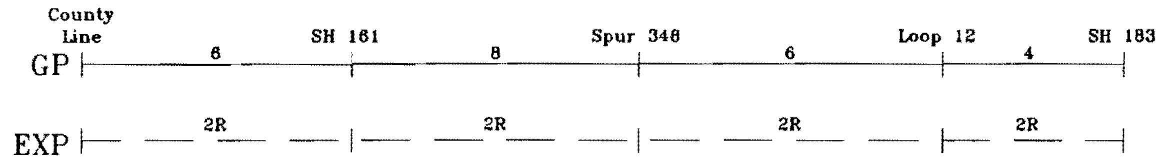
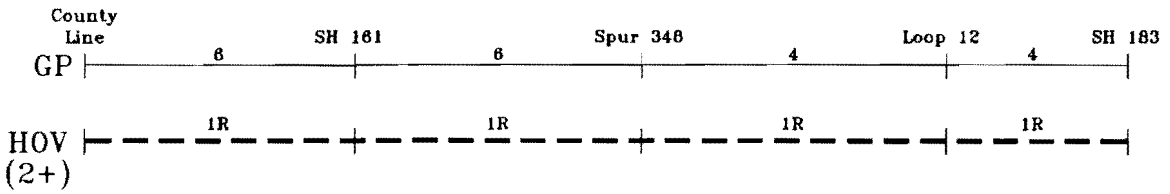
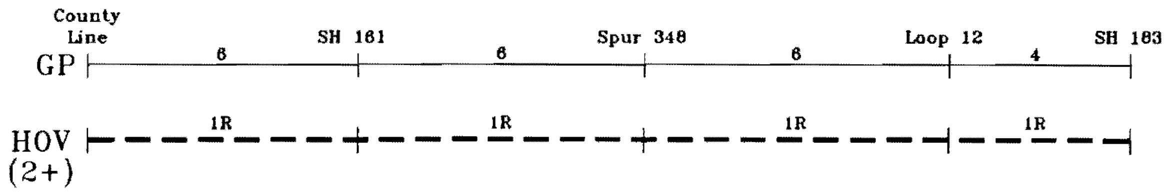
Table B-11. Average Annual Costs for US 175
(1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)	
1 (No Action)	0.4	0.0	0.4	0.1	17.1	17.6	
2 Cons Budget (COG Mobility Plan All G-P)	1.6	0.0	1.6	0.1	9.0	10.7	
3 (All G-P)	5.7	1.0	6.7	0.1	0.5	7.3	
4 (All G-P)	6.2	1.0	7.2	0.1	0.2	7.5	
5 (G-P + Exp)	4.7	0.4	5.1	0.3	0.7	6.1	
6 (G-P + HOV, 2+)	5.7	0.7	6.4	0.35	0.9	7.7	
7 (G-P + HOV, 2+)	3.7	0.2	3.9	0.35	5.1	9.4	

LEGEND

———	At-Grade GP	▬▬▬	Elevated Express
— —	At-Grade Express	▪ ▪ ▪ ▪	Elevated HOV
▬ ▬ ▬	At-Grade HOV	R	– Reversible
		B	– Bi-Directional

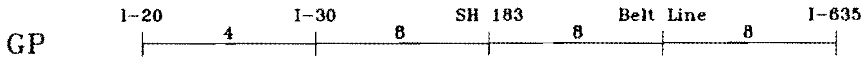
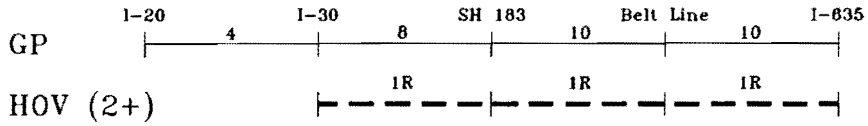
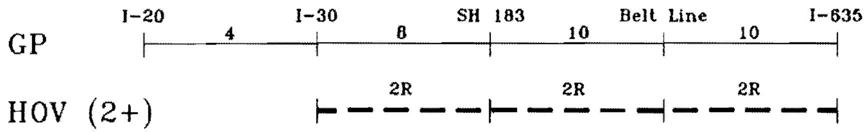
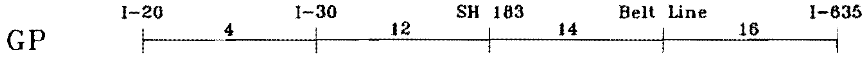
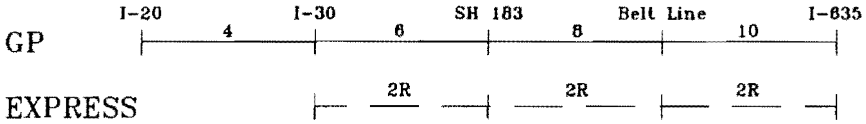
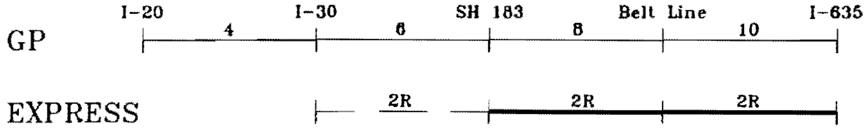
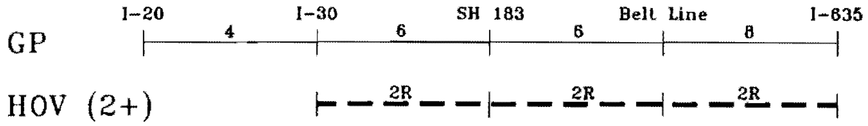
Table B-12. Average Annual Costs for SH 114 (1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.3	0.0	0.3	0.0	3.5	3.8
						
2 COG Mobility Plan (All G-P)	2.4	0.0	2.4	0.1	0.0	2.5
						
3 (G-P + Exp)	4.2	0.0	4.2	0.3	0.0	4.5
						
4 (G-P + HOV, 2+)	2.4	0.0	2.4	0.35	0.8	3.6
						
5 (G-P + HOV, 2+)	3.6	0.0	3.6	0.35	0.3	4.3
						

LEGEND

———	At-Grade GP	▬▬▬	Elevated Express
— —	At-Grade Express	■ ■ ■ ■	Elevated HOV
▬ ▬ ▬	At-Grade HOV	R	– Reversible
		B	– Bi-Directional

Table B-13. Average Annual Costs for SH 161 (1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (TxDOT)	34.6	0.0	34.6	0.1	41.0	75.7
	 					
2 COG Mobility Plan 1 (G-P + HOV, 2+)	40.3	1.9	42.2	0.35	6.3	48.9
	 					
3 COG Mobility Plan 2 (G-P + HOV, 2+)	42.0	2.9	44.9	0.35	0.7	46.0
	 					
4 (All G-P)	44.8	5.3	50.1	0.1	0.2	50.4
	 					
5 (G-P + Exp)	38.0	1.4	39.4	0.3	4.0	43.7
	 					
6 (G-P + Elev Exp)	39.0	0.9	39.9	0.3	4.0	44.2
	 					
7 (G-P + HOV, 2+)	37.1	0.4	37.5	0.35	4.1	42.0
	 					

LEGEND

——— At-Grade GP

— — At-Grade Express

▬ ▬ ▬ At-Grade HOV

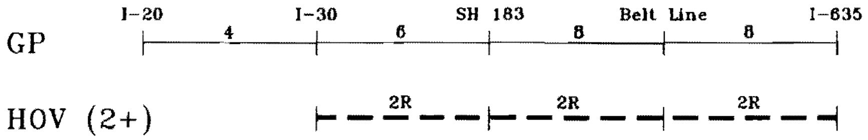
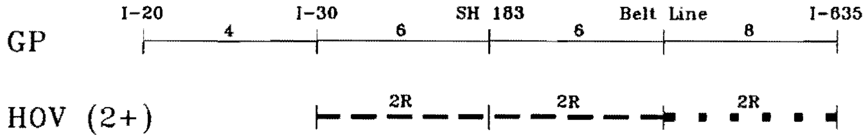
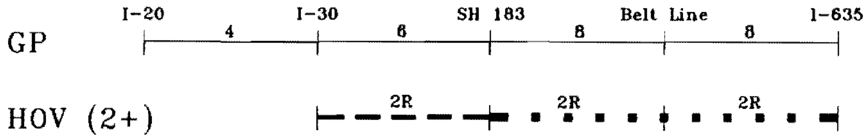
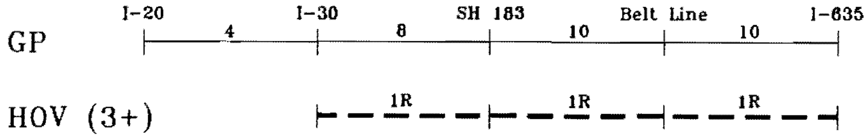
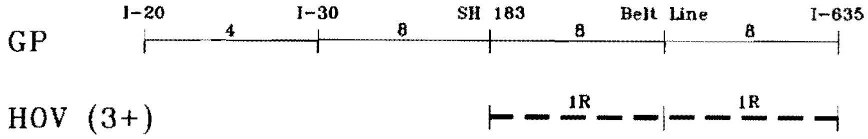
━━━ Elevated Express

• • • • Elevated HOV

R – Reversible

B – Bi-Directional

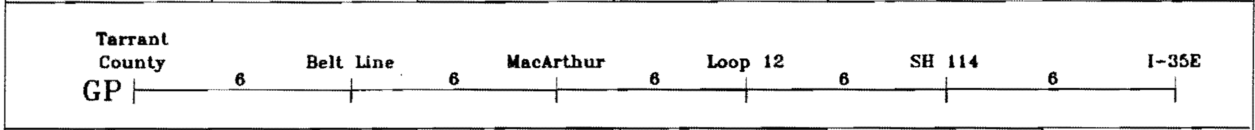
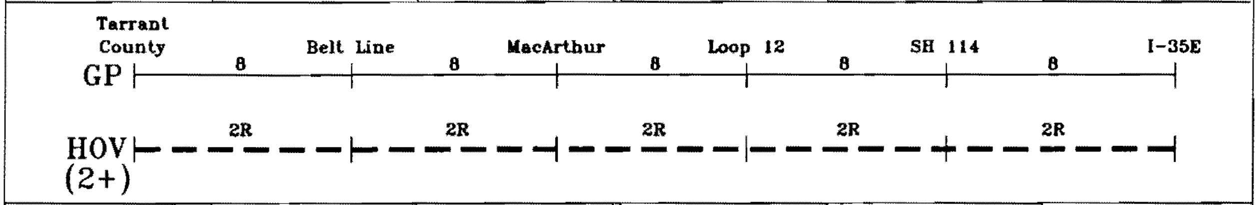
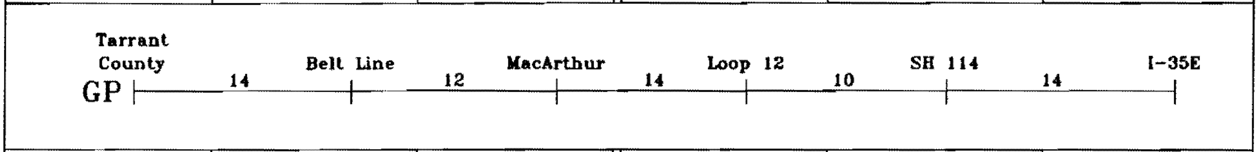
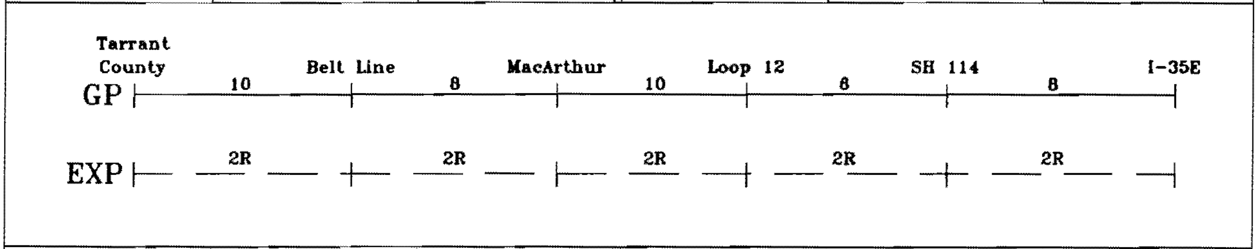
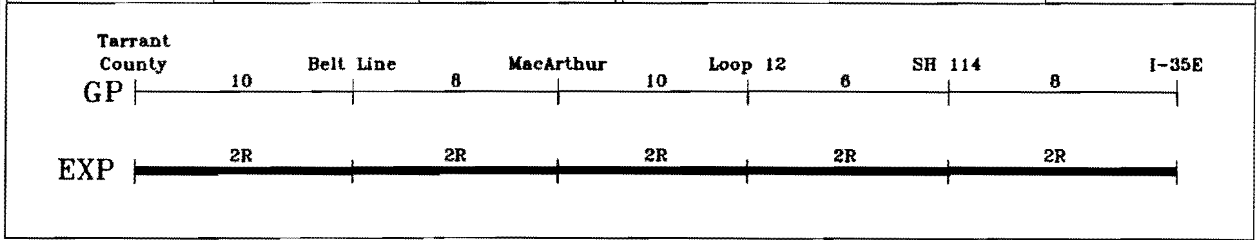
Table B-13. Average Annual Costs for SH 161 (cont.) (1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
8 (G-P + HOV, 2+)	38.2	1.0	39.2	0.35	0.9	40.5
						
9 (G-P + Elev HOV, 2+)	37.5	0.2	37.7	0.35	4.1	42.2
						
10 (G-P + Elev HOV, 2+)	39.0	0.5	39.5	0.35	0.9	40.8
						
11 (G-P + HOV, 3+)	40.3	1.9	42.2	0.35	2.1	44.7
						
12 (Cons Budget G-P + HOV, 3+)	36.5	0.5	37.0	0.35	13.6	51.0
						

LEGEND

——— At-Grade GP
— — At-Grade Express
▬ ▬ ▬ At-Grade HOV
▬▬▬ Elevated Express
■ ■ ■ ■ Elevated HOV
R – Reversible
B – Bi-Directional

Table B-14. Average Annual Costs for SH 183 (1990-2015)

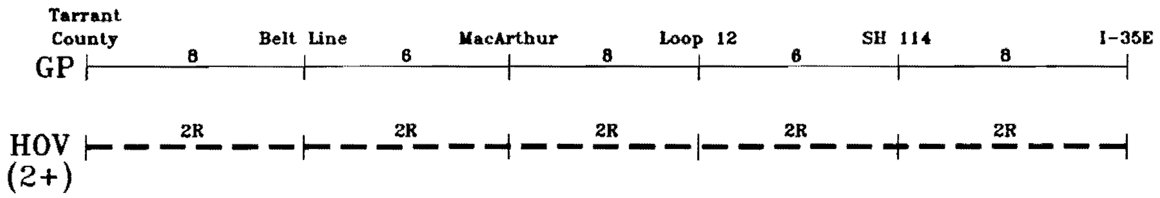
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.3	0.0	0.3	0.1	55.5	55.9
						
2 COG Mobility Plan (G-P + HOV 2+)	15.3	2.6	17.9	0.35	2.4	20.7
						
3 (All G-P)	22.0	7.7	29.7	0.1	0.4	30.2
						
4 (G-P + Exp)	13.2	3.9	17.1	0.3	3.2	20.6
						
5 (G-P + Elev Exp)	15.2	3.2	18.4	0.3	3.2	21.9
						

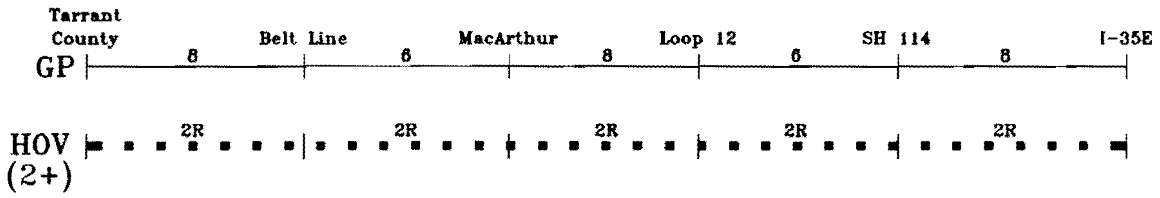
LEGEND

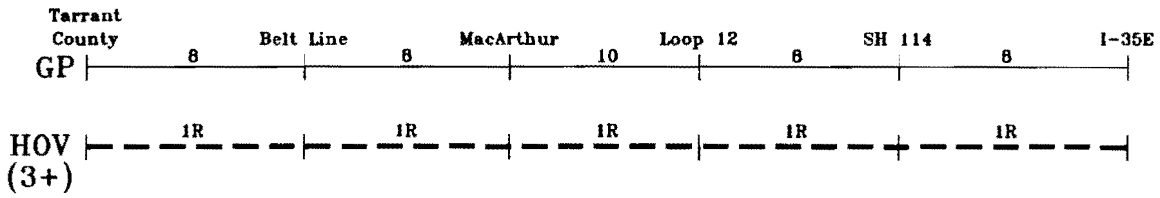
——— At-Grade GP	━━━ Elevated Express
— — At-Grade Express	▪ ▪ ▪ ▪ Elevated HOV
‒ ‒ ‒ At-Grade HOV	R – Reversible
	B – Bi-Directional

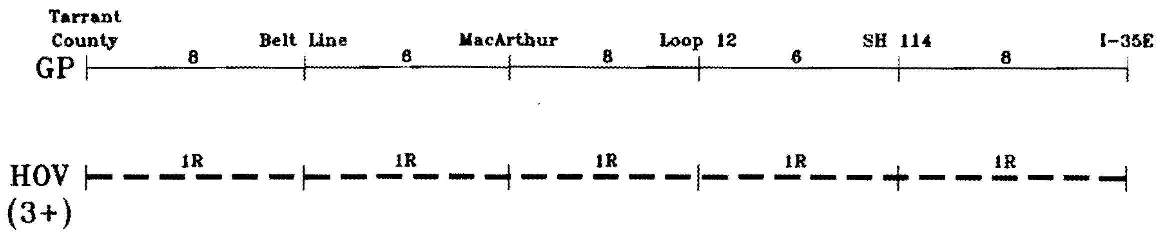
Table B-14. Average Annual Costs for SH 183 (cont.)
(1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
6 (G-P + HOV, 2+)	11.7	2.5	14.2	0.35	4.9	19.5
7 (G-P + Elev HOV, 2+)	13.0	1.9	14.9	0.35	4.9	20.2
8 (G-P + HOV, 3+)	12.9	3.3	16.2	0.35	8.2	24.8
9 Cons Budget (G-P + HOV, 3+)	9.7	1.9	11.6	0.35	19.6	31.6





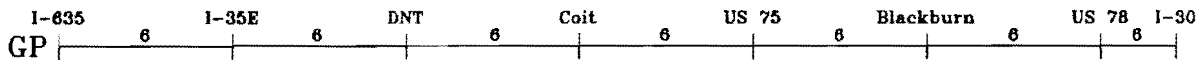
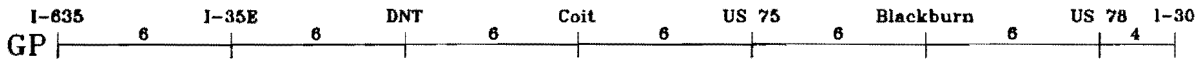
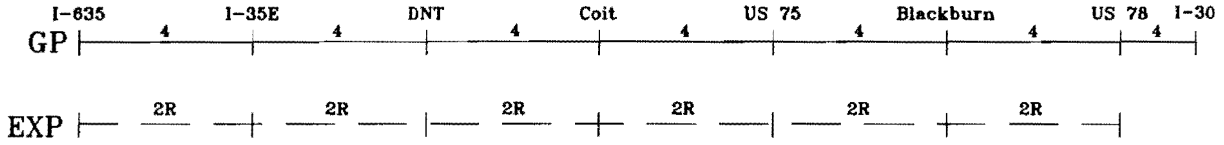
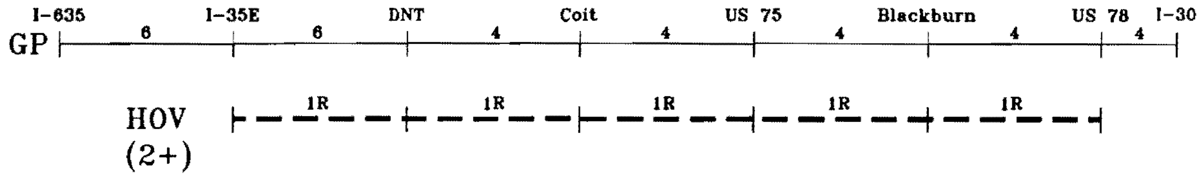




LEGEND

─── At-Grade GP
— — At-Grade Express
▬ ▬ ▬ At-Grade HOV
━━━ Elevated Express
▪ ▪ ▪ ▪ Elevated HOV
R – Reversible
B – Bi-Directional

Table B-15. Average Annual Costs for SH 190 (1990-2015)

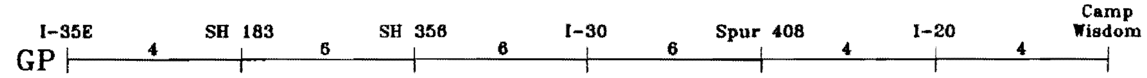
<table>
<tr><th>Alt.</th><th>Constr Cost ($mill)</th><th>R.O.W. Cost ($mill)</th><th>Total Capital Cost ($mill)</th><th>O & M Cost ($mill)</th><th>Congest Cost ($mill)</th><th>Total Avg Annual Cost ($mill)</th></tr>
<tr><td rowspan="2">1
(TxDOT)</td><td>57.4</td><td>1.3</td><td>58.7</td><td>0.1</td><td>0.4</td><td>59.2</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="2">2
(COG Mobility Plan All G-P)</td><td>54.7</td><td>0.0</td><td>54.7</td><td>0.1</td><td>0.7</td><td>55.5</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="2">3
(G-P + Exp)</td><td>56.5</td><td>0.0</td><td>56.5</td><td>0.3</td><td>1.4</td><td>58.2</td></tr>
<tr><td colspan="6">
</td></tr>
<tr><td rowspan="2">4
(G-P + HOV, 2+)</td><td>57.0</td><td>0.6</td><td>57.6</td><td>0.35</td><td>1.5</td><td>59.5</td></tr>
<tr><td colspan="6">
</td></tr>
</table>

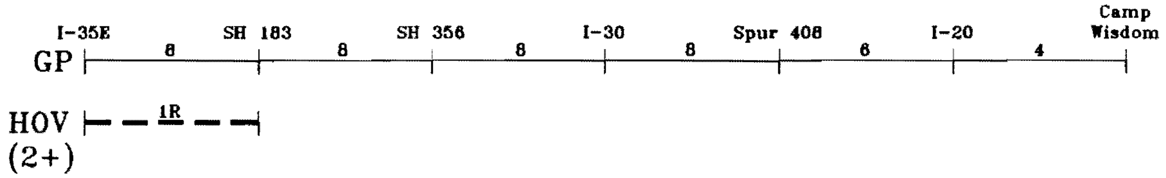
LEGEND

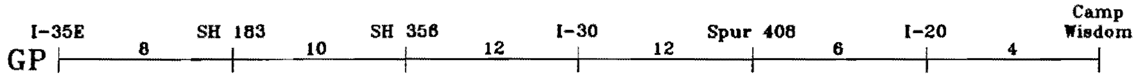
——— At-Grade GP
— — At-Grade Express
– – – At-Grade HOV
▬ Elevated Express
■ ■ ■ ■ Elevated HOV
R – Reversible
B – Bi-Directional

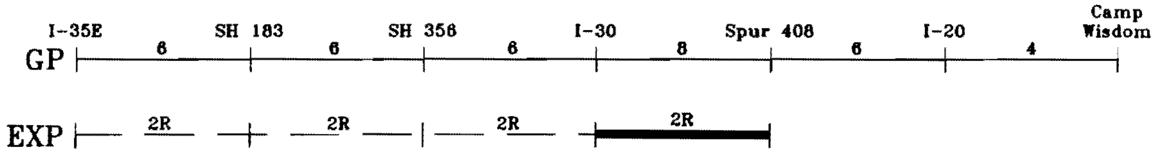
Table B-16. Average Annual Costs for Loop 12/Spur 408 (1990-2015)

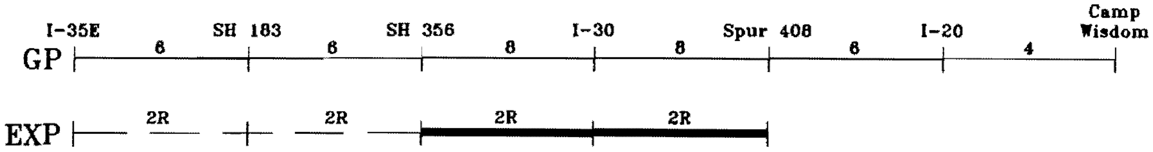
Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (No Action)	0.5	0.0	0.5	0.1	39.8	40.4
2 (COG Mobility Plan G-P + HOV, 2+)	8.3	0.3	8.6	0.35	15.2	24.2
3 (All G-P)	16.5	2.1	18.6	0.1	0.4	19.1
4 (G-P + Exp)	7.2	0.0	7.2	0.3	2.5	10.0
5 (G-P + Exp)	8.6	0.0	8.6	0.3	0.9	9.8







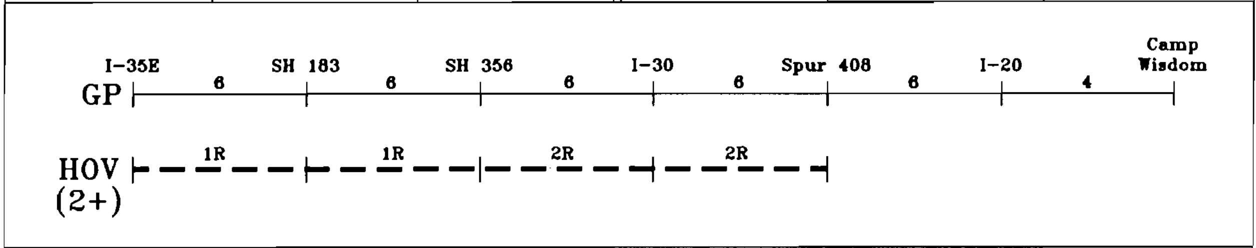
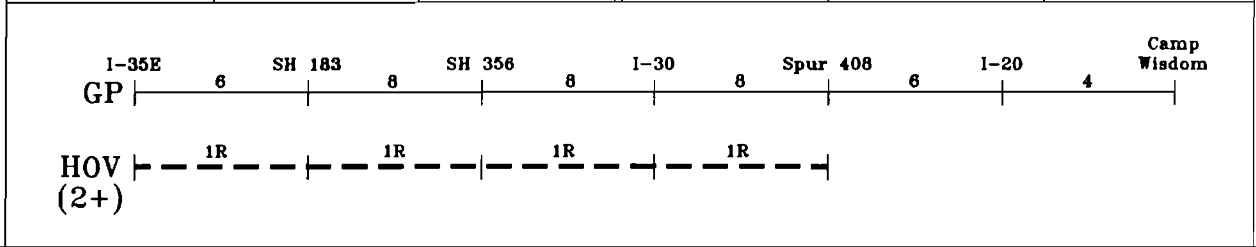
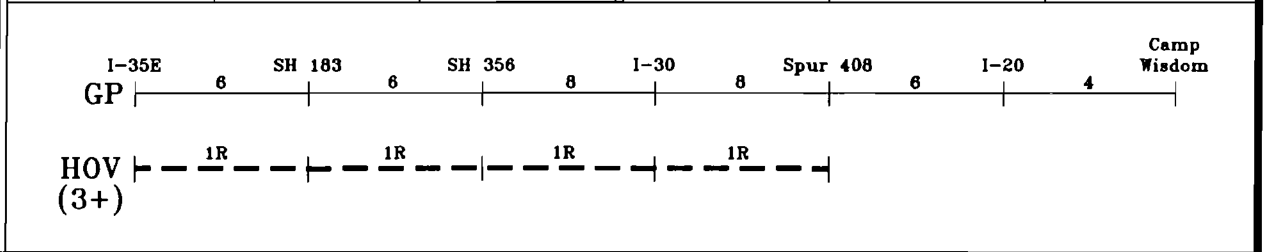
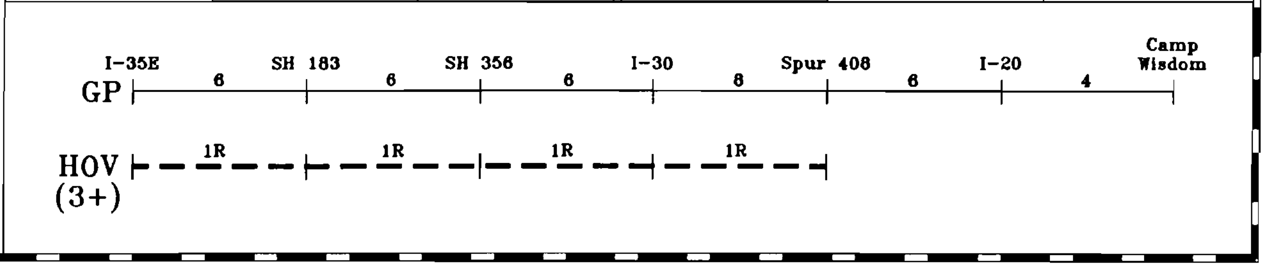




LEGEND

━━━ Elevated Express
──── At-Grade GP
▪ ▪ ▪ ▪ Elevated HOV
— — At-Grade Express
R – Reversible
▬ ▬ ▬ At-Grade HOV
B – Bi-Directional

Table B-16. Average Annual Costs for Loop 12/Spur 408 (cont.) (1990-2015)

<table>
<tr><th>Alt.</th><th>Constr Cost ($mill)</th><th>R.O.W. Cost ($mill)</th><th>Total Capital Cost ($mill)</th><th>O & M Cost ($mill)</th><th>Congest Cost ($mill)</th><th>Total Avg Annual Cost ($mill)</th></tr>
<tr><td rowspan="2">6
(G-P + HOV, 2+)</td><td>6.0</td><td>0.0</td><td>6.0</td><td>0.35</td><td>5.5</td><td>11.9</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">7
(G-P + HOV, 2+)</td><td>7.5</td><td>0.0</td><td>7.5</td><td>0.35</td><td>5.3</td><td>13.2</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">8
(G-P + HOV, 3+)</td><td>6.9</td><td>0.0</td><td>6.9</td><td>0.35</td><td>2.8</td><td>10.1</td></tr>
<tr><td colspan="6"> </td></tr>
<tr><td rowspan="2">9
(Cons Budget G-P + HOV, 3+)</td><td>5.1</td><td>0.0</td><td>5.1</td><td>0.35</td><td>14.5</td><td>20.0</td></tr>
<tr><td colspan="6"> </td></tr>
</table>

LEGEND

——— At-Grade GP

— — At-Grade Express

▬ ▬ ▬ At-Grade HOV

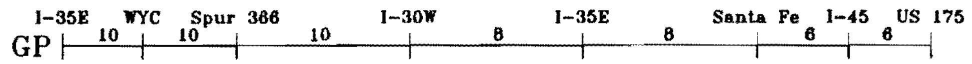
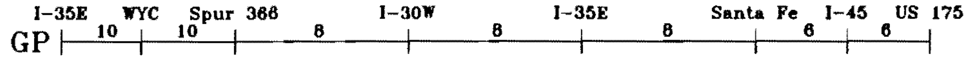
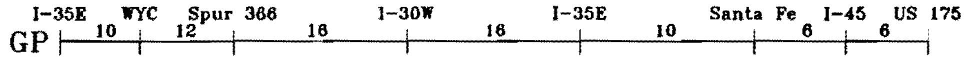
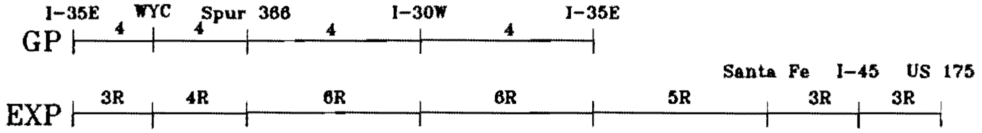
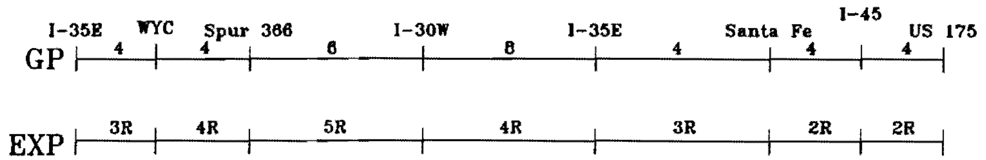
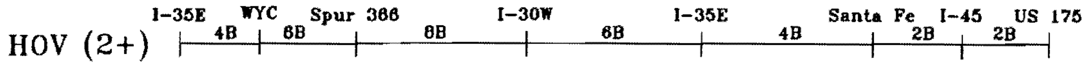
▬▬▬ Elevated Express

▪ ▪ ▪ ▪ Elevated HOV

R – Reversible

B – Bi-Directional

Table B-17. Average Annual Costs for Trinity Parkway (1990-2015)

Alt.	Constr Cost ($mill)	R.O.W. Cost ($mill)	Total Capital Cost ($mill)	O & M Cost ($mill)	Congest Cost ($mill)	Total Avg Annual Cost ($mill)
1 (TxDOT)	16.3	0.0	16.3	0.1	15.1	31.5
						
2 COG Mobility Plan (All G-P)	15.9	0.0	15.9	0.1	15.1	31.1
						
3 (All G-P)	20.0	1.5	21.5	0.1	1.4	23.0
						
4 (G-P + Exp)	14.6	0.0	14.6	0.3	1.4	16.3
						
5 (G-P + Exp)	16.5	0.3	16.8	0.3	1.2	18.3
						
6 (HOV, 2+)	8.7	0.0	8.7	0.15	0.2	9.1
						

APPENDIX C - RECOMMENDED SYSTEM

The recommended alternatives for the Dallas urban area in the year 2015 resulting from the analyses discussed previously in the final draft report are shown in Figure C-1. This figure also shows the recommended number of general-purpose lanes, HOV lanes, and express lanes. These recommendations reflect the least costly improvements that are compatible with adjoining freeway sections.

The acronyms used in Figure C-1 have the following meanings: 1) H = high-occupancy vehicle lane(s); 2) X = express lanes; 3) R = reversible; and 4) B = bi-directional (not reversible).

As alluded to in the final draft report, one of the major constraints associated with implementing freeway improvements is funding limitations. It is recognized that the recommended system outlined in Figure C-1 is rather ambitious in consideration of the current state (and probable future) of the economy. This recommended system can, however, be considered as a realistic identification of the infrastructure improvements required to efficiently meet the peak-hour travel demands in the Dallas urban area in the year 2015.

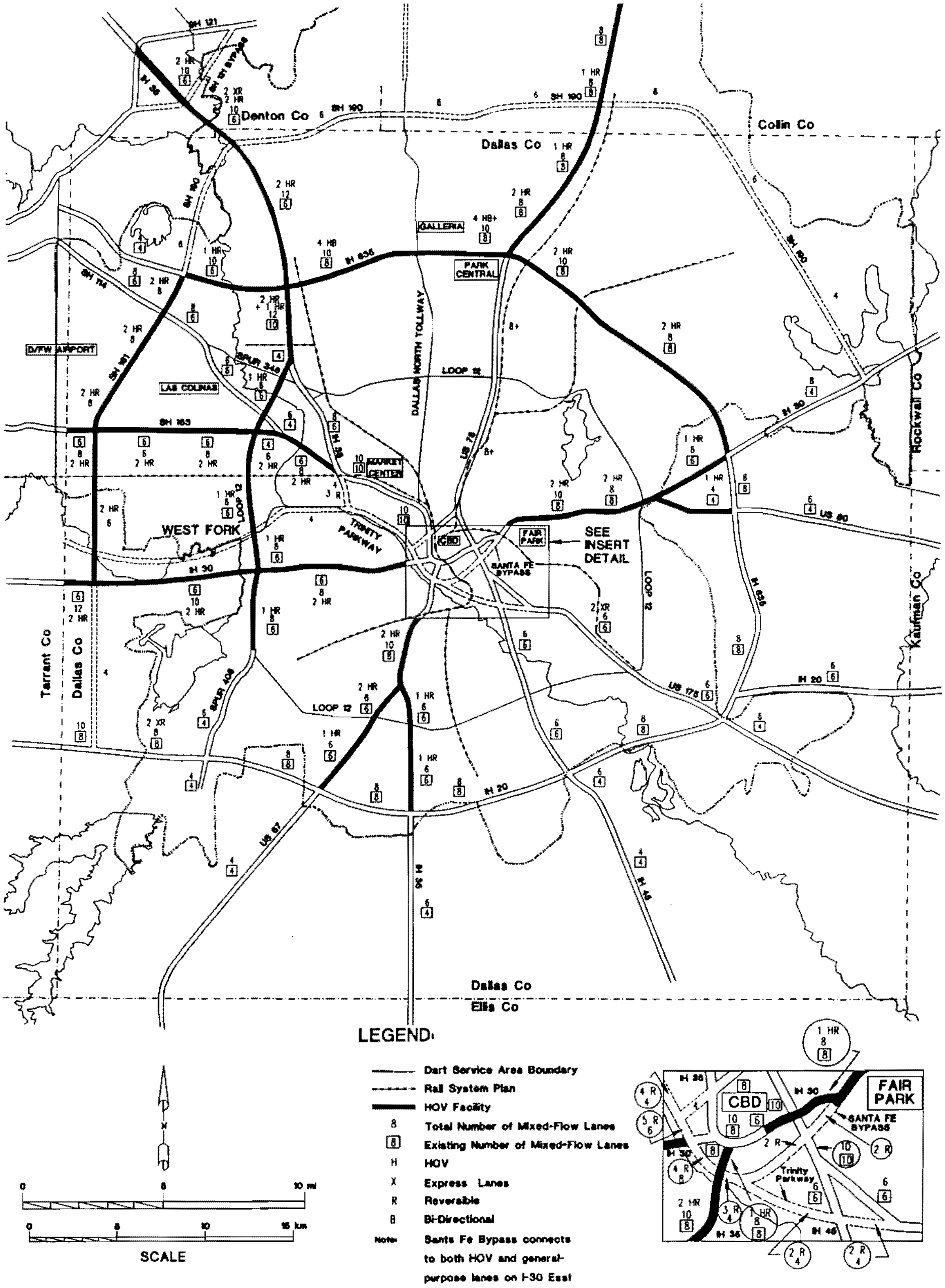


Figure C-1. Recommended System for Dallas in the Year 2015